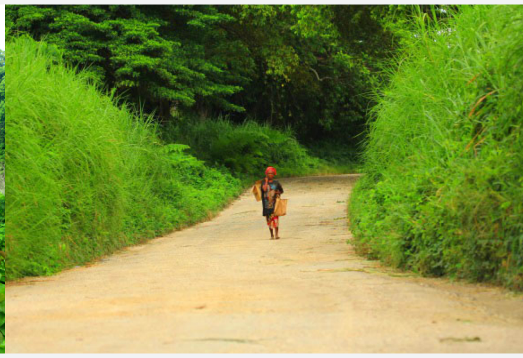
VANUATU RESILIENT ROADS MANUAL

A Design Guide for Low Volume Rural Roads in Vanuatu Based on Accessibility, Security and Sustainability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Manual

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Preamble

- The purpose of these Guidelines is to develop and promote appropriate methods of road engineering that gives the best possible access to communities at minimum cost.
- This Draft Guide to Standard Design has been prepared for use across PWD for the rural road network in Vanuatu.
- Standard specifications are a complementary document addressing how the work should be undertaken. It has been prepared as a separate document.
- The first draft should be reviewed following a peer review and provincial consultations and in no more than 12 months, so that any updates and revisions based on its practical application in Vanuatu can be taken into account and design guidelines revised accordingly.
- The standards referred to in this guideline do not include Urban Roads. Port Vila Urban Development Project consultants (Roughtons) are currently undertaking a significant study in Port Vila, which includes design, reconstruction and major road works, and their input should be used when revising this guideline for any future application to urban roads. At the time, consideration should be given to including urban roads in the next revision of this guideline, or it may be more appropriate to develop a stand-alone document.
- The Austroads Road Design Series is the basis for the Vanuatu Standards

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PART A

1 PART A DESIGN GUIDE FOR GEOMETRY, PAVEMENT AND DRAINAGE

2 Introduction

Currently in Vanuatu, there is no classification and design standards for roads.
MIPU/PWD have never adopted official geometric design standards and technical specifications for road works. Rather, road design has been undertaken on a case-by-case basis, often design-by-eye and dictated by provincial engineer / consultant / donor driven projects.

Surveys reveal that road widths are inconsistent. In some cases, some roads are very wide without a requirement, whilst others in comparison are narrow without requirement. In this case restricted access can affect the safety of users including pedestrians. A lack of guideline is leading to inefficient spending through overdesign or under design, ultimately resulting in road development that does not match the needs of its users.

There are 2,241 kilometres of public roads in Vanuatu with 83% (1861 km) over 8 islands. Most of the public roads network already exists and there is a low demand for new roads. Nevertheless, all roads need to be maintained and many of them need to be upgraded from a basic track to a standard that is compatible with the actual need. In addition, there is also need to address ways to make road infrastructure more climate resilient and these design guidelines are a significant step forward to addressing these issues in future road design and maintenance.

With the adoption of the Road Act, there is a need for MIPU / PWD, design standards and technical specifications for roads to be developed and implemented. They should be based on Vanuatu's environment and experiences, forming a pragmatic point of view recognising the particular conditions of the Vanuatu context, in particular:

- Access needs for communities
- Low traffic volumes and light traffic type (70-80% of vehicles constituting 4WD pick-up trucks and max of 5% of heavy vehicles)
- Environmental factors (rainfall, topography, cyclone and other extreme weather events)
- Limited budgetary resources for road works
- Lack of uniformity in the network due to lack of standards and guidance

It is essential to develop and promote appropriate methods of road engineering that give the best possible access to communities at minimum cost. Therefore, this Technical Note is a Draft Guide to Standard Design for the rural road network in Vanuatu.

3 Austroads Standard Guides

In 2009, Austroads launched a comprehensive set of technical guides covering 10 subjects relating to road construction and management:

- Asset Management
- Bridge Management
- Pavement Technology
- Project Delivery
- Project Evaluation
- Road Design
- Road Safety
- Road Transport Planning
- Traffic Management
- Road Tunnel

It is a very detailed and comprehensive set of documents containing 96 individual parts and sub-parts, which may not all be relevant to conditions and context in Vanuatu.

The vast majority of the roads in Vanuatu fall into Rural Class 5 roads of Austroads classification and as such are defined as *“Those roads, which provide almost exclusively for one activity or function which, cannot be assigned Classes 1 to 4”.* In addition, Australian Road Research Board (ARRB) edited in 2009 a Manual for Unsealed Roads - Guidelines to Good Practices, which also gives a full range of relevant information. However, the range of roads considered in this Manual is often on flat and open terrain with an important percentage of heavy traffic (similar to Central Australia).

Consequently, considering the Austroads Guides series allow enough flexibility to accommodate the local context, it was decided to retrieve from Austroads and ARRB the most relevant guidelines and insert it in an adapted brief “Design Guide” that would best suit Vanuatu’s environment.

From AUSTROADS GUIDE TO ROAD DESIGN, Part 1, section 2.1

"Although local conditions and circumstances may sometimes require unique or innovative approaches to design, the bulk of works can be well accommodated by the approach outlined in the Guide to Road Design. However, it is recognised that member organisations may develop and publish supplementary guidelines and manuals to cover specific design situations. "

From AUSTROADS GUIDE TO ROAD DESIGN, Part 3, section 2.2.2

"Most road authorities in Australia [sic] have developed a functional hierarchy for their road networks. This hierarchy enables each authority to systematically plan and develop their network to meet the needs for local access, cross town/city travel, intrastate and interstate travel."

It is suggested that the Austroads Standard Guides be adopted by PWD as Reference Guides for any particular design or particular case, excluding the day-to-day standard design. A Design Guide for low-volume rural roads in Vanuatu is herein proposed.

4 Methodology

4.1 Road network description

According to the 2014 road inventory, there are a total of 2,241 kilometres of public roads in Vanuatu distributed across 24 islands. From this, 50% of the road network is found on 3 islands (Santo, Efate and Malekula) and 83% on 8 islands. The distribution is shown on Table 1 and Figure 1 below.

Province	Island	Km
Sanma	Santo	520
Shefa	Efate	337
Malampa	Malekula	267
Penama	Pentecost	199
Penama	Ambae	182
Tafea	Tanna	177
Sanma	Malo	94
Malampa	Ambrym	84
Shefa	Epi	71
Penama	Maewo	46
Sanma	Aore	43
Shefa	Tongoa	37
Tafea	Erromango	31
Malampa	Paama	23
Torba	Vanua Lava	23
Shefa	Nguna	22
Shefa	Emae	20
Torba	Moto Lava	14
Torba	Gaua	13
Sanma	Tutuba	12
Tafea	Aniwa	12
Shefa	Emao	9
Shefa	Tongaoriki	5
Shefa	Pele	4
	Total	**2241**

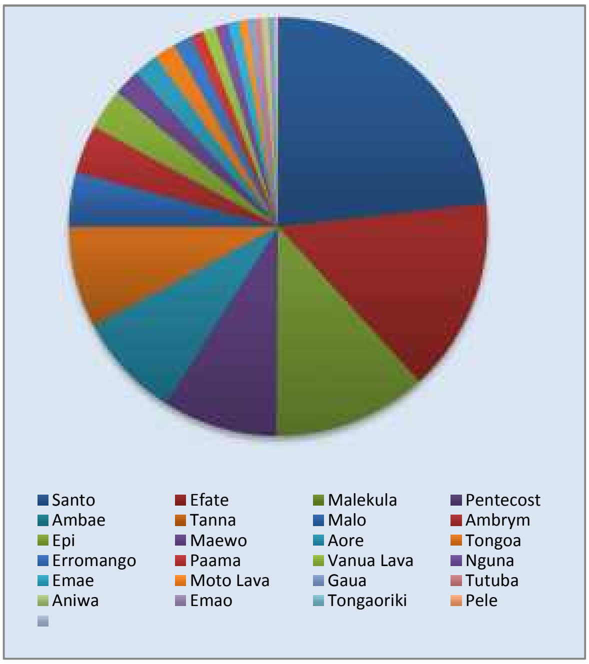


Table 1 and Figure 1. - Road Distribution (% of kilometres)

4.2 Approach to Design Standards

Unpaved gravel and earth roads constitute around 95 per cent of the designated road network in Vanuatu, whilst earth roads and tracks dominate the undesignated network. Only about 5% of the road network is paved, and these roads are located on Efate and Santo only. Therefore, unpaved roads are the primary road network on all other islands. They play a vital social and economic role in the development of rural areas where the majority of the population live.

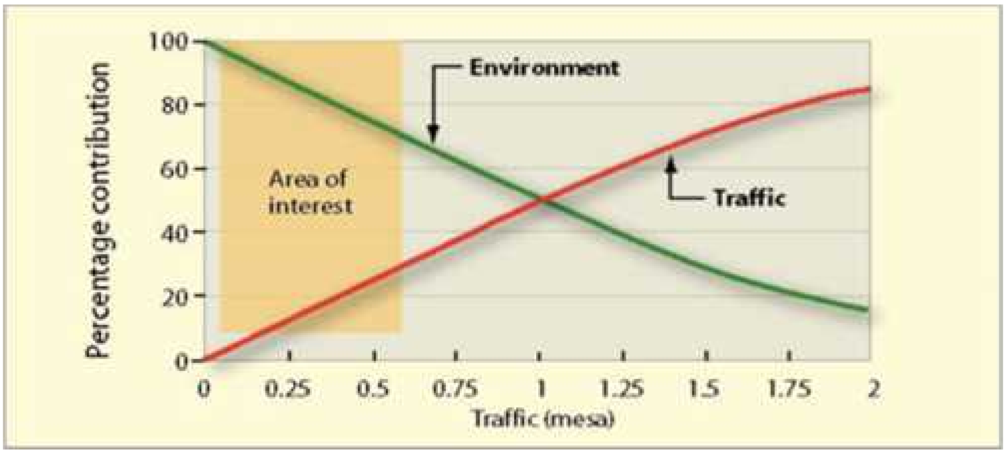
> ***Low-volume roads are more affected by rainfall (erosion, landslide, overflows, etc), than by***

The traditional approach of road design generally consider traffic parameters (volume and type) to address security and sustainability aspects. However, for low-volume roads such as those in Vanuatu, innovative solutions need to challenge the conventional assumptions regarding road design criteria. The concept of an appropriate, or locally environmentally optimised design approach provides a way forward. Low volume road standards and designs need to support the function that the road is providing as well as recognising the important influences of the deterioration mechanisms. The approach needs also to consider the availability of funds, the local technical capacity and the social impacts.

Recent research around the world has questioned many of the accepted assumptions about the planning, design, construction and maintenance of low-volume roads. This research has quite clearly shown:

- The importance of adopting a more holistic, sustainable approach to the provision of low-volume roads
- The need to revise conventional approaches to planning, economic appraisal and the environment
- The shortcomings of conventional specifications and, to some extent, of test methods, in assessing the adequacy of local materials for use in low-volume roads
- The advantages of adopting more appropriate geometric and pavement design standards
- The economic success of innovative construction methods
- The importance of paying greater attention to the environmental aspects of road provision

Austroads and ARRB base their assumption on the fact that the traffic is the major factor to contribute to the deterioration of the road. However, for low volume roads, as in Vanuatu, where climate conditions can be severe, the environment will be the major contributor. According to the last traffic count (November 2013), the busiest road would have less than 0.1 Mesa. This is shown in Figure 2. Below.



Ref. World Bank

Figure 2. Relative effect on Traffic and Environment on road deterioration

Controllable factors include engineering design, selection of materials, construction quality and control, standard and timeliness of maintenance intervention and to name a few. Uncontrollable factors include climate, ground shape (terrain), geological and geomorphological conditions, surface and sub-surface hydrology. Thus there are many very influential factors that the engineer cannot control and hence understanding risk and reliability is a key aspect of design to cater for this uncertainty.

The Public Works Department is responsible for significant lengths of low volume road and on this basis, the establishment of the following is recommended :

- A Road Classification System for Vanuatu to ensure consistency in the management (design, maintenance, etc.) of the road network across the range of roads on all islands.
- Design Guide together with Standard Drawings and Standard Specifications
- Procedures to monitor the performance of road conditions for the various road types and appropriate intervention levels to set priorities for scheduling road maintenance works.
- Periodic training for local contractors and inspectors in order to allow the implementation of all the above

The key principles for the classification and design approach proposed are summarised in Table 2.

	Based On	To Achieve	Design parameter
Accessibility	Road function, climate	The right management of accessibility and mobility to communities and users	River crossing, all design aspect (for all weather roadway access)
Security	Traffic of vehicles and pedestrians, slope, climate	Security for all user (geometry)	Geometry, pavement, drainage design
Sustainability	Traffic of vehicle, slope, climate	Resilient when flood or other environment event, better value for money and	Geometry, Pavement design, drainage

Table 2. Design approach

This report proposes:

- A Road Classification System;
- Guidelines for appropriate Design Standards for each road class;
  - Geometric Design
  - Pavement Design
  - Drainage Design

5 Proposed Road Classification System

5.1 Road Function

With the recently adopted Road Act, the public road network has been divided into 3 functional classes. The road function classification does not consider traffic volume, but only the function as the accessibility and the connectivity. Classifications are as follows:

- Arterial roads (71 % of the public road network)
- Feeder roads (20 %)
- Urban roads (9 %)

Arterial and Feeder roads are found in rural areas on all islands. Urban roads are found only in Port Vila, Luganville and Lakatoro. This proposed Design Standard will address only the Arterial and Feeder rural roads.

As arterial roads are the major link (and often the only one) to critical economic and social infrastructure (e.g hospitals, airport, etc), it is appropriate that they provide a high degree of accessibility and connectivity all year round. Therefore, the function of the road will determine the level of access expected for each type of road and therefore, to adapt the appropriate design component to suit this requirement.

In addition to the functional classification included in the Road Act, a supplementary classification has been established in order to address particular environmental characteristics, which might need to be considered for design purposes.

5.2 Traffic Class

An understanding of traffic volume is essential to establish the appropriate pavement design and the geometry. It also helps to better plan the level of maintenance on the pavement (pot holes, reshaping, etc).

In November 2013, a traffic count was conducted on the main roads on 4 islands with finding in Figure 3:

- Malekula (8 roads, 4 days)
- Pentecost (1 road, 1 day)
- Ambae (5 roads, 2 days)
- Tanna (6 roads, 3 days)

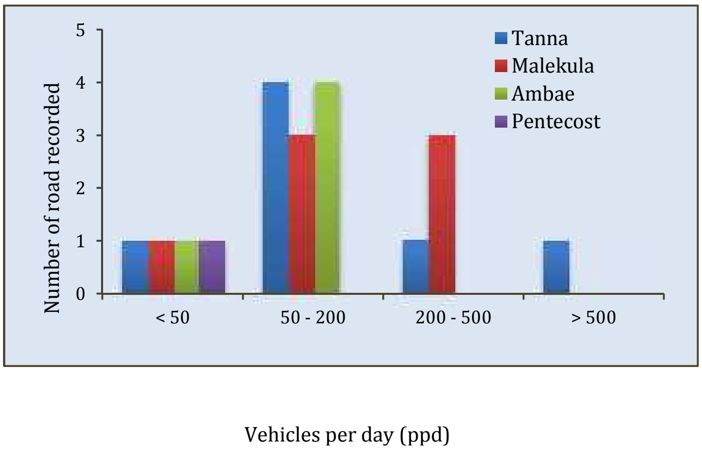


Figure 3. Traffic distributions

The findings were as follows:

- The maximum daily traffic recorded on average for one road section was 681 vehicles per day (vpd) on Lakatoro Aoup, in Malekula
- Four sections had between 200 and 500 vpd (2 on Malekula and 1 in Tanna
- Eleven had between 50 and 200 vpd (3 in Tanna, 4 in Malekula and 4 in Ambae)
- Four had less than 50 vpd (1 on each 4 islands)

Therefore, in order to address the technical and security aspects of the road design (geometry, pavement), 4 traffic classes along with the number of lanes required were designated for unsealed rural roads in Vanuatu, shown in Table 3:

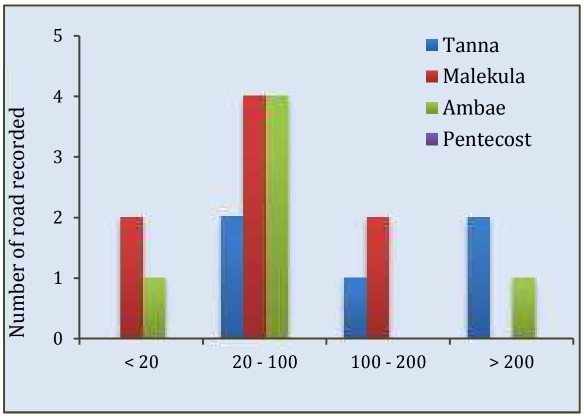
Traffic classes	TRAFFIC (Vehicles per day (vpd))	Number of lane
T4	> 500	2 lanes
T3	200 – 500	2 lanes
T2	50 – 200	2 lanes
T1	< 50	1 lane

Table 3. Traffic classes

These classes will guide the design specifications in terms of security and sustainability. For example, a 1 lane road would not be suitable if the traffic is more than 500 vpd. A summary of the traffic counts performed on 4 islands is included in Appendix A.

5.3 Pedestrian users

In addition to traffic counts, the number of pedestrian was also recorded. On almost half of the roads surveyed, the number of pedestrians was higher than the number of vehicles. This highlights the need to consider pedestrian requirements and road safety design for non motorised users. An increase in the shoulder width of the road addresses this situation in most instances. This is shown in Figure 4 below:



Pedestrian per day (ppd)

Fig. 4 Number of roads per pedestrian class

Photo Tanna - Children walking to school

5.4 Terrain and Slopes

The major effect on steep slopes is erosion, particularly due to heavy rain. Average annual rainfall in Vanuatu is around 2500 mm per year, with peaks of up to 4000 mm per year. Deterioration of slopes will affect security when slippery and/or cause the occurrence of deep ravelling. This may lower or stop access through a given section.

A simple classification of ‘flat’, ‘rolling’, “hilly” and “steep” terrain descriptions has been adopted as a basis for specifying appropriate geometric standards. The definition of each can be described in general terms as follows in Table 4:

Terrain	Class	Description	Gradient	
Steep	S4	Roads in rugged with substantial restrictions to both horizontal and vertical alignments	> 1:7	> 15%
Hilly	S3	Roads can have substantial cuts and fills	1:10 to 1:7	10-15%
Rolling	S2	Roads can have substantial cuts and fills	1:20 to 1:10	5-10%
Flat	S1	Roads generally follow the ground contours	Up to 1: 0	< 5%

Table 4. Terrain / slope class

6 Guidelines to Geometric Design Standards

6.1 Design Considerations

The geometric design standards for roads are generally governed by the function of the road (level of access), traffic volumes and vehicle type (width and security factors), non-motorised users (security), terrain (security and sustainability), social environmental (communities, farm) and physical environmental (rainfall, climate) issues as well as cost considerations. Ideally a compatible cross section, horizontal and vertical alignment is required which will provide users with an adequate quality of service in terms of ride comfort, and convenience, resulting in a safe facility.

The geometric design of low volume roads presents unique challenges, which require the application of common road engineering practices to a lower cost facility that serves only a small number of vehicles, with many pedestrians, often in sensitive environmental conditions and with constrained budgets. The design must provide a road, which can cater for vehicles, recognise the safety of all road users, and be accomplished at minimal cost. This requires a unique and flexible approach, without overlooking the principles of roadway engineering.


Photo Tanna

The quality of service is a qualitative term based on the concept of providing varying levels of convenience, comfort and safety to a driver. Convenience can be associated with the travel time taken for a journey, (i.e. travel speed). Comfort can be associated with ride quality (i.e. road profile), and safety related to the consistency of road standards (i.e. no surprises). Considering the traffic is low and the islands are small (normally less than 80 kilometres in overall length), comfort riding and travel speed are not the priorities. Priorities are focussed on accessibility, security and sustainability.

Road works in Vanuatu should be ideally designed to withstand heavy storm events to extend maximum levels of access to as many people as possible within the current resource allocations. The principle of life cycle costing should be incorporated when designing major road rehabilitation projects, especially those for Arterial roads.

Design standards proposed for road works make use of existing modalities from countries with similar environmental, geological and topographical conditions as is found in Vanuatu. In addition, it is necessary to use local materials for pavement, in particular Coronous and volcanic scoria (base / wearing course) as well as aggregates in masonry / concrete works.

To ensure that expectations are met, quality control procedures need to be specified and enforced during project preparation and construction.

Guidelines relating to the geometric design standards for each road class are given in Part C, Section 30, Figure 71. The standards are based on the roadway engineering principles with applied judgement to reach practical and reasonable standards relating to a range of low volume roads. However, for the lowest design class of road, it is considered inappropriate to design on the basis of geometric standards, and the sole criterion should be the achievement of an appropriate level of access. Design in these situations should be based on the limiting values of radii, width and gradient for the passage of a suitable design vehicle.

This proposal is a starting point for further discussion towards Vanuatu design standards and technical specifications. The notes below outline the main geometric design considerations used in arriving at the various values given in Appendix A.

6.2 Design Speed

The design speed considered has a major impact on the capital and maintenance cost of a road. The design speed, together with other considerations will determine geometric features, including sight distance, horizontal and vertical alignments, width of lanes and shoulders, etc.

The design speed considered is based on several overseas studies relating to low volume roads as well as traffic volume and practical local experiences.

The design speed proposed varies with the topography, (the main factor) adjacent land use, function of the road and type. Ideally, every effort should be made to use as high a design speed as practicable to attain the desired degree of safety, comfort and convenience while under the constraints of economics, environmental and aesthetics requirements. However, for rural roads in Vanuatu, the objective was to set an appropriate speed, which may be below the geometric design speed capability of the road, for environmental reasons, amenity of site users and safety. In such cases appropriate signs or road humps could be necessary to control speed to the desired level.

Certain features, such as curves radius, super-elevation, and sight distances are directly related to the design speed adopted. The design speed is adopted for design purposes as shown in Table 5 below.

Terrain	T4	T3	T2	T1
Rolling	40 km/h	30 km/h	30 km/h	10 km/h
Flat	60 km/h	40 km/h	40 km/h	30 km/h

Table 5: Design speed

Lower design speeds are appropriate for hilly and steep terrain because of horizontal and vertical constraints. Higher design speeds are appropriate in flat terrain where horizontal and vertical geometry requirements may be attained without an appreciable increase in construction costs.

Ideally the design speed should be continuous throughout the length of the route. If this cannot be maintained because of physical or economic reasons, consideration should be given to actions that will alert a driver to a change in travel speeds, possibly with the use of transition zones and/or appropriate warning signs.

6.3 Terrain Considerations

Due to economical constraints, it has been considered that in most cases where the road already exists, current slopes should remain. However, in the case of a new road or whenever it is possible to rectify the slope, it is highly recommended that the slope be kept at the following maximum slope:

- 12% for a maximum distance of 600 m
- 15% for a maximum distance of 200 m and
- 18% for a maximum segment of 50 m

This would reduce the devastating effect of rainfall and increase the level of service and standard of operation.

Considering the heavy level of rainfall all over Vanuatu, hilly and steep roadways sections are much more susceptible to erosion and very deep ravelling and this is observed on many roads. Therefore, terrain and slopes are also used to recommend segments, which can be sealed with concrete slabs, tracks, grouted stone or other approved sealant options.

Steep hills on unpaved roads, where the longitudinal gradient is steeper than the crossfall, are prone to severe erosion in the wheel paths, particularly when these coincidewith the centre of the road. Considerable attention must be paid to maintaining adequate crossfall in these situations as this will minimise the erosion. If severe damage persists, consideration should be given to paving the gradient either by surface dressing or with a concrete pavement.

6.4 Cross Section Elements

The main elements of a road cross section, for both a sealed and unsealed road, are shown in Figure 5.

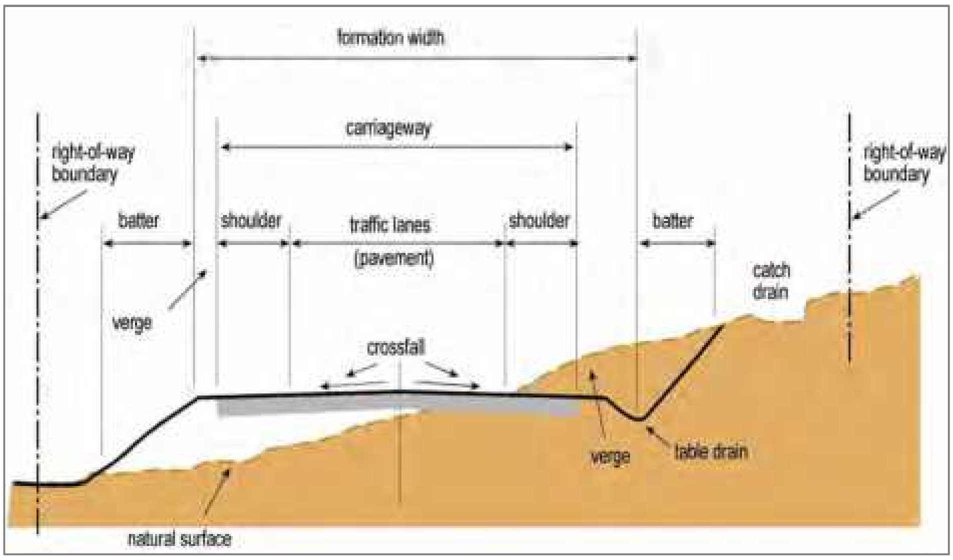


Figure 5. Road Cross Section Elements (Source Austroads 1989)

For most access roads with low volumes of traffic (<100 ADT) single lane operation is often adequate as there will only be a low probability of vehicles meeting. In such circumstances passing manoeuvres can be undertaken at reduced speeds using passing places or the road shoulder. or higher traffic levels a wider cross section should be adopted to allow 2 lanes.

Cross sections should be kept as low as possible within the terrain with the dimensions chosen to ensure that the material cut from the side drains and back slope is sufficient to construct a low embankment and fill the side slopes, and to minimise haulage.

6.4.1 Width

Carriageway widths, which include traffic lanes and shoulders are based on the functions of road, traffic volume, traffic mix, design speed and surface type. The standard width selected does not provide for emergency and leisure stops because the frequency of traffic conflicts on low volume roads associated with stopped vehicles does not justify an additional width for sheltering. Locations where there is such a requirements will need to be considered on a case-by-case basis.

For roads carrying truck traffic over 20% of ADT, the overall roadway width could be increased by 0.5 m to allow for the safe passage of opposing vehicles. However, according to the traffic count performed in 2013, a maximum of 5% of trucks was recorded on only 2 segments out of 20 segments surveyed.

Due to economic considerations, if very low traffic volumes are recorded (T1), 1-lane two-way road is proposed with a roadway width of 3 metres. This limits the road to a 1-lane facility with a layover area which may be necessary for opposing vehicles to pass. Layover lanes should desirably be inter-visible and a maximum distance between layovers should be in the order of 300 metres and locations for these should be selected when natural terrain suit.

In the case of a sealed single lane, two-way road it is desirable that the road shoulders are constructed from material suitable for carrying vehicles both in dry and wet weather and be large enough to allow passage of two vehicles. A traffic lane width of less than 3.5 metres can results in excessive shoulder wear. A width greater than 4.5 metres but less than 6.0 m may lead to vehicles trying to pass with each remaining on the lane sealed. A width of 3.5 metres ensures that one or both vehicles must have the outer wheels on the shoulder when passing.

For unsealed roads the traffic lanes and shoulders are all considered as part of the travelled way or carriageway as there is no distinction to the driver. Carriageway widths should be selected for either a double or a single lane operation as in between widths will result in the ‘three wheel’ effect causing extra wear on the road crown. Figure 6 below illustrate the various traffic lanes width compared with vehicle width.

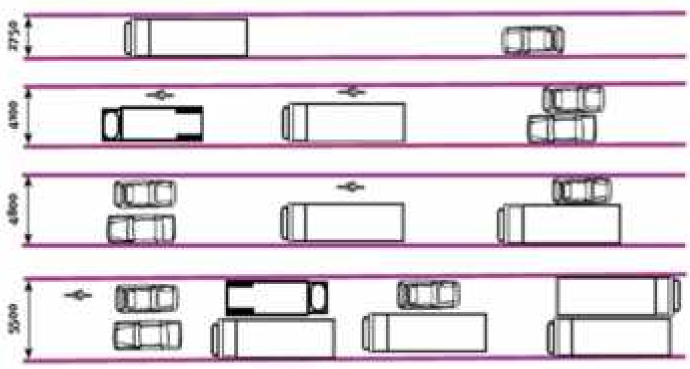


Figure 6 Various carriageway width (not recommended)

Traffic lane and shoulders width for standard situations are designated (in metres) as follows in Table 6:

UNSEALED ROAD	Traffic class			
	T4	**T3**	**T2**	**T1**
Traffic lane	6.0	5.0	5.0	3.0
Shoulders [1]	0.5	0.5	0.5	0.5
Total carriageway	7.0	6.0	6.0	4.0

SEALED ROAD	Traffic class			
	T4	**T3**	**T2**	**T1**
Traffic lane	6.0	6.0	6.0	3.5
Shoulders	1.0	1.0	1.0	1.5
Total carriageway	8.0	8.0	8.0	6.0

[1] Increase shoulder width of 0,5 m if there are more than 100 pedestrians per day (on arterial roads), especially if it is in the vicinity (500-1000 m) of a school, hospital, town, church, airport, etc.

Table 6. Traffic lane and shoulder width

6.4.2 Crossfall

Sufficient crossfall should be provided to allow the easy run-off of water from the surface and to prevent potholes developing. If too great a crossfall is applied, the surface material will be prone to scouring and erosion.

It is recommended for ease of construction and maintenance operations, shoulders should have the same surface crossfall as the traffic lanes for unsealed roads so that they may be constructed and maintained to the same crossfall.

Unfortunately, it is common to find that most unsealed roads are not provided or maintained with the desired crossfalls and shaped to a crown. While flat crossfalls may be desirable for the travelling public, it is most undesirable for road maintenance purposes because it will not permit the shedding of surface water off the road, which will lead to the rapid development of potholes and deterioration of the pavement. Steep hills on unpaved roads, where the longitudinal gradient is steeper than the crossfall, are prone to severe erosion in the wheel paths, particularly when these coincide in the centre of the road. Considerable attention must be paid to maintaining adequate crossfall in these situations as this will minimise the erosion.

Crossfall measurements can be expressed in various forms:

- By ratio such as 10:1 (10 horizontal H and 1 vertical V distance m/m)
- By percentage such as 10% (vertical divided by horizontal distance and X by 100%)
- By degrees.

Crossfalls in the field can be measured in various ways. Some graders have levelling devices that provide the crossfall of the road. Care should be taken that the rear wheels on which the level is based on the actual roadway being measured and the tyres are all correctly inflated. A better method is to use a 'smart level', which provides a digital readout, in either percentage values or degrees of the actual crossfall of the road being measured. An alternative is to use a camber board which is cut to the required crossfall and has a spirit level on top to show when the desired crossfall is achieved. Checks should be made at regular intervals along the road and if the camber is too steep or too flat, then the road must be graded again. See below in Figure 7.

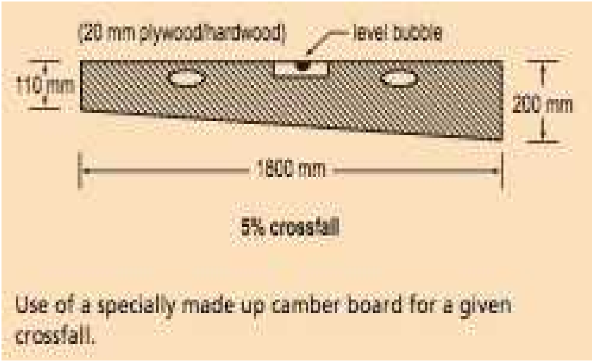


Figure 7 Camber board

The crossfall which should be used is dependant on the local conditions and material properties. Crossfalls in the range of 4–6% have been used with success. In practice it is recommended that the road crossfall be initially constructed at 6% as it will not be long before it flattens to around 4%. In terms of fall from the crown to the edge of the roadway the values for different crossfalls and road widths are given in Table 7 below.

Crossfall	Total Road width			
	4 m	**5 m**	**6 m**	**8 m**
4%	80 mm	100 mm	120 mm	160 mm
5%	100 mm	120 mm	150 mm	200 mm
6%	120 mm	150 mm	180 mm	240 mm

Table 7. Differential thickness with crossfall

Camber from 6% to 8% could be specified when drainage is or is suspected to be an issue. This will encourage water to be shed quickly from the running surface and will reduce the rate at which ruts form and areas of ponding water.

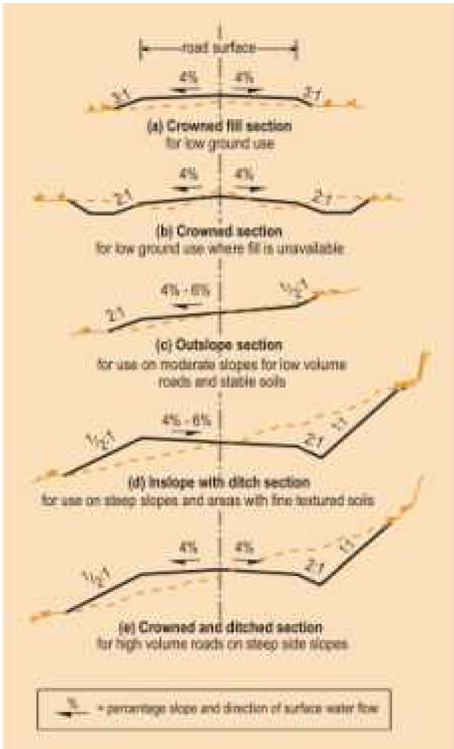


Figure 8 Alternative road shapes and crossfalls

It is very important to ensure correct camber on steep alignments. 'Flat' cambers are frequently the cause of the longitudinal gullying commonly found on such alignments. Lack of adequate crossfall is suggested (Ferry 1986) as the most common defect of New Zealand's unsealed roads as this does not provide adequate drainage of the road surface.

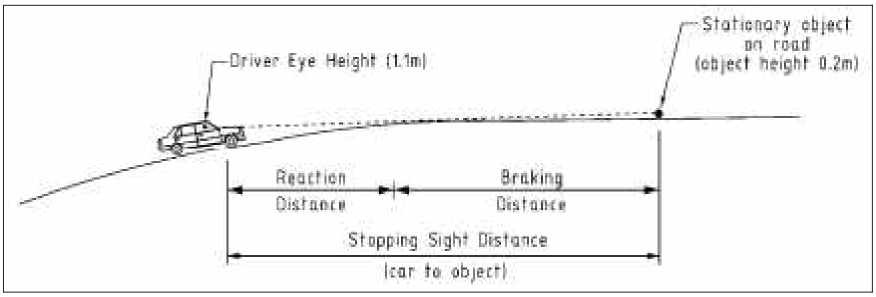
Two-way crossfalls should meet with a crown. This will help to prevent the development of potholes in the road centre. For single-lane carriageways, it may be best to have a single crossfall for ease of grading during regular maintenance.

Five road cross-sections typically used in road construction are shown in Figure 8. The choice of which cross- section should be used depends on drainage needed, soil stability, slope and the expected traffic volume on the road.

6.5 Sight Distance Requirements

A principle aim in road design is to ensure that a driver is able to see any possible hazards on the road in sufficient time to avoid an accident.. To help calculate this requirement the term stopping sight distance has been used.

Details on the basis of the sight calculations are given in Austroads (1989) and Giummarra (2000). The values provided in the Table in Appendix D are based on two of the main safety requirements. The designer should also take into account other possible requirements relating to passing, and lateral sight distances particularly at tight horizontal curves.



Source: Based on Austroads (2003).

Figure 9. Car stopping sight distance

Definitions used are as follow:

- Minimum stopping sight distance (SSD) – This is the distance required for a vehicle to stop in time to avoid hitting a fixed object on the road. This is applicable for two-lane and one-lane two-way roads. Shown in Figure 9 above.
- Intermediate sight distance (ISD) – This is applicable for one-lane two-way roads where enough sight distance is required for two vehicles approaching each other to stop before colliding. It is taken as twice the stopping sight distance required for a vehicle approaching a fixed object. The values given in Appendix D are based on selected friction values appropriate for sealed and unsealed roads.

Sight stopping distance is mainly based on Design Speed and slightly on the slope, which will act on the level on deceleration. The following table, Table 10 outlines recommended stopping sight distances for flat terrain.

Metric				
	Brake reaction distance (m)	Braking distance on level (m)	Stopping sight distance	
Design speed (km/h)			Calculated (m)	Design (m)
20	13.9	4.6	18.5	20
30	20.9	10.3	31.2	35
40	27.8	18.4	46.2	50
50	34.8	28.7	63.5	65
60	41.7	41.3	83.0	85
70	48.7	56.2	104.9	105
80	55.6	73.4	129.0	130
90	62.6	92.9	155.5	160
100	69.5	114.7	184.2	185
110	76.5	138.8	215.3	220
120	83.4	165.2	248.6	250
130	90.4	193.8	284.2	285

Note: Break prediction distance on a time of 2.5 s, deceleration rate of 3.4 m/s2 used to determine calculation sight distance.

Table 8 Stopping Sight distance

These stopping sight distances are provided as a guide to address design on sharp curves, steep hill top, etc. in cases where there is a security issue may for a given road segment.

6.6 Vertical Curves

Crest and sag vertical curves for low volume roads should be based on the minimum stopping sight distance. The calculations are based on a driver height of 1.15 m and a fixed object height of 0.2 m. This is considered to provide an appropriate basis for low volume roads where there may be an absence of continuous maintenance and a likelihood of a vehicle having to stop for a fixed object such as logs, washouts etc. The values in Appendix allow for vertical curves on two-lane two-way roads based on providing minimum stopping sight distance.

On single-lane, two-way roads the values for stopping sight distance do not provide an adequate level of safety for the situation of two approaching vehicles travelling in the same lane. In this situation the stopping sight distance is required with a sight line from driver eye height to eye height. For such cases the 'K' values need to be doubled. Where this increased stopping sight distance is not available or is uneconomical to provide, an alternative is to widen the road (by about 3 m) to form a two-way road over the length of the vertical curve to allow oncoming vehicles greater manœuvering space to take evasive action.

For sag curves, on low volume roads, the design value proposed is based on comfort control criterion. See figure 10 below:

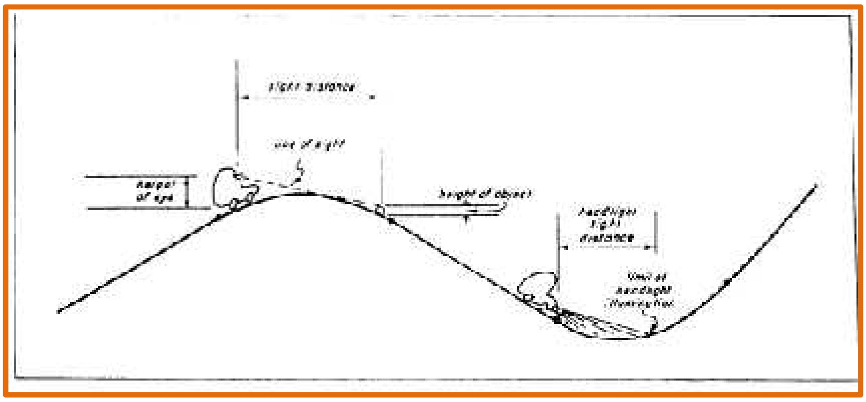


Figure 10. Crest and Sag vertical curve

it is recommended to refers to the Austroads (2009) - Guide to Road Design Part 3 – Geometric Design, for further details it there is any localised issue potentially or effectively unsecured along the road alignment as the:

- Vertical curve overlaps one or both ends of the horizontal curve,
- Insufficient separation between the curves,
- Dissimilar length horizontal and vertical geometric elements,
- Long flat grades,
- Roller coaster grading or
- Any other issues affecting the security,

7 Guideline to Pavement Design

7.1 Pavement requirements

Unsealed road pavements are often constructed in development stages as they move from unformed to formed, and formed and gravelled pavements.

A formed and gravelled road pavement generally consists of distinct layers as shown in Figure 11 below. The preferred pavement make-up, (Digram A) consists of a base and a wearing course. In some cases where pavement thickness required is greater than 150 mm a sub-base may be used.

The common pavement type found consists of just a base course or a wearing course, which also serves as a base course (Diagram B). In this case the base course must also perform the function of a wearing course. This is not the best option as the base course will need to have a higher plasticity index (PI) to bind the pavement material to withstand the abrasive action of vehicles. However in Vanuatu like in many other countries, it is common to have only one pavement material that acts as both a base course and wearing course

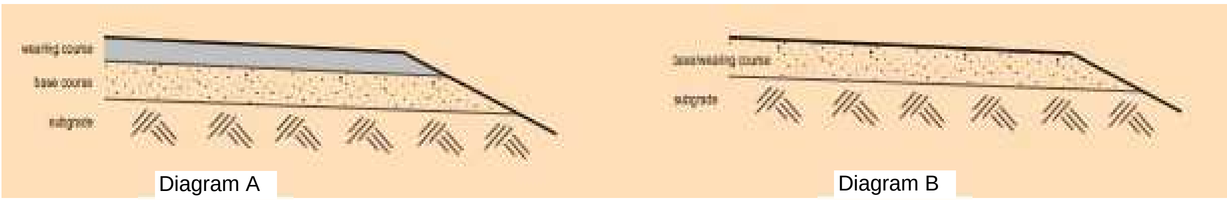


Figure 11. Pavement layer options

The “best practice” requirement for the different preferred layers are described below.

Sub-grade – consists of in situ soil or rock, previously placed landfill or spoil or other existing natural local material over which a road is to be placed.

The support provided by the subgrade is the most important factor in determining pavement design thickness. The subgrade support is dependent upon soil type, material density and moisture content both during construction and seasonal changes whilst in service.

Subgrade strength is commonly defined in terms of the California Bearing Ratio (CBR), which essentially represents the ratio, expressed as a percentage, of the penetration resistance of a soil to the penetration resistance of a standard crushed rock.

Sub-base – is the lower layer within the base course of a road. It usually consists of compacted granular material. Marginal materials and coarse rocks are the general components of this layer. Apart from providing structural strength, by distributing heavy wheel loads over a larger area, they also serve other purposes such as preventing intrusion of the subgrade soil into the base course and providing a working platform for construction traffic on the base course.

Base course – is the layer of crushed aggregate placed directly onto the subgrade or sub-base if used. Usually better quality aggregates are used with the required grading and moisture content. The base course provides the main source of the pavement strength. Material specifications for the base course are generally more stringent than for sub-base material.

Wearing course – is the uppermost layer of the pavement that comes into direct contact with vehicle tyres. An unsealed road surface should generally be constructed with fine gravel with closely controlled grading and plasticity to help bind the material together to avoid ravelling under load and to minimise dust emissions. The primary purpose is to provide a more tightly bound surface to reduce aggregate loss. This in turn provides a smooth running surface to minimise tyre wear, and high surface friction for vehicle braking and accelerations. It can also be referred to as a surface course as its purpose is to gradually wear away under traffic whilst protecting the base course from ravelling.

7.2 Pavement development

As the surface of an unsealed pavement is maintained by routine grading and periodic reshaping and re-gravelling, the consequences of loss in shape are of less concern than a similar deformation of a sealed pavement. Because of these circumstances, staged development of unsealed pavements is widely practised.

Consequently, the first consideration in the design of an unsealed pavement is the determination of the stage to which it is to be constructed, e.g. cleared and made trafficable, formed, formed with minimum paving, partially paved, or fully paved. This decision depends on the following factors:

- Soil type
- Type and volume of traffic
- Climatic conditions
- Drainage
- Social and economic benefits derived from

the improvement
- Cost
- Availability of material
- Future maintenance cost

7.3 Design Stages

7.3.1 Unformed roads

This is the first stage in the construction of a road where the road alignment is cleared and the surface made trafficable. The permanent alignment is cleared of all vegetation and topsoil with the running surface consisting only of in situ materials. This stage of construction will sustain only very light traffic. Usually, minimum drainage is provided. Building at this stage enables subsequent improvements to be made on the final road alignment. Cleared vegetation and topsoil should be stockpiled separately for later use.

7.3.2 Formed roads

At this stage, the earthworks are constructed on the permanent alignment. Further drainage is provided.

Fair to good soils (e.g. sand-clay or sand-silt-clay) are likely to sustain higher volumes of traffic for the same maintenance cost as poor soils (e.g. clays or silts). For example, 80 vpd on fair to good soils may be equivalent to 20 vpd on poor soils.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Good drainage of the road surface, i.e. by having adequate crossfall, a hard surface and table drains, will enhance the performance of these roads. At the most, 50 mm of gravel is needed only on sections of poor soil.

7.3.3 Formed and paved (gravel) roads

An earth road may warrant paving (or sheeting) when maintenance costs increase to unacceptable levels, where existing soils are weak or when economic or social benefits are evident. Average traffic for gravel roads usually varies between 20 and 200 vpd.

It would require a consequent drainage system.

7.3.4 Pavement design

The design of an unsealed road pavement requires the determination of the granular base thickness, which depends on the strength/CBR (California Bearing Ratio) of the underlying soil (generally measured when the soil is wet) and the number of heavy vehicle axle passes converted to the number of equivalent standard axles (ESA) within the design life.

Often granular pavement thickness is not designed and normally a minimal thickness of granular material is used. This thickness is based on experience and ranges from 100 to 300 mm in depth. This is because unsealed roads are more forgiving than sealed roads in that if significant rutting occurs on a sealed road, the seal has also to be replaced and becomes a more costly operation. While this may be common practice, it is more cost-effective to provide the required thickness initially, rather than having to undertake additional maintenance, or providing a greater pavement thickness than is needed.

In theory the pavement structure of a sealed or unsealed road is the same, as both are required to support the same traffic load over a given subgrade. A spray seal adds no strength to a pavement but provides greater abrasive resistance to traffic wheels and reduces penetration of moisture into the pavement compared to a gravel-wearing course. In practice, however, the material specifications for unsealed roads are typically of a lower standard than for a sealed road due to limited funding available and the extensive coverage in the road network.

Pavement design needs only to be undertaken for formed, gravel roads or particular road segments to establish the thickness of gravel that should provide for the design life. The other road types, unformed and formed roads, have usually no granular materials added.

Australian Pavement Research Group Report No. 21 (APRG 1998) provides pavement thickness design curves for constructing both sealed and unsealed rural roads of low structural integrity with granular materials. The empirical design chart is shown in Figure 12 and is based on a probability level of 80% (i.e. 20% risk of rehabilitation of the pavement being required before the end of the design life).

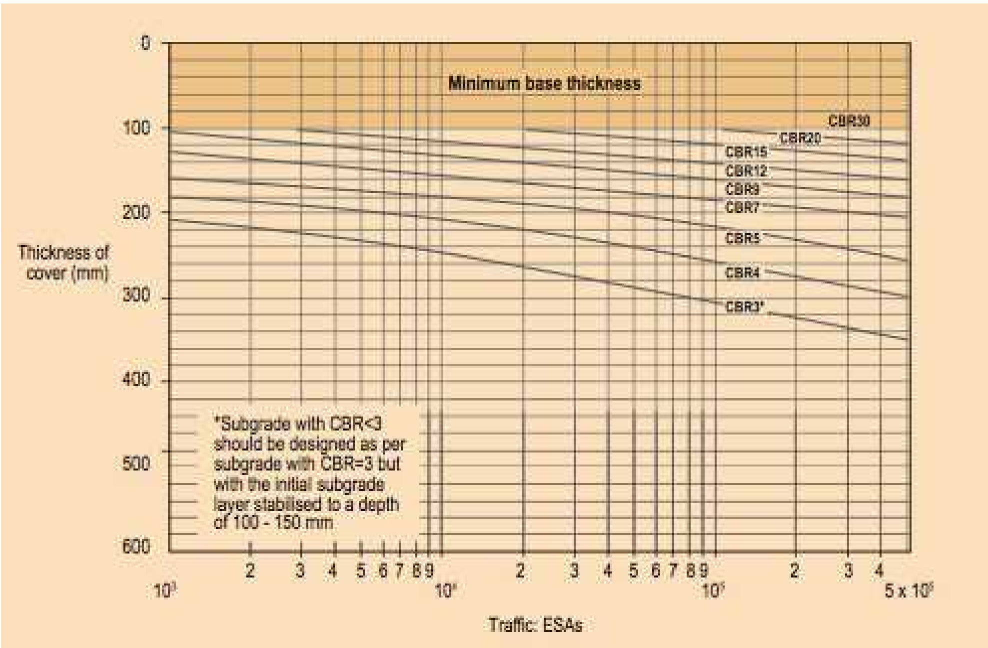

Figure 12 Design chart for granular pavements (80% confidence)

Source: APRG (1998).

Unsealed roads can be periodically reshaped, and regravelled. The 80% probability curves will provide a reasonable estimate of the full thickness of pavement for unsealed roads, taking into account traffic - equivalent standard axles, (ESA), subgrade soil strength (CBR) and moisture conditions. If a wearing course is applied, it should not be included as part of the structural thickness as it will wear away over time.

Specifically the curves apply to the design of flexible pavements if the design traffic is in the range 10^3 to 5×10^5 ESA. This accords reasonably well for sealed roads and their use is recommended for the pavement thickness design for most of the unsealed roads in Vanuatu.

The relevant pavement design procedures include:

1. Subgrade evaluation − determining the design CBR for the subgrade at equilibrium moisture content.
2. Design traffic estimation − determining the design traffic value, i.e. the number of equivalent standard 80 kN axles (ESA).
3. Thickness design − using the design traffic ESA and the design CBR value, determining the pavement thickness from the thickness design curves).

The top layer of the pavement should desirably consist of a wearing course material. The minimum depth of wearing course should be taken into consideration as well as the likely loss of material during the period of the re-gravelling cycle. This is usually in the order of 10 to 45 mm/ year / 100vpd for the first phase of the deterioration cycle lasting possibly two or three years.

7.3.5 Environment factors

Roads which are subject to low traffic volumes have relatively more pavement distress attributable to the environmental effects than is the case for higher volume situations.

This leads to a requirement for a greater pavement thickness than the traffic volume alone would indicate. The main environmental factors affecting pavement performance are moisture and temperature.

Moisture environment

The moisture regime associated with a pavement has a major influence on its performance. The stiffness, strength and susceptibility to permanent deformation of unbound materials and subgrades are heavily dependent on the moisture content of the materials.

Factors influencing the moisture regime within a pavement include:

- Rainfall and evaporation pattern
- Permeability of the wearing surface and adjacent areas
- Surfaces and drains
- Effectiveness and proximity of drainage (table drains, culverts)
- Depth to the water table
- Roadside vegetation, in particular overhanging trees
- Shading pavement
- Movement of ground water
- Relative permeability of the subgrade and pavement layers
- Local geology – specifically the presence of open jointed or fractured rock materials which frequently have permeable layers which may allow in high seepage flow
- Pavement construction type (boxed or full width).
- Topography

Most pavements contain measures to control the ingress of water into the pavement structure.

The provision of a high crossfall, (4–6%), a wearing surface that is tightly bound, table drains, cross drains and, if necessary, sub-surface drainage (or moisture barriers) will help to reduce the influence of water on pavement performance. These effects may be more significant adjacent to the edge of the pavement, the critical area of the pavement in respect of moisture effects.

Temperature environment

The temperature environment and wind effects can have a major influence on pavement performance. At high temperatures the pavement surface can become dry and dusty and may crack. At low temperatures, usually associated with periods of precipitation, moisture can remain within the pavement layers and subgrade for considerable amounts of time, potentially softening the materials and weakening the structure.

7.3.6 Subgrade evaluation

Subgrade support is in many respects beyond the control of either the designer or constructor, and is therefore the primary factor influencing the pavement thickness design. The designer should assign a CBR value to the subgrade. This may be evaluated by field and/or laboratory testing and/or experience.

The purpose of subgrade evaluation is to estimate the support provided to the pavement during its lifetime. The support will be dependent upon the material type, its moisture content and degree of compaction. Although the material at the top of the subgrade may be uniform along the project, the moisture variations that will occur in this material, both along the road (due to topography, drainage, underlying soil profile etc.) and cyclically with time (annual wetting and drying cycles), should be considered in assessing the support provided. For pavement design procedures presented in this Manual, the subgrade strength is characterised by its design CBR.

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The strength / CBR of the subgrade soil is affected by water. In pavement design, three different subgrade CBRs can be defined by moisture content:

- At equilibrium moisture content (EMC) which is described as the moisture content at any point in a soil after moisture movements and changes have stabilised in a constructed pavement.
- At in situ moisture content which is dependent on the time of the year the CBR is measured. This may be wetter than EMC if the road and drainage ditches are not yet constructed.
- At a four day soaked moisture content as

commonly used in Australia and New Zealand for sealed pavements.

Subgrade evaluation is an important component of pavement design. It can be undertaken using either presumptive CBR values, based on overall experience or by field-testing.

The subgrade should have a CBR of more than 8%. In most part of the Islands, the subgrade will have a much higher bearing capacity than that. However, soft material containing a high proportion of clay and/or organics can be lower. If the pavement designer is uncertain about subgrade capability, it is strongly recommended to undertake a subgrade evaluation. The Dynamic Cone Penetrometer (DCP) is very easy and fast to use. The correlation is shown in Figure 13 below.

Suggested spacing of test sites should vary from a minimum of 20 metres for spot improvement to a minimum of 300 metres for longer rural projects. However, not less than three sites should be tested in any one project so as to enable confirmation of the CBR value. Where there is generally some variation along a project, at least three test sites should be selected in each subgrade, topography and drainage combination. It is recommended that the project be subdivided into sections, in areas deemed to be homogeneous. A design subgrade CBR should then be determined for each section taking the 10th percentile low value of all estimated equilibrium CBRs.

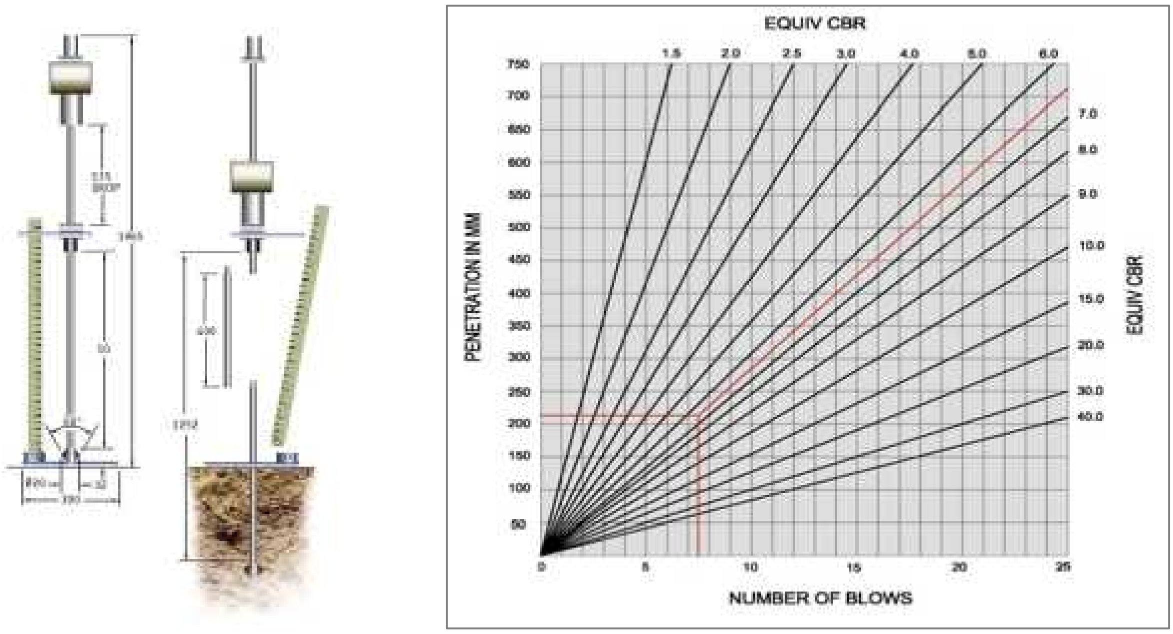


Figure 13. Correlation between DCP penetration and CBR

If results are marginal, subgrade may be sampled to verify various characteristics such as laboratory CBR testing (unsoaked or four day soaked), natural moisture content, particle size distribution and Atterberg Limits.

In addition, visual appearance, the feel of the material in the palm of the hand and local knowledge provide valuable additional information when assessing materials.

The soil composition (gravel, sand, silt, and clay) and the degree of moisture present can give a quick and simple indication of the soil strength. Dry materials will generally have a higher strength than wet. Coarser- grained and well-graded mixtures will generally be stronger than fine-grained or uniform sands or clays. In a dry environment clays can be very strong but will rapidly lose strength when wetted. A small amount of moisture in a sandy material will actually improve cohesive strength. Where available field data is insufficient to indicate a CBR value, typical presumptive CBR values can be used as given in Table 9 below.

Description of subgrade		Typical CBR values (%)	
Material	USC* classification	Well drained	Poorly drained
Highly plastic clay	CH	5	2–3
Silt	ML	4	2
Silty clay	CL	5–6	3–4
Sandy clay	SC	5–6	3–4
Sand	SW, SP	10–15	5–10

* USC – Unified Soil Classification system.
Source: Austroads (2004 b).

Table 9. Typical presumptive design CBR values

7.3.7 Design traffic estimation

Light vehicles such as cars contribute very little to structural deterioration and only commercial or heavy vehicles are considered in pavement design. A commercial vehicle (CV) is defined as one with more than two axles or dual rear tyres. For the traditional pavement design approach, traffic volumes in terms of the number of heavy vehicles and vehicle type, are needed to convert to the number of ESAs to estimate pavement thickness. As there is little (5%) or no heavy traffic in Vanuatu on most roads, the maximum number of ESAs should be below 10^5 ESA, and average around 10^3 ESA. For some particular stretches of roads they maybe subject to more heavy traffic locally, for example near a port or a quarry. In these instances, these particular stretches should be addressed separately.

7.3.8 Pavement Thickness

Knowing the number of ECAs (derived from ADT and %HV and number of lanes) and the CBR of the subgrade, the chart in Figure 14 recommends the design thickness.

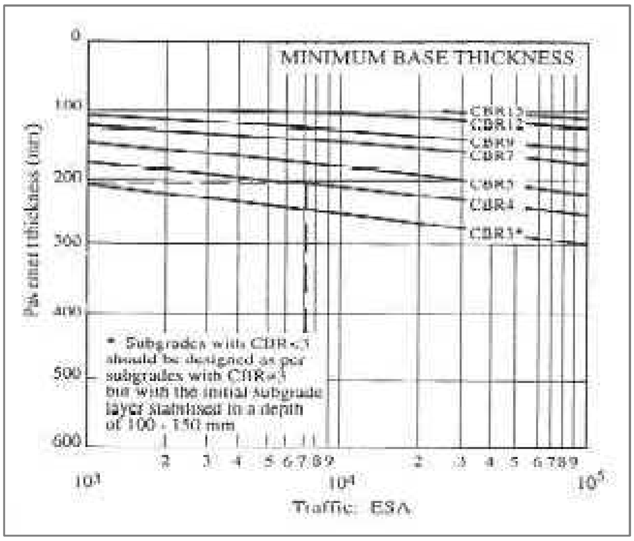


Figure 14. ARRB Gravel Thickness Design Chart

Pavement thickness in Vanuatu based on traffic volume should have a thickness of 100 mm to 300 mm, with 100 mm being the minimum. Most pavement thickness in Vanautu is specified at 150 mm. If the subgrade CBR (when wet) is higher than 5 %, this thickness should be suitable for most traffic purposes. Even 100 mm should be fine if the subgrade CBR is higher than 15%. However, if the subgrade is weaker than 5%, thickness should be increased. It is therefore important to be able to evaluate the real subgrade CBR when weakness is suspected. Some examples are illustrated in Table 10 below.

ADT[1]	% HV[2]	Lanes	ECAs	CBR values			
				3	5	9	15
50	1	1	4×10^2	100	100	100	100
150	2	2	1×10^3	210	160	100	100
250	3	2	3×10^3	220	165	100	100
250	10	2	9×10^3	245	180	130	100
400	4	2	6×10^3	240	155	110	100
600	5	2	1×10^4	250	180	130	100
800	20	2	6×10^4	290	210	150	115

[1] Average daily traffic [2] Percentage Heavy Vehicles

Table 10. Estimated Pavement thickness required (mm)

7.4 Selection of pavement material

Materials for unsealed road pavements are usually selected on the basis of availability, material properties, cost, environmental factors or social issues. Often the selection decision is a compromise between achieving the desirable properties and available funds.

Environmental factors may eliminate some sources of new materials due to inappropriate location (erodible beach) or the difficulty and delays in obtaining approvals from the environmental agency. Social issues may result in refusal from landowners or communities to access borrow pits.

7.4.1 Base / Wearing course material

The wearing course material should be durable and of consistent quality to ensure it wears away evenly. The desirable characteristics of the wearing course of an unsealed road are:

- Resistance to raveling and scouring
- Wet and dry stability
- Low permeability
- Cohesive properties
- Load spreading ability.
- Skid resistance
- Smooth riding characteristics

For ease of construction and maintenance, a surface material should also be easy to grade and compact. The material properties having the greatest influence on these characteristics are the particle size distribution and the chemical/physical properties of the fine particles in terms of plasticity. Particle size distribution and its effects may conveniently be described in terms of standard particle size classifications (e.g. gravel, sand, silt and clay) or, alternatively, the fraction passing various sieve sizes. Visual evaluation in the field, using standard classifications, and/or laboratory tests, can be employed to assess a material's potential.

Gravels and sands that are low in fines will be porous, lack stability when dry and will ravel under traffic. However, fines in the form of a sand–clay may be incorporated into these materials to give added stability.

Corrugation in Ambae

Gravel loss in Tanna

The least desirable materials are those with silty fines, lacking gravel-sized particles, i.e. silts and silty-sands. These materials are likely to be porous and unstable and will ravel under traffic. They also tend to generate considerable dust.

Predominantly clay soils can provide a good dry-weather surface but will be slippery and/or will rut when wet. Sand–clay or sand–silt–clay mixtures can provide a satisfactory surface course for low traffic volume roads.

Either the Plasticity Index (PI) or the Linear Shrinkage (LS) can be used to evaluate whether the clay content of a material is appropriate. The PL or LS should desirably fall within minimum and maximum values, depending on climatic conditions, grading of the material and traffic conditions.

Particle strength and susceptibility to weathering will affect the ultimate grading and plasticity of paving material. In general, it can be said that the easier a rock is to rip, the more it is likely to break down in construction and service. A material, which breaks down readily or has a history of weathering, should be thoroughly evaluated before use. It may be useful to expose the material to the elements over a short section of roadway for a while to test its suitability.

The specifications proposed, have been developed to comply with the requirements of "ideal" wearing course materials, which also perform as a base course. On this basis the following should be considered in the context of Vanuatu. The specifications should:

- Be kept as simple as possible, with as few requirements or different test methods as possible.
- Give limits as wide as possible and not restricted to a narrow range of significant property (e.g. a tight grading envelope), but comprehensive enough to accept suitable materials and reject unsuitable materials.
- Require properties that require inexpensive, quick, simple tests, which are repeatable and reproducible and need minimal sophisticated equipment and a relatively low level of operator training.
- Be practical to implement and apply to the total area for which they are intended.
- Adequately define important properties (indirectly if necessary) such as cohesion and strength and eliminate obvious problems such as oversize material.
- Be in terms of existing test methods or combinations of results from existing methods, although scope exists for the development of simple new methods.
- Be based on performance related studies.
- Be rigidly adhered to. The user should appreciate the consequences of use of non-complying materials e.g. increased construction, maintenance and road user costs, increased dust and poor safety standards.

The choice of the gravel surfacing material is most often a compromise between a material, which possesses sufficiently high plasticity to prevent gravel loss in the dry season and sufficiently low plasticity to prevent serious rutting and deformation in the wet season. Choice of materials will also depend, when possible, on haul distances, as this will greatly affect construction costs and rate of progress.

Malekula

Tanna

Material specifications proposed are provided below in Table 11:

Sieve	Envelope (% passing)	Note on grading specification
53	100	This envelope is assuming that some of the largest particle (37,4-53mm) will break down during compaction. It is also assuming that the spread-water-compact operation is performed adequately. Some quarries may also have harder particles, which wouldn't break down. This could make the wearing surface to become fairly rough after few months of heavy traffic and rain. In that case, it is advised to revise the grading specifications in order to reduce (or eliminate) the coarser content (37,5-53mm), at least for the wearing course. A smaller nominal size would ease spreading and compaction and smoother ride.
37,5	90-100	
19	70-100	
2,36	35-65	
0,425	15-50	
0,075	10-30	

Table 11. Specification for Grading

Considering the variation in the characteristics of the Coronous and scoria between quarries and even within the same borrow pit, it is suggested to perform regularly a visual assessment of the fine content of the material during the extraction process and to sample the quarry to build the knowledge of the material. It is also important to sample in different zones.

Other characteristics that can be relevant to verify are PI, LS and CBR. Therefore, the specifications would ideally be the following those listed inTable 12.

Characteristics	Specification	
Grading Coefficient	16 – 34	(% passing 26.5 mm - % passing 2 mm) x % passing 4.75 mm / 100
Grading Modulus	1.5 – 2.5	(200 – (% passing 2 mm + % passing 0.425 + % passing 0.075)) / 100
Fine to sand ratio	0.25 – 0.24	5 passing 0.075 / % passing 2.36
Plasticity Index (PI)	Max 15	If CBR in unknown or < 8 %
Plasticity product	300 - 400	PI x % passing 0.425 mm
Shrinkage Product (Sp)	100 - 365[1]	LS x % passing 0.425 mm
Soaked CBR	Min 30%	

[1] 240 Preferable

Table 12. Indicative specification for other properties

The limits stated for the characteristics in Table 12 come from experience in other countries and documented studies. These may or may not be suitable for Vanuatu. In order to develop specific requirements for local material, a better knowledge of the material properties are needed. The actual information required for this is almost non – existent and sometimes irrelevant. Therefore, sampling and testing must be done on the local material.

When properties of the local material are better known, revision of the above limits will be required.

8 Guidelines on Drainage Design

8.1 Overview

Drainage is probably the most dominant factor affecting the performance of a rural road. When such roads fail it is often because of inadequacies in drainage resulting in the ingress of water into the road structure, causing structural damage and needing costly repairs.

One of the most important aspects of the design of a road is the provision made for protecting the road from surface water or ground water intrusion. If water is allowed to enter the structure of the road, the pavement will be weakened and it will be much more susceptible to damage by traffic. Water can enter the road as a result of rain penetrating the surface or as a result of the infiltration of ground water. The road surface must be constructed with a camber so that it sheds rain-water quickly and the formation of the road must be raised above the level of the local water table to prevent it being soaked by ground water.

Drainage is one of the most important and critical factors in the ability of an unsealed road to withstand traffic loads. Its main components are illustrated in Figure 15

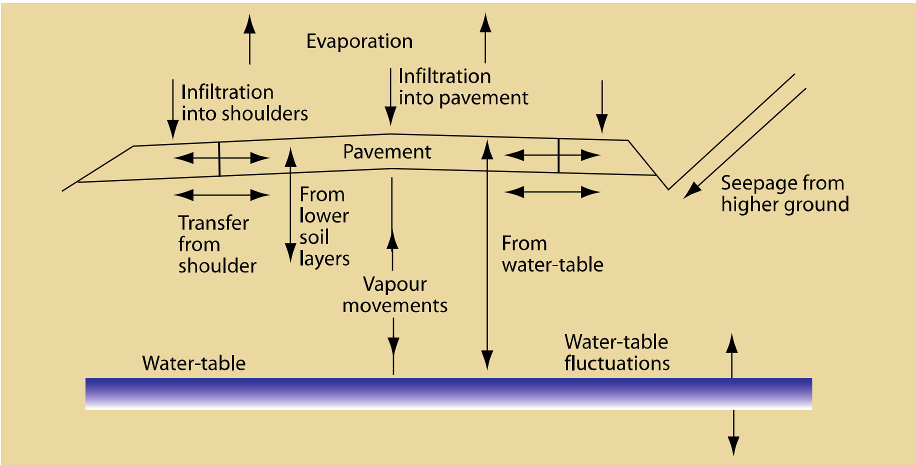


Figure 15. Moisture movements in pavements and subgrades (NAA SRA, 1987)

Water can also have a harmful effect on shoulders, slopes, ditches and other features. High water velocities can cause erosion which, when severe, can lead to the road being cut. Alternatively, low velocities in drainage facilities can lead to silt being deposited which, in turn, can lead to a blockage. Blockages often result in further erosion. In addition, surface water can form a road safety hazard for vehicles.

A good road drainage system, which is properly maintained, is vital to the successful operation of a road. It has four main functions:

- To convey rainwater away from the surface of the carriageway to outfalls (streams and turn-outs)
- To control the level of the water table in the subgrade beneath the carriageway
- To intercept surface water flowing towards the road
- To convey water across the line of the road in a controlled fashion.

The first three functions are performed by side drains and the fourth by culverts, drifts and bridges.

Common drainage problems include:

- Blocking of drains by debris or vegetation
- Silting: the deposition of silt in the bottom of drains and culverts, often reducing the gradient
- Erosion of the bottom of side drains in erodible soils or on steep gradients, particularly where insufficient turn-outs result in large flows in drains
- Erosion at culvert outfalls, resulting from high discharge velocities
- Erosion of shoulders and side slopes.

Even if the drainage system of a new road has been carefully designed, it is likely that for several years after construction it will be necessary to observe its performance closely and to make additions and amendments to it. It is important to consider design as this forms part of the maintenance requirements.

Both in the design and maintenance of drainage, it is important to interfere as little as possible with the natural flow of water. Culverts on natural watercourses should follow the existing alignment as closely as practicable and re-alignment resulting in sharp changes in direction should be avoided. The surface flows in drains and culverts should also be kept to a minimum by the use of frequent turn-outs where side drains cannot be discharged to existing water courses. In side-long ground, where discharge from the side drain on the high side passes to the low side, it is best to use frequent small culverts rather than occasional large ones. But in this choice, maintenance needs to be addressed. In such cases, the spacing will be governed by the maximum flow acceptable in the side drains and the capacity of the culverts will not usually be a constraint as the minimum requirements for access for maintenance (often taken as 600mm diameter for a pipe drain or 600mm x 600mm for a box drain) will ensure adequate capacity.

8.2 Internal and External Aspects of Drainage

Many rural roads have been constructed with inadequate engineering and drainage design. Even with properly engineered roads, on-site inspection is necessary to correct any unforeseen conditions during construction.

Two inter-related aspects of drainage require careful consideration during construction, namely:

- Internal drainage of the pavement which seeks to avoid the entrapment of water by allowing it to permeate through and drain out of the pavement structure.

- External drainage which seeks to divert water away from, and prevent its ingress into, the pavement structure through measures such as the construction of sealed shoulders, side drains, etc.

Figure 16. Pavements and Shoulders Breaking-up

Internal drainage involves measures to minimise moisture contents in the embankment and pavement layers and importantly to prevent unwanted movement of water within the structure. Internal drainage is vital for the satisfactory performance of earthworks and pavement layers made of natural soils and gravel, especially those that utilise fine grained materials.

External drainage involves methods of crossing of watercourses, measures to divert water away from the road and prevention of damage caused by erosion as seen in Figure 16 above. In the construction of rural roads there is often wide scope for the use of various measures to improve external drainage, such as low-level structures, drifts etc. where 100% passability to traffic throughout the year may not be required.

8.3 Internal Drainage

8.4 Permeability of Pavement Layers

Wherever possible, each layer in pavement and earthworks should be more permeable than the overlying layer in order to prevent any water entering the structure from being trapped. It is often not possible to meet this requirement consistently and the provision of **crossfall** in all earthworks and layer works for water to escape from the pavement structure can alleviate the problem.

Under severe conditions, especially where there is risk of water seeping into the pavement structure, consideration should be given to installing subsurface drainage systems or, better still, to **increase the height** of the road in such areas.

8.5 Seepage and Subsurface Drains

Inadequate surface and subsurface drainage are typical deficiencies associated with cut-and-fill pavement sections. Figure 17 shows typical problems resulting from inadequate drainage.

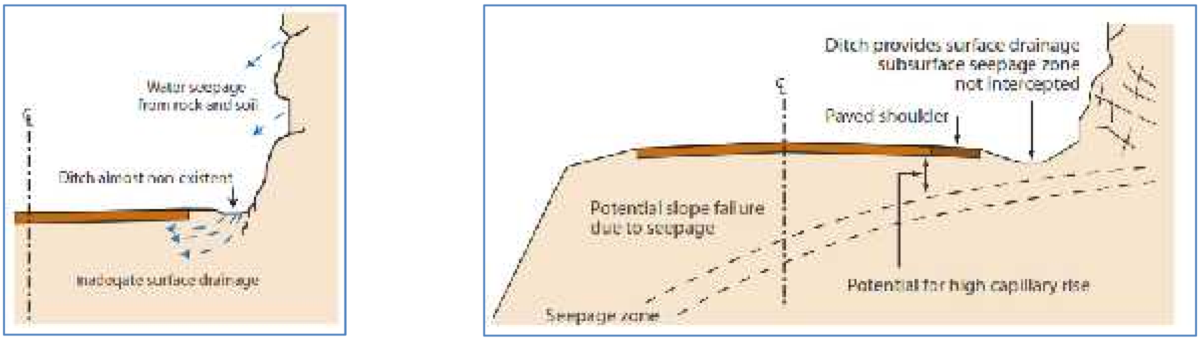


Figure 17. Typical problems resulting from inadequate drainage

Subsurface drainage may be constructed using pipe or rubble drains set into the subgrade or by using a subbase layer of material with free draining properties such as a coarse gravel or sand.

Subsurface drains can be made of geotextiles wrapped around aggregate, with or without pipes installed, but various specialised systems are also marketed. Such drains have commonly been made out of aggregate surrounded by filter sand instead of geotextiles, depending on the grading of the in-situ soils.

These drains are expensive and may not be justified for low-volume unsealed roads, except for localised areas where no other way of preventing ingress of water into the pavement is possible. As subsurface drainage systems usually incur relatively high installation costs and there is the risk of blocking of buried systems, alternative options are preferred.

8.6 External Drainage

It is not possible to provide a detailed description of all the various measures that make up a good drainage system. Conditions on site will vary tremendously in respect of in-situ soils, topography, vegetation, climate, human settlement patterns, environmental concerns, etc. Knowledge about local conditions are critical for successful installation of mitre drains, catch-water drains, side drains, berms, channels, cut-off drains and crossings along roads which are essential components of an effective drainage system.

8.7 Surface drainage

The need for subsurface drainage can be reduced by use of adequate surface drainage, which prevents water penetrating into the pavement and subgrade.

Surface drainage comprises those elements that collect and remove water from the surface of the road. It includes culverts and any other drainage system designed to intercept, collect and dispose of surface water flowing towards and onto the road surface from adjacent areas.

8.8 Crossfall and Shoulders

It is very important to provide adequate crossfall to allow surface water to run off the pavement on unsealed roads.

However, in areas of negligible slope, which are prone to flooding, a raised formation may act as a dam for floodwaters and this should be avoided. In such cases the alignment should be chosen to be along the higher elevated sections of the ground surface. If the ground level is such that the road formation will act as a dam, then the road should be designed so that the surface of the road is level with the natural surface level. This means that the road will not be passable when wet. The decision as to when to re-open the road, after flooding, will depend on the likely initial deformation and other damage caused by traffic on the wet road.

Low formation roads, which closely follow the natural surface level (about 300 mm above), have many benefits and risks. The benefits are less earthworks and costs with the risks associated with a higher water table and increased moisture in the pavement.

Construction of shoulders needs to be undertaken carefully if typical drainage problems are to be avoided. Preferably, the granular base should extend to the embankment slope with sufficient height above the ditch to prevent water intrusion.

Shoulder materials should be selected which have a permeability similar to that of the base course, so that water does not get trapped within the pavement. However, the material properties for unsealed shoulders may well be different from those required for the base for reasons of durability. Unsealed shoulders are similar to a gravel wearing course and require material with some plasticity, which is a property that might be considered less desirable for road base material.

A common problem is water infiltration into the base and subbase, which occurs for a number of reasons as illustrated in Figure 18 below. The figures show effects with a sealed surface but similar problems can arise with an unsealed but well compacted wearing course:

- Rutting adjacent to the sealed surface
- Buildup of deposits of grass and debris
- Poor joint between base and shoulder (more common when a paved shoulder has been added after initial construction)

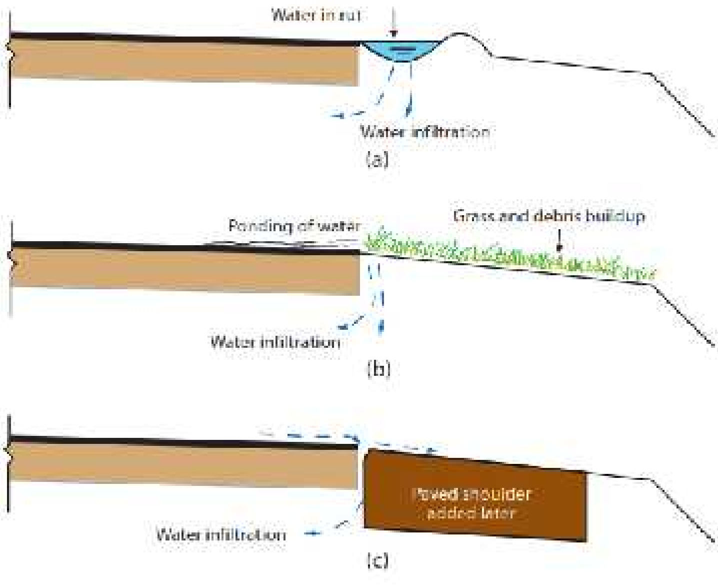
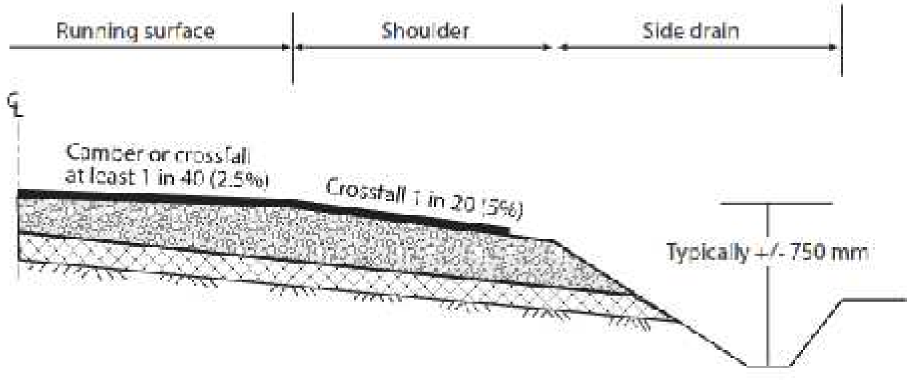


Figure 18. Drainage deficiencies in pavement shoulder construction

Ideally, as illustrated in the figure below in Figure 19, the base and subbase layers should be extended outwards to form the shoulders, which should preferably be sealed if the road is sealed.



Crossfall = > 2.5% if sealed

= 4-6% if unsealed

Figure 19. Ideal shoulder construction / drainage arrangements

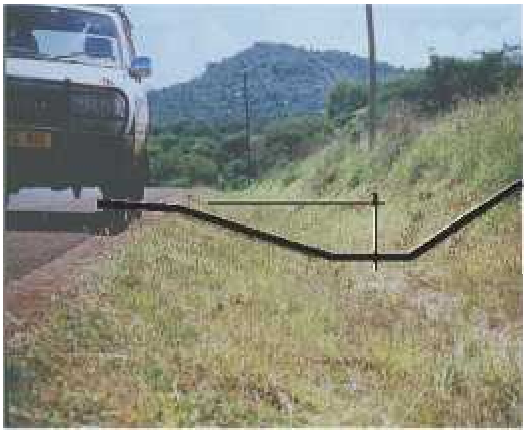
8.9 Crown Height

Crown height is the vertical distance from the bottom of the side drain to the finished road level at centre line and needs to be sufficiently great to allow proper internal drainage of the pavement layers. It maintains the height of the pavement above the adjacent water level in the drains.

Economical ways to achieve sufficient crown height include the use of material from the side drains and road reserve to lift the height of the road. Maintaining sufficient crown height through cuttings is of particular importance, owing to the unfavourable drainage conditions in such areas.

However, this may result in a considerable increase in the quantity of earthworks. Alternatives, such as subsurface filter drains, should be considered as a last resort because of cost and maintenance implications. The traffic safety aspects of large crown heights should be taken into account by moving the side drain further away from the shoulder break point.

In areas where in situ soils are considered to be self-draining, such as in sandy areas, priority should be given to providing good side support within a low embankment profile and shallow side slopes (typically 1:6 or 1:8) rather than a large crown height and relatively steep side slopes.



Minimum crown height 750 mm recommended.

Figure 20. Minimum crown height

Such deficiencies can affect the pavement by erosion, decreasing soil support or initiating creep or failure of the downhill fill or slope.

8.10 Road Elevation

In order to minimise subsurface drainage, elevation of the road on to an embankment should be considered whenever high water tables are encountered. Table drains should be constructed to be 600 mm below the bottom of the wearing surface.

8.11 Table drains

Table drains otherwise known as drainage ditches or side drains, run parallel to the road and are used to drain water from the road surface and adjoining slopes. These drains are usually placed in cut sections and at grade sections, but can be used along the toe of a fill section if required to collect water to discharge to a suitable location. Table drains can have flat bottoms and may be lined or unlined. For low-volume unsealed roads, most table drains are unlined, unless there is a potential scouring problem.

In cuttings, table drains on one side of a road may be eliminated by either in-sloping or out-sloping the road formation as shown in Figure 21 and Figure 22 respectively.

8.11.1 In-sloping

In-sloping can be used :

- To keep water away from unstable fill slopes
- With or without a table drain or ditch (subject to grade)
- For short sections of roads
- Cross drains can be installed as required to avoid buildup of fast running water in table drains.

It is important to ensure at curves that the crossfall conforms to superelevation requirements.

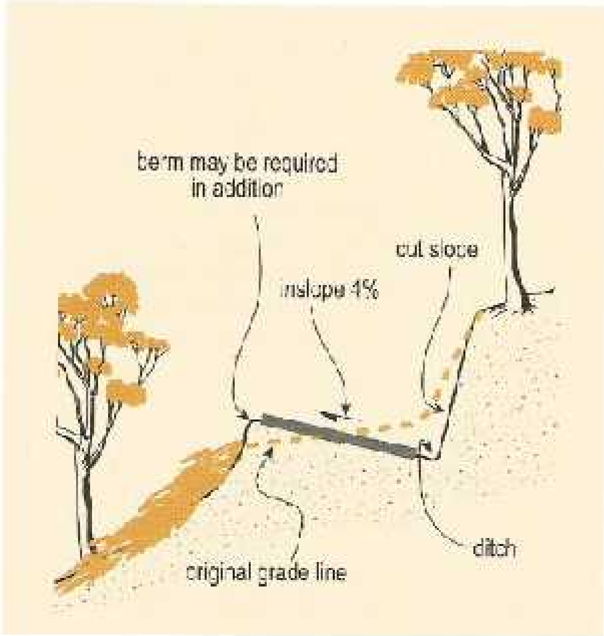


Figure 21. In-sloping

8.11.2 Out-sloping
Outsloping :

- provides a means of dispersing water in a low energy flow from the road surface
- is appropriate where fill slopes are stable
- is good for contour roads having gentle gradients

It is important to ensure at curves that the crossfall conforms to safety requirements.

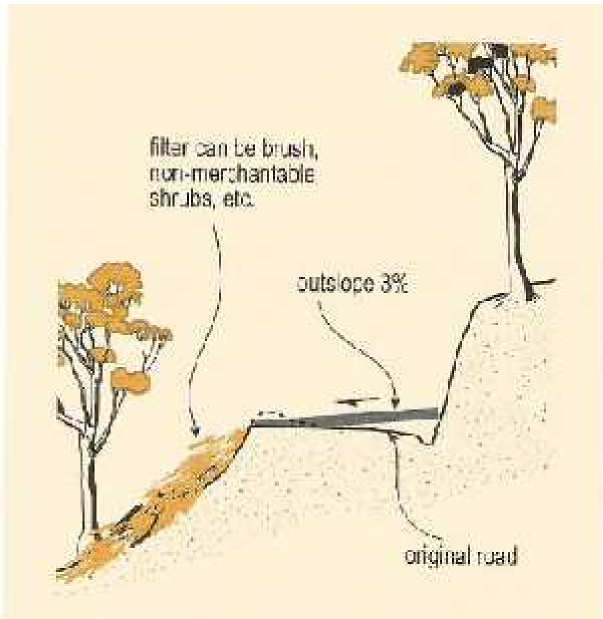
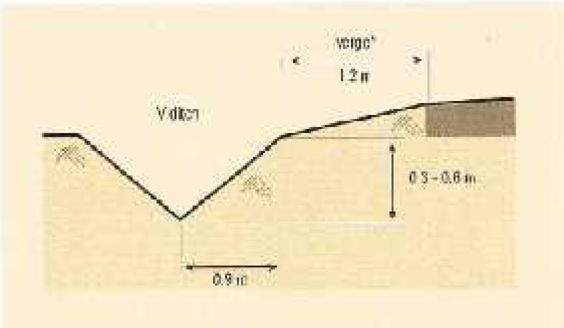


Figure 22. Outsloping

It is preferable to transfer high water flows in the table drain to discharge to the lower side of the road more frequently by the use of cross drains (or culverts) rather than to carry excess water which can cause additional scouring and possible overflow onto the pavement. Lining table drains with materials to minimise erosion should be avoided as this is where most of the fines will be deposited which will need to be collected during routine maintenance operations.

8.11.3 V-shaped and Trapezoidal Drains

V-shaped drains as shown in Figure 23 will be sufficient for normal rainfall. For prolonged heavy rainfall larger volume side drains are usually trapezoidal in shape and have a lower flow velocity. Trapezoidal or wide V shaped drains are better as they provide a greater flow capacity, reduce the flow velocity and thereby minimise scour. They should be vegetated with grass where possible and maintained by mowing.



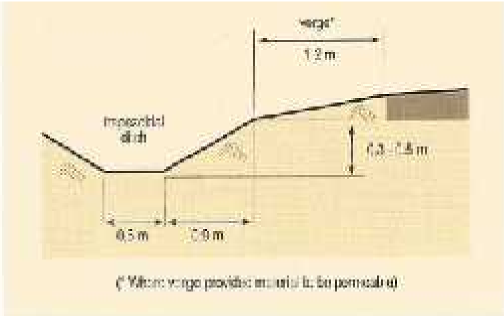


Figure 23. V – shaped and Trapezoidal Drains

In flat areas, consideration should be given to the problems of longitudinal flows between widely spaced culverts. The geometry of the drains should be compatible with the maintenance techniques to be used. It is important that, at any time, the lowest point in the pavement is well above the free water level in the table drains (aim for a distance of> 0.5 m).

To provide reasonable safety for vehicles which run off the road, the inverts of the ditch should be preferably rounded and it is recommended that the side slopes should not be steeper than 1: 1.5.

Use of swales which have a wide base and gently sloping sides are preferable for safety reasons providing the extra width required is not excessive.

The longitudinal slope of the drain should be sufficient to avoid silting, but below the value at which scouring and erosion can occur. To avoid silting a minimum longitudinal slope is recommended of 0.5% (1:200) for an unlined ditch, and 0.33% (1:300) for a ditch lined with concrete or asphalt. Also recommended is a maximum slope of 5% (1:20) for an unlined ditch.

Provisions to prevent erosion are recommended for ditches which will carry a fast flow and which due to topography cannot be restricted to less than 5% longitudinal slope. Check walls and drop walls can be used at intervals on steep slopes, as can stepping the ditches down. However, attention must then be paid to localised erosion damage (e.g. at the steps). Grassing of the drain may also be used to reduce erosion and catch silt. However, during maintenance operations there is a risk that the grass cover may be removed as table drains are cleaned out and re-established.

8.12 Cut-off (or mitre) drains

Cut-off (or mitre) drains, taking water away from the table drains into the surrounding area, should be constructed as often as the terrain will permit water to flow into a natural drainage course.

Figure 24. Lateral Drains

The principle is to place the cut-off drains at intervals which avoid ponding, adjacent to the road but not too far apart to allow build up of high concentrations and flow velocities, which lead to scouring. Frequent cut-off drains will minimise the amount of water flowing in a table drain, reduce the potential for scouring, erosion and the need for cross drains, and minimise the concentration of water discharge into the surrounding land. Where cut-off drains are constructed it is essential that the water from the drain be dispersed as far as practical to minimise erosion downstream. In some cases it may be necessary to provide obstructions downstream of the discharge point by the use of a dense cover of filtering ground vegetation. This may consist of windrow trees, logs (100 mm diameter), rocks or brush laid across the slope.

In locations with restricted road reserve widths, it will generally be necessary to negotiate with downstream property owners for access to construct and maintain side drains as well as give consideration to the legal point of discharge.

8.13 Cross Drains

The spacing of cross drain culverts to transfer water from the high side of the table drain to the low side is a function of the slope of the table drain, the soil erodibility and quantity of water flow.

As a general rule, water should be dispersed from the table drain as frequently as possible either in cut-off drains or across the road

Fig 25 below, provides a design layout of a cross drain such as to ensure self-drainage with a slope across the road.

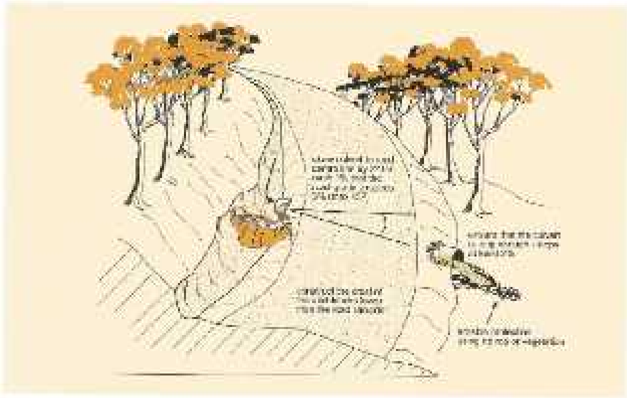


Figure 25. Fig Cross Drain Layout

As a rule of thumb the spacing of cross drains used to reduce erosion along table drains, is: Spacing of cross drains (m) = 300 / % grade of longitudinal drain

This must be checked based on local knowledge. Alternatively, Table 13 gives various spacing criteria for rural roads.

Road grade	Soil erodibility class		
	Low to moderate – high (m)	High (m)	Very high (m)
1–5 %	150	120	70
6–10 %	120	90	40
11–15%	95	70	30
16–20%	50	35	30

Table 13. Spacing of Cross Drains

The minimum diameter of culvert pipes should be 600 mm to minimise frequent blockage. The optimum size will depend on local knowledge of climate and catchment conditions. It is preferable to go for a larger size where possible.

Aim to achieve a grade of pipe which will promote scouring velocities to maintain self-cleaning. Provision of a silt trap on the inlet side is desirable to minimise potential silting in a pipe. In some cases a small diameter pipe may be used (375 mm) due to costs. Culvert pipes should be reinforced concrete or alternative materials of sufficient strength with the required soil cover to handle the estimated traffic loads.

When a road is overtopped with water, an inspection to scour around the head wall will be required. When grading a road ensure that culvert ends are not buried and lost.

Bar screens should be fitted on the upstream side of cross drains to catch debris. These will require regular cleaning.

8.14 Catch drains/banks

Catch drains/banks are used to drain water flowing towards the road from the higher surrounding area. These drains are often used at the top of deep cuts. If these drains are not used, then severe erosion can occur at cut batters leading to batter instability, higher maintenance cost and table drains becoming blocked. Where it is not possible to provide a catch drain/ bank then special provisions have to made to stabilise the cut batter slope (i.e. use of revetment or retaining walls).

The same care should be taken, as for other surface drain types, to prevent erosion and scour. Typical shapes and dimensions of catch drains are similar to those used for table drains. They should be as near as possible to the top of a cutting and channelled into culverts or natural watercourses wherever possible.

If the material surface is prone to scour and it is undesirable to cut the natural surface, catch drains can be formed by creating levees or catch banks. Catch drains at the top of slopes are frequently located beyond the reach of equipment for maintenance, and consideration should be given to gaining access for maintenance.

The longitudinal slope of the catch drain should be greater than 1 % to prevent pooling of water above catch batters and the potential of creating landslips. To prevent scouring, the slope should be less than 5%, depending on the likelihood of the soil to erode.

Vegetating the drain is an environmentally sound way to minimise erosion, even on difficult soils. This can be carried out by covering the surface of the drain with hessian or plant slashings, and applying grass seed.

8.15 Culverts

Culverts can be pipe culverts or box culverts. Culverts are constructed on roads using a variety of methods and materials. Pipe culverts include corrugated plastic pipes, steel pipes or arches, pre-cast or fresh concrete pipes, boxes, arches or half arches.

Box culverts can be precast or cast in situ, and road crossings can be reinforced concrete slabs resting on a box culvert.

Pipe culverts must be designed so as to accommodate traffic loads and the depth of superimposed fill. There are also minimum cover requirements for pipes and box culverts.

Culverts should be provided with sufficient cover to protect them from traffic loads in accordance with manufacturers guidelines e. g. minimum 600 mm for reinforced concrete pipe.

8.15.1 Location

Wherever possible, culverts should be located in the original stream bed with the invert following the grade of the natural channel. Stream bed realignment may be undertaken in exceptional cases.

Figure 26. Box culvert from concrete and pipe culvert from corrugated metal sheeting

8.16 Grade

The ideal grade line for a culvert is one that produces neither silting, excessive velocities or scour. Normally, the grade of the culvert should coincide with the stream bed; however; in some circumstances it may be desirable to deviate from it to be in the range of 1-3%. Examples are:

- Where sediment is expected to occur, the culvert invert may be set several millimeters higher than the stream bed, but at the same slope.
- Where headroom is limited, setting the culvert below the stream bed grade is likely to result in sediment and reduced waterway area. This should be avoided either by using a low, wide culvert such as a box culvert or pipe arch, or by raising the road grade.
- In steeply sloping areas, as on hillsides, it is not always necessary to place the culvert on the same steep grade. The culvert can be put on a 'critical' slope and then a spillway provided at the outlet to prevent scouring. This keeps the culvert shorter and under shallow cover.
- At times a shorter length of culvert can be used and/ or a better foundation obtained by shifting the culvert to one side of the natural channel. When this is done, care should be taken to construct the inlet and outlet channels to provide for a smooth flow of the water, particularly on the downstream side so as to minimise or prevent erosion.
- Any new watercourse crossings designated to be of significant environmental value should be designed and maintained to minimise disturbance to the passage of fish and other aquatic fauna.
- Culvert outlets on watercourses should be protected by energy dissipaters, such as large rocks, to provide sufficient protection against bed scour or erosion.

8.16.1 Foundations

Ideally, culverts should be located on sound foundations such as rock. Soft, saturated and expansive clayey soils may cause settlements or seasonal movements of the culvert. Removal of poor soils or stabilisation of the foundation should be considered.

8.16.2 Siltation in Culverts

To minimise silting problems in culverts:

- the level of the invert of a culvert at its outlet should be a minimum of 75 mm below that at the inlet
- pipes of less than 450 mm diameter and box culverts of less than 300 mm high should be avoided
- the use of galvanised steel pipes should be avoided where water is acidic.

8.16.3 Inlets

Culvert inlets should be eased to a smooth entry without abrupt changes in direction or drops which can cause turbulence. Where these are unavoidable they should be adequately protected by concrete, gabion mattresses or rip rap. Geotextile material should be placed under gabions or riprap and a cut-off wall to prevent undermining.

To avoid silting, culvert inverts should be placed at a grade of not less than 1.25 % for pipes, and 0.5 % for box culverts. Invert gradients should be increased by 1 % in the case of culverts provided with drop inlets.

8.16.4 Outlets

The invert level at the outlet of a culvert should coincide with ground level. Where culverts are unavoidably constructed on a steep slope, the energy generated must be dissipated to avoid serious erosion at the discharge end of the culvert. A stilling box and widening at the outlet are effective methods of reducing the velocity of the water.

8.16.5 Energy Dissipation

Rock dissipaters or gabions can be used in channels as shown in Figure 27. These also assist natural channel restoration by trapping silt and preventing it from reaching downstream waterways. Other means to trap sediment can consist of logs, rocks, straw bales etc. These can also be used in places where high flows of water are expected on high erodible soils or other sensitive areas.

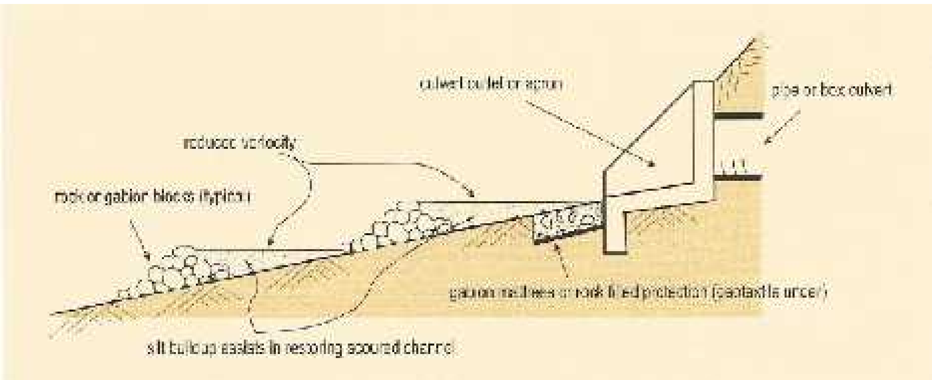


Figure 27. Culvert Outlet and Energy Dissipation

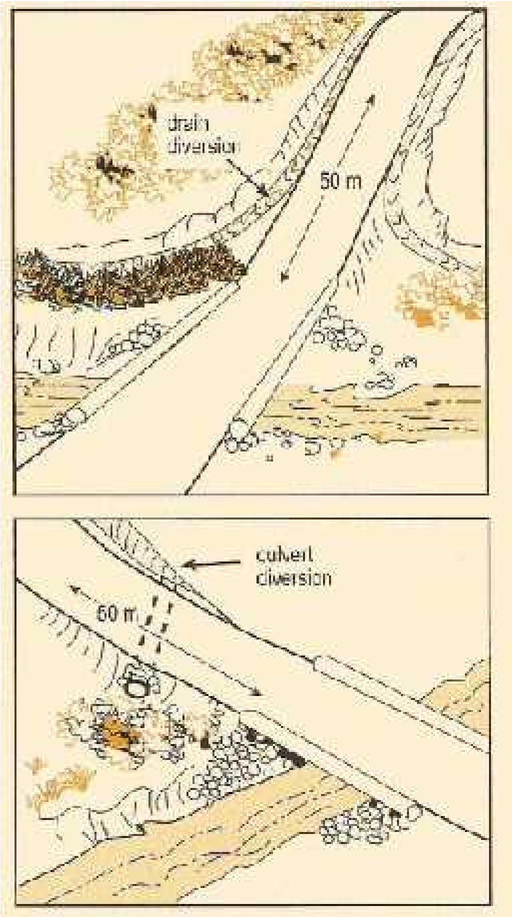


Figure 29 Avoiding discharge to streams

For culvert outlets, extension of the protection or energy dissipaters to prevent downstream scour should be considered.

Figure 28. Vegetation flattened by flood waters

8.16.6 Avoiding Discharge to Streams
During the last 50 m before a road crosses a significant watercourse the roadside drainage should be diverted into the surrounding vegetation or sediment traps and not allowed to continue to the stream unchecked. Where necessary, a culvert should be installed to pass drainage from the top side of the road to the lower side and then diverted into the surrounding vegetation Figure 28. This is to ensure that sediment carried by the water is not discharged directly into a watercourse to the detriment of aquatic life.

8.16.7 Allowing Water Flow over Road
As most culverts provided on unsealed roads are not designed to take the higher storm flows, consideration should be given as to the various ways the higher discharge should be accommodated so as to minimise future road repairs and restoration work.

For larger catchments, a floodway with scour protection can be used to supplement a culvert designed to take low flows only. For smaller catchments, a 'drop-section' may be used, i.e. a section of the grade line of the road is lowered close to the natural surface to allow part or all of the discharge to pass over the road with the minimum of obstruction and without the need for any substantial scour protection.

For unsealed roads because of lower traffic volumes, and where the costs of delays are usually lower than on sealed roads, a lower rainfall intensity is adopted based on lower storm frequencies (e.g. l, 2 or 5 years). Consequently, in the design of culverts for unsealed roads, it is acceptable that water be allowed from time to time to pass over the road or be temporarily ponded upstream, when the discharge from the catchment is of greater magnitude than the discharge of the culvert. In so doing, care must be exercised to minimise possible damage to the road embankment and it is strongly recommended that inspections are conducted after such events to assess the extent of damage and works required to restore the road.

8.16.8 Calculating Size of Culvert

The size of a culvert (*waterway area*) to be provided under a road is mainly a function of the catchment size, the rainfall intensity and the nature of the vegetative cover of the area. The estimation of storm discharge for the detail design of a drainage structure should make use of the Rational Method. (See Section 8.22)

Inadequate culvert capacity can result in severe damage and expensive remedial works. At all natural watercourses an appropriate culvert or water crossing must be provided to take the estimated design flow. The detailed calculation of the flow and waterway area required is given in Section 8.16.8/9. A simplified method of calculating the size of a culvert required is to use Talbot's Formula method below.

8.16.9 Simple Culvert Sizing Method

Although the accepted method of estimating peak discharge and designing culverts should be used whenever time permits, there may be occasions when such a degree of accuracy is unwarranted. In these situations, the Talbot's Formula method could be used (Australian Army 1985).

Talbot's Formula method provides a convenient way of determining the cross-sectional area of waterways required for small catchment areas. Talbot's Formula should be used with caution in tropical areas where seasonal rainfall is extreme.

Talbot's Formula is an empirical relationship between the area of waterway required, the catchment area, and the run-off coefficient relating to the type of country being drained. The results of the formula have been plotted in Figure 30.

This relationship was derived for a catchment area having an anticipated rainfall intensity of 100 mm in 1 hour. For areas having a different rainfall, the result should be divided by 100 and multiplied by the anticipated rainfall. Where accurate prediction of the maximum rainfall intensity in 1 hour is not known, then any of the following will give acceptable values:

- If the daily rainfall is known, assume 40% could fall in any 1 hour period.
- If the average annual rainfall is known use:
  - 8% of the value for areas having less than 2,500 mm of rain per year
  - 4% of the value for areas having greater than 2,500mm rain per year.

Selection of an appropriate value of C (the catchment coefficient) is critical to the accuracy of this method. Figure 30 should be used to set an appropriate value.

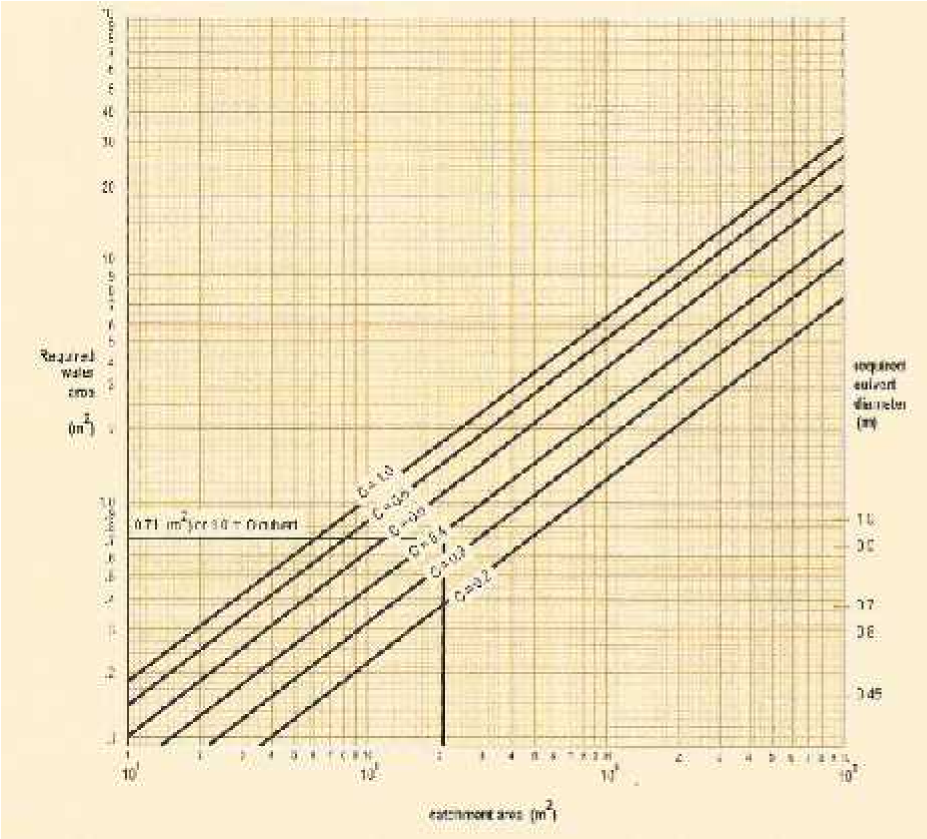


Figure 30. Talbot's Formula

Above figure shows required waterway area using Talbot's Formula based on rainfall of 100 mm in one hour.

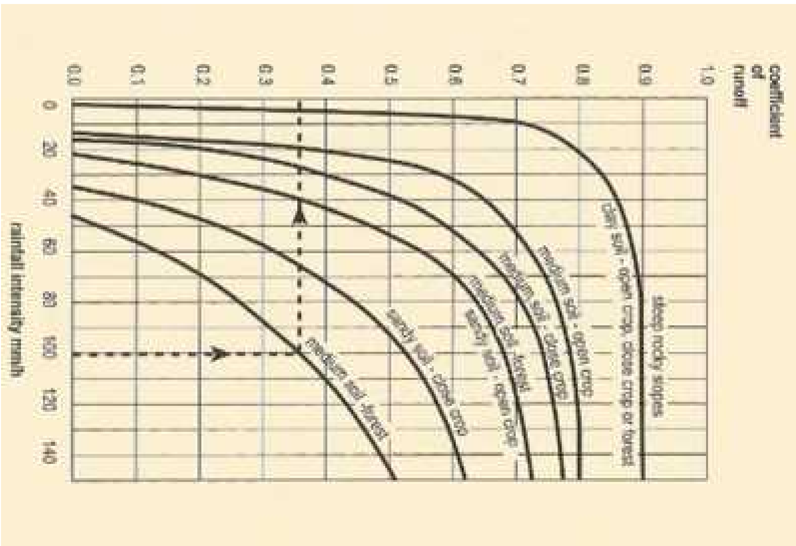


Figure 31. Run-off co-efficient for rural catchments

Example

The following are two examples of the use of Talbot's Formula:

1. Select a suitable culvert size for a catchment area measured at 210,000 m^2. The rainfall is 100 mm in 1 hour and the catchment area is predominantly medium soil in a forest area.

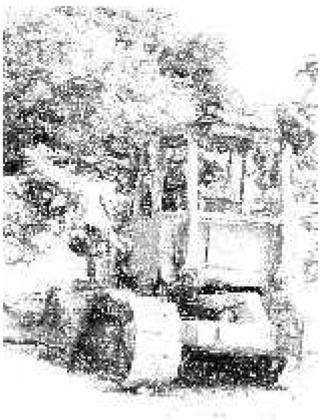
By referring to Figure 30 for a rainfall intensity of 100 mm the run-off coefficient is estimated at 0.36.

For a catchment area of 2.1×10^5 m^2 and referring to Figure 31 he area of waterway is estimated at 0.7 m^2. This is close to a pipe with a **diameter** of 1 m.

2. What area of waterway is required for the same catchment area if the anticipated rainfall is 160mm/h?

$$\text{Area of waterway required} = 0.7 \times \frac{160}{100} = 1.12\ m^2$$

8.17 Use of Labour-Based Methods



Labour-based methods are very well suited for the construction of drainage structures, excavation of drainage channels, construction of soil berms, stone pitching, scour protection, etc. Pre-cast concrete culverts are not well suited for rural roads if the weight of each element is too great for manual handling.

8.18 Maintenance

The importance of maintenance cannot be overemphasized. Inadequate maintenance, or total absence of maintenance, will lead to blockages, particularly of small diameter pipes. This will lead to structural failure of the drainage system and eventually the road.

Figure 32. Cross drainage poorly maintained

If necessary drainage systems should be adopted which do not rely on regular maintenance, such as proving crossing drifts at grade and allowing stream water to flow over them.

8.19 Bridges and Stream Crossings

Bridges and other forms of stream crossings are key elements in any road network and represent a major investment. Because of the cost and importance of road structures, main water crossings require careful selection of site, structure type and design. Design of large bridges is a specialist subject and is not included in this guide.

Figure 33. Wooden bridge and concrete bridge, Malekula

8.19.1 Site Selection

Careful site selection provides the greatest potential for cost savings. Poor site selection can result in longer, wider or higher structures than are really needed or may result in a costly foundations. Poor site location can cause operational difficulties, unsafe alignments and shorten structural life.

Determining the optimum stream crossing site requires balancing many variables, involving road design, structure type and bridge design.

An ideal stream crossing has some or all of the following characteristics:

- A road would cross the stream in an area with well-defined banks. The stream is generally narrower at these locations and the stable banks indicate a stable stream flow.
- The road would cross the stream away from curves in the stream. These areas are often unstable because the stream tends to move to the outside of a curve. Also a stream usually is wider in a curve.
- A road would cross the stream in an area with uniform stream gradient. An increasing gradient increases erosion and scour potential. A decreasing gradient can cause stream bed loading and debris deposition.
- It would cross the stream at a location where the channel has relatively non-erodible stream bed materials. Non-erodible stream bed materials reduce scour potential.
- The road should cross at right angles to the stream to reduce the span length of the bridge pipe or other structure used.
- The road should cross the stream at the minimum elevation necessary to pass the design flood flow. Raising the elevation of the bridge increases the abutment costs and in some cases lengthens the bridge or pipe, if used.

Obviously ideal crossing locations are seldom found and balancing all of the above variables is a complex process. Solving the problem in the most cost-effective way requires working closely with road and bridge design engineers

8.19.2 Selection of structure type

After site selection the next greatest cost savings potential occurs in structure type selection. There are a number of possible structures for different stream sizes. It is taken that fish passage is required at nominated stream crossings. Further details on the requirements of fish passage can be obtained from Department of Environment.

8.19.3 Small stream crossings (< 6 m)

For small stream crossings, culverts with about 0.5 - 1m of stream bed material over the invert are possible alternatives to bridges.

8.19.4 Medium stream crossings (6-15 m)

For larger sizes, with spans up to 15 m, the culvert requires special site considerations including adequate depth of embankment to allow space for the structure plus 1.5 m of fill over the pipe. Culverts can be constructed faster than most bridges and often at substantially less cost. The culvert has environmental advantages. Culverts can become blocked by debris particularly after a storm and require regular maintenance.

For bridges across medium stream crossings, concrete precast or prestressed multi-beam sections can provide an economical alternative to conventional treated timber or cast in-situ concrete superstructures.

Most bridges on low volume roads are of simple configuration, based on standard drawings, which are made to order for precast work. The precast bridge can be constructed much faster than the cast in-place type and erection can proceed during all weathers.

8.19.5 Large stream crossings (> 15 m)

For bridge lengths of 25 m or under, consider using single spans. They present the minimum obstruction to the waterway and may also be the most economical. For longer structures over flood plains, consider using span lengths of 15-30 m as they often will be more economical than shorter spans depending on bridge height and type of intermediate piers.

The relationships between the type of material, the span length of the superstructure and the cost must be considered. Simple timber bridges are the most economical for spans up to 10 m for heavy vehicles. Simple span reinforced concrete superstructures are feasible for spans up to 30 m. Spans can be as long as 45 m if prestressed girders are used.

8.19.6 Low-water crossings

Low-water crossing structures are generally designed to allow flooding during periods of high annual run-off. However, the design flow is something that should be evaluated in the design process.

The standard of the road, its importance and use, the magnitude of the stream flow and its variability, the topographical characteristics of the crossing site are all factors that should be considered in determining the design flow of the low-water crossing structure.

A low-water crossing can substantially reduce costs. Typical design standards that can be adopted for low-cost crossings are as low as a one in two year flood with greater floods overtopping a low bridge structure.

Low-water crossings involve compromises and trade-offs between providing access and often conflicting objectives to:

- provide for traffic safety
- permit water, sediment and debris passage on flooded plains
- Limit construction and maintenance costs.

Designing a crossing aims to optimise these objectives. Road access needs and water crossing characteristics largely control whether a structure, if designed for overtopping, will be appropriate. Selecting the best structure for a low-water crossing depends on a number of factors listed in Table 14 below.

Considerations	Most desirable	Least desirable
Access priority	Low	High
Alternative route available	Available (within a 2 hour trip)	Not available (or > 2 hour trip)
Traffic speed	Low	High
Average daily traffic	Low (< 100 vpd)	High (> 200 vpd)
Flow variability	High	Low
High flow duration	Short (< 24 hours)	Long (3 days)
High flow frequency	Seldom (rare closure < 10 times per year)	Often (frequent closure > 10 times per year)
Debris loading	High	Low
Channel entrenchment	Shallow	Deep

Table 14. Low-water crossing selection factors

8.19.7 Safety in Low-water crossings

A low-water crossing is a possible alternative for any size of stream. Low-water crossings come in two basic forms, as illustrated in Figure 33.

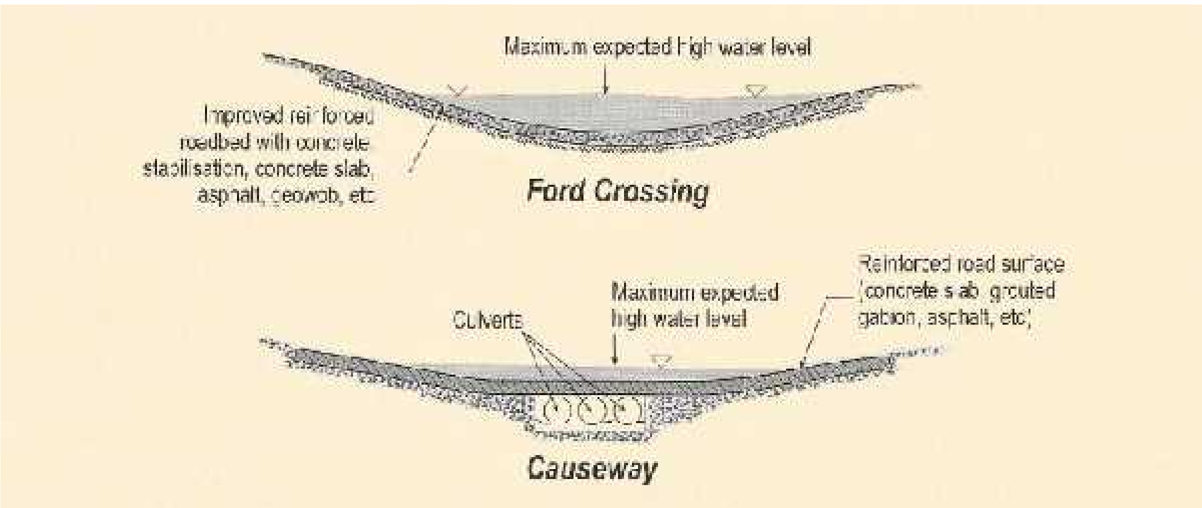


Figure 33. Types of Low Water Crossings

Low-water crossings can have substantial limitations and are most suited for roads with low traffic volumes and tracks. Safety is of primary concern and it is reported that 10 deaths per year occur in Vanuatu when people attempt to cross flooded crossings. Drivers may underestimate how fast small streams can rise in some parts of the country during a flood. Even 300 mm of water can float a car or truck causing it to lose control and 600mm can cause it to overturn (Figure 32).

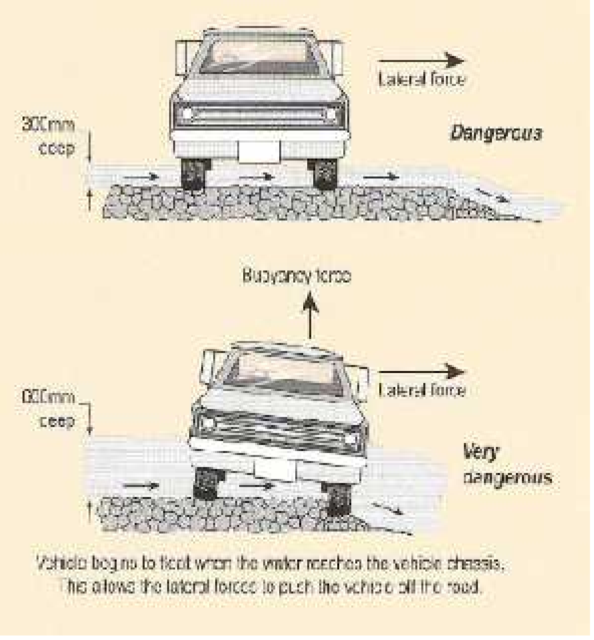


Figure 32. Effects of Water flow on crossing vehicles

8.19.8 Floodways

The road crosses the stream at the location where the stream banks are low and the road grade follows the cross-section of the stream. It is often used when the stream flows infrequently and traffic disruption is minimal during the year.

In order to minimise bank erosion, floodways should be designed to cause minimal interference to the natural stream flow. This is best achieved by siting them at right angles to the direction of water flow and level to the existing stream bottom for buried floodways. This is the case for wide riverbeds or creeks, which are normally dry, but at times carry considerable volumes of water.

If they are elevated, floodways will create a weir effect and the downstream velocity of flow may increase to a level which will cause erosion of the stream bottom. Construction of a causeway at grade generally consists of excavating any soft material until firm material is reached and replacing the excavated material with sound granular material to provide a sound trafficable surface.

8.19.9 Gabions

Gabions can be used to provide a strong road base across a stream bed. It is desirable to strengthen the road surface against scour using either a sealed surface or concrete base or providing a cement stabilised pavement.

Figure 33. Gaions used in watr crossings

8.19.10 Causeways

These are a form of floodway except that the roadway is elevated above the stream bed. They have a more substantial road bed constructed and a number of culverts provided for the passage of low water flows. The frequency of flooding and disruption to traffic is less than a floodway.

Causeways are sections of roadway designed to be temporarily overtopped by water flow. They are used when it is more economical and practical to ford an intermittent flowing creek or river than to use major culverts or bridging, and when interruptions to traffic for short periods are not of great importance. Various types are illustrated below.

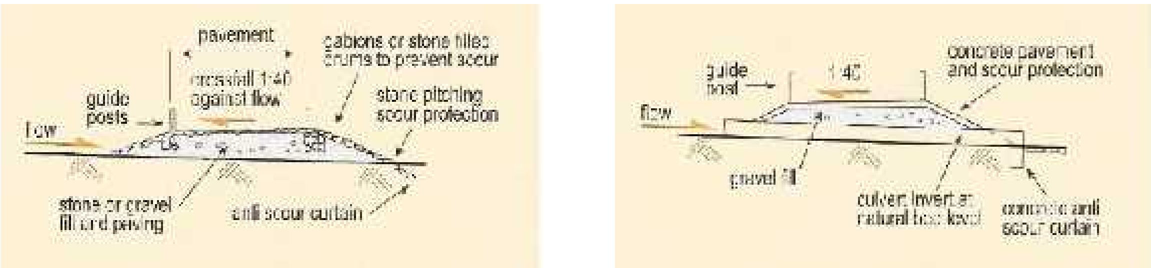


Figure 34. Causeways

When it is necessary to elevate a causeway in order to minimise the time it will be covered by water during flooding, it must be designed as a series of culverts using hydrological design procedures to calculate flows and culvert sizes. The ends of the structure must be well anchored into the banks and obstruction to flow should be kept to a minimum by using gentle batter slopes on the up and downstream faces.

The best material for elevated floodway constructions is concrete. Well-graded riprap, dumped on the roadsides of a causeway, is superior to a mass of uniformly large stone, since the latter has large voids through which the filter material can be drawn by the action of water.

8.19.11 Drifts

In Vanuatu a low-level structure designed to accept overtopping without damage is ideally suited for rural roads in locations where full all-weather passability is not necessary and delays are acceptable to the community.

Various alternative names are sometimes used to describe these structures. Drifts are designed to provide a firm driving surface in the riverbed, where traffic can pass when water levels are moderate. Road safety must be considered and guideposts should be provided.

It is essential to erect guide posts and flood gauges so that the edges of the causeway are defined and water depth can be determined.

Figure 35. Low Level Crossing with flow and drift with guideposts

Vented drifts, sometimes named fords, causeways or Irish bridges, (larger structures are called low level bridges) allow water to pass through openings, but can withstand overtopping without damage.

Vented Drifts fords fall into two categories—low vent-area ratio (VAR) and high VAR—each of which affects stream channels differently (fig. 1.4). Vented fords with culverts that are small relative to the bankfull channel area have a low VAR. A vent opening that approximates or exceeds the size of the bankfull channel has a high VAR.

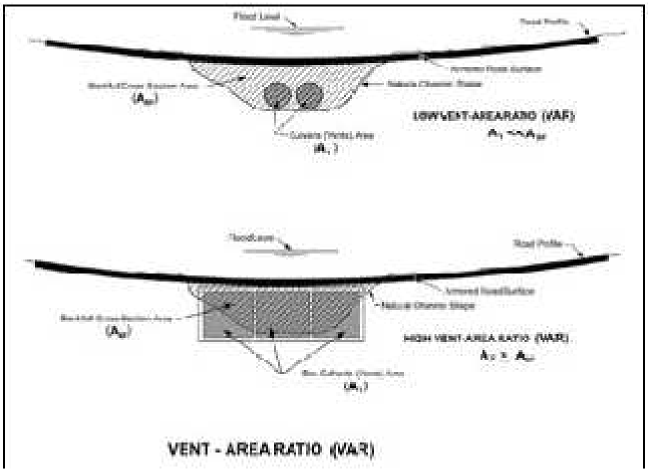


Figure 36. VAR definition sketch

In very stable streams, low-VAR fords may not have severe detrimental effects on channel stability. It is common, however, to see at least a fair amount of channel instability associated with these structures. When flow begins to exceed the vents' capacity, low-VAR fords begin to function like low dams. They backwater flow upstream of the structure, and where the stream is carrying a substantial bed sediment load, deposition reduces channel capacity and elevates the streambed. This frequently leads to bank erosion and channel widening. In channels that are already laterally unstable, low-VAR structures exacerbate the tendency for bank erosion and channel shift

Openings in vented drifts should, like culverts, be made large enough, preferably not less than 600mm diameter, although 900mm is preferable, so that cleaning during maintenance is made easier and the risk of blockage is minimised.

8.20 Erosion

8.20.1 Introduction

Any disruption to the natural flow of water carries a risk of erosion that may lead to environmental degradation, silting, damage to roads, damage to buildings and services, destruction of farming land and loss of fertile soil.

Thus, there is a responsibility to ensure that the construction of the drainage system for a road receives the same attention to good practice as the construction of other roads. Indeed, avoidance of erosion can be more critical in the case of rural roads because of the greater challenges faced in maintaining the drainage system in remote areas where these roads are often located.

8.20.2 Scour Checks

There are many examples in the region of inexpensive and effective methods that are used to protect drainage channels and side drains by the use of scour checks that are easily constructed by labour-based methods. The scour checks can be made of wooden sticks, rocks, concrete or other materials depending on the most economical source of materials. The frequency of scour checks needs to be properly adjusted according to slope gradient in order to prevent erosion between the checks causing damage to the system. The following can be used as a guide:

Gradient of the ditch	Scour check spacing (m)
4% or less	(not required)
5%	20 m
8%	10 m
10%	5 m

Scour checks can also be placed across pavements to prevent loose materials being carried away. (Figure 37)

Figure 37. Horizontal scour checks

Figure 38. Cross road scour checks

8.20.3 Slope Protection

If required, placing of topsoil and planting of vegetation on the slopes of embankments should take place in order to minimise erosion before indigenous vegetation can establish roots. Where grass or other vegetation is planted for protection of slopes, advice should be obtained from local residents or farmers.

Figure 39.Need for protection of slopes against erosion

8.20.4 Erosion of Culverts

Short culverts requiring high headwalls and wingwalls are prone to erosion around both inlets and outlets, especially along the wingwalls. Constructing culverts that are sufficiently long to reach the toe of the embankment will minimise necessary protection measures, future maintenance and the risk of damage to the embankment around the openings. It is necessary to carefully assess the additional cost of lengthening culverts against these benefits, especially in the case of rural roads that are often located in remote areas where regular maintenance is a challenge.

8.21 Hydrology

The drainage methods used for unsealed roads are the same as those used for sealed roads. The capacity of drainage structures should ideally be calculated on the basis of local experience gathered over a long period of time and should be updated to cater for any recent changes in rainfall pattern and climate. However, such information is often not readily available, prompting a need to develop standards for drainage design and calculations. In all cases it is advisable to combine calculations with observations on site, in addition to information from reliable local sources. It is desirable to increase the size of drainage structures to a minimum of a 600 mm opening so that they can be easily maintained although a 900 mm opening is preferable.

8.21.1 Return Period

The return period for a given flow of water is related to the estimated statistical risk of overtopping of drainage structures. It is part of the hydraulic calculations required for each type of structure for each project on the basis of policy and anticipated consequences to the road or the public. The return period is therefore a critical parameter in the design of rural roads because it controls the level of risk in relation to cost of construction and the type of structure that is appropriate.

As a broad guide, the following return periods can be considered for rural roads:

Structure	Minimum ARI	Desired ARI
Major Bridges	50 years	100 years
Lesser Bridges	10 years	50 years
Culverts: 5 - 10 years	5 years	10 years
Low Level Drifts	2 years.	5 years.
Flumed Drifts	5 years	10 years
Lateral Drainage	5 years	10 years
Cut off Drains	2 years.	5 years.
Cross Drainage	2 years.	20 years.

Table 15. Return periods for structures

8.22 Hydraulic Calculations by the Rational Method

The 'rational method' is a standard approach to estimating floods for drainage of small catchments.

The basic formula is : $Q = 0.278\ C\ I\ A$
Where Q is peak flow rate in m^3/sec
C = runoff coefficient
I = rainfall intensity in mm/hr
A = Area in km^2

0.278 = Conversion factor for flow in m^3/s, rainfall in mm/hours and area in km^2.

To use the method one must first derive basic data on the drainage area (or catchment).

- Catchment area (A in km^2) ,
- distance from the further point to the outlet (L in km)
- "Fall" between the highest point and the outlet (H in metres).

Calculate the slope (S in m/km) which is given as the fall, H, divided by distance, L.

The duration of the critical storm is then calculated by the Bransby Williams formula :

Duration = $L / (A^{0.1} \times S^{0.2})$ where duration is in hours.

If the duration is given in minutes the formula is Duration = $58.5 \times L / (A^{0.1} \times S^{0.2})$

Given the duration, the intensity can be calculated from the IDF curve.

The final element to be estimated is the runoff coefficient, C. The runoff coefficient can be calculated by the method of partial runoff coefficients. [1]

[1] "California Department of Transportation, Highway Design Manual, 1995, pp. 810-816". And other older references.

The four elements are:

- 0.30: Hilly with average slopes of 10 % to 30 %,
- 0.20 Negligible surface depression. Drainage paths with steep banks and small storage capacity. No ponds or marshes.
- 0.10: Normal , deep loam
- 0.05: Good to excellent; about 50 % of area in good grassland; woodland or equivalent cover

The methodology is applicable in small rural catchments.

8.23 Summary of Key Points

- Appropriate drainage design is one of the most important factors that enables a road to withstand traffic loads and minimise maintenance.
- Balance design standards with the purpose of the road and maintenance levels in mind.
- Consider the economics of the design standards in relation to road classification, volume and type of traffic.
- Keep in mind the variable characteristics of unsealed road surfaces and be on the generous side of design standards where possible.
- Crossfall will be determined by the ability of the pavement to drain water and the materials used in the pavement.
- Crossfalls should generally not be less than 4% and preferably as high as 6%.
- Drainage channels, drains/ ditches and inverts should be rounded to provide reasonable safety for vehicles which may accidentally leave the road.

9 APPENDICES

Appendices

Appendix A1 - Standard Proposed for Road Design

Appendix A2 - Sampling of Material

Appendix A3 - Use and Field Testing of Local Materials

A. Traffic count

B. Standard Proposed for road Design

1. Geometry
2. Pavement
3. Drainage

9.1 Appendix A – TRAFFIC COUNT - October 2013

SUMMARY OF TRAFFIC COUNT

TANNA

Type	Date	Road	Lenakel/ VTSSP1 End	Lenakel/Nose Blong Pig	Whitegrass/Tanna Lodge	Imanaka/ Lowiaaru jnt	NoseBlong pig /Lowiaru jct	Lowiaru jct/Imafin	TOTAL
Pedestrian	2013-10-11	Friday (pay week)	126	143	272	48	109	229	927
	2013-11-06	Wednesday (non pay week)	133	34	207	47	34	153	608
	2013-11-07	Thursday (non pay week)	25	264	132	38	146	477	1082
		Average	**95**	**147**	**204**	**44**	**96**	**286**	**872**
Motor Vehicle	2013-10-11	Friday (pay week)	183	122	598 / 4	140	41	51 / 1	1135
	2013-11-06	Wednesday (non pay week)	110	12	369	64 / 1	4	41	600
	2013-11-07	Thursday (non pay week)	68	71 / 2	162 / 3	74	37	68	480
		Average	**120**	**68**	**376**	**92**	**27**	**53**	**738**

Heavy vehicle (ponctual data): **Max 2%**
0 HV for 13 days reading point /16 days

More pedestrian than vehicle (average 1.2 x)
Highest average 1 pedestrian for 0.2 vehicle (5 x)
Lowest average 1 pedestrian for 2 vehicles

Traffic count in 2006
Max average: 550 (Tafea Cap Jct)

MALEKULA

Type	Date	Road	Litzlitz / Lakatoro	Aoup Jnt / PRV Jnt	Aoup Jnt / Kona Point	Norsup Loop at Airport	Lizlitz / Vao	PRV Jnt / Notre D Jnt	PRV Jnt / Norsup Loop	Lakatoro / Aoup	TOTAL
Pedestrian	2013-10-16	Wednesday (non pay week)	226	1	9	48	82	49	62	47	524
	2013-10-18	Friday (non pay week)	180	2	14	20	99	42	47	142	546
	2013-10-21	Monday (pay week)	137	7	25	11	106	55	78	185	419
	2013-10-23	Wednesday pay week)	184	5	9	11	108	108	101	194	720
		Average	**182**	**4**	**14**	**23**	**99**	**64**	**72**	**142**	**552**
Motor Vehicle	2013-10-16	Wednesday (non pay week)	647	690 / 6	73 / 4	326 / 4	32	189 / 4	140	630 / 14	2727
	2013-10-18	Friday (non pay week)	456 / 20	355	88	544	46	174	193	681	2578
	2013-10-21	Monday (pay week)	406 / 26	129	94	393	54	158	172	743 / 3	2149
	2013-10-23	Wednesday pay week)	444	123	66	344	59	153	216	672	1189
		Average	**488**	**324**	**80**	**402**	**48**	**169**	**180**	**681**	**2 161**

Heavy vehicle (ponctual data): **Max 5%**
0 HV for 24 days reading point /32 days

Less pedestrians than vehicle (average 4 x)
Highest average 1 pedestiran for 0.5 vehicle (2x)
Lowest average 1 pedestrian for 65 vehicles

Traffic count in 2006
Max average: 728 (Lakatoro Loopt)
48% increase

AMBAE

Type	Date	Road	Nahala / Lolopuepue	Lolowai / Saratamata	Saratamata / Novonda (Tankoru)	Longana airport / Novonda	Malangamara quarry	TOTAL
Pedestrian	2013-10-08	Wednesday (pay week)	103	344	49	100	13	609
	2013-10-11	Friday (pay week)	183	1078	60	193	24	1538
		Average	**143**	**711**	**55**	**147**	**19**	**1 074**
Motor Vehicle	2013-10-08	Wednesday (pay week)	51	163	117	92	24	447
	2013-10-11	Friday (pay week)	88	186	117	104	46	541
		Average	**70**	**175**	**117**	**98**	**35**	**494**

Heavy vehicle (ponctual data): **0%**

More pedestrian than vehicle (average 1.2 x)
Highest average 1 pedestiran for 0.2 vehicle (5x)
Lowest average 1 pedestrian for 2 vehicles

PENTECOST

Type	Date	Road	Waterfall
Pedestrian	2013-10-29		137
		Average	**137**
Motor Vehicle	2013-10-29		19
		Average	**19**

324	ADDT > 300
147	More pedestrian than cars
73 / 4	73 motor vehucle (all kinds) / number of 3 axial

Table 16. Summary of Traffic Count

9.2 Appendix B – Standard proposed for ROAD DESIGN

9.2.1 GEOMETRY

a) Cross section

	UNPAVED				PAVED		
Road Function	**Arterial**				**Arterial**		
			Feeder				**Feeder**
Road Class	**T4**	**T3**	**T2**	**T1**	**T4**	**T3**	**T2**
Average Annual Daily Traffic (AADT)	> 500	200 - 500	50 - 200	< 50	> 500	500 - 200	200 - 50
Number of lane	2	2	2	1	2	2	2
Min. traffic lane width (m)	3 m	2.5 m	2.5 m	3 m	3 m	3 m	3 m
Min shoulders width (m) [1.]	0.5 m	0.5 m	0.5 m	0.5 m [2]	1 m	1 m	1 m
Min carriageway width (lanes + shoulders)	7 m	6 m	6 m	4 m	9 m	9 m	8 m
Target speed (km/h) (Flat - Rolling terrain)	60 – 40	40 – 20	40 - 20	30 - 10	60 – 40	40 - 20	40 - 20
Desirable maximum grade [3]	12 %				12 %		

[1] Increase shoulder width of 0,5 m if there are more than 100 pedestrians per day (on arterial roads), especially if it is in the vicinity (500-1000 m) of a school, hospital, town, church, airport, etc.

[2] If natural gravel is suitable and passing lane (3 m wide) is provided min every 300m or when condition facilitate, shoulder may not be necessary.

[3] It is suggested to keep the minimum following slope: 12% for a maximum distance of 600 m; 15% for a maximum distance of 200 m and 18% for a maximum segment of 50 m

b) Camber (cross fall) after compaction

- Minimum 5% for Coronous wearing course (could be increase to 8% when issues are found or expected like steep slopes)
- 3% (flat camber) for free draining cohesion less volcanic scoria and scoria.
- Minimum 3 % for bituminous / concrete surfaced roads and

c) Horizontal / vertical alignment (desirable)

	T4	T3	T2	T1
Minimum radius curve	100 m	60 m	60 m	10 m
Maximum superelevation	8 %			
Minimum stopping sight distance (m) for 2 lanes roads	85 (60 km/h)	65 m (50 km/h)	50 m (40 km/h)	35 (30 km/h)
Minimum meeting sight distance (m) for 1 lane roads	Not applicable	130 (50 km/h)	100 (40 km/h)	70 (30 km/h)

NOTE: Guide need to be validated with every provincial engineer

9.2.2 PAVEMENT

a) Unsealed / sealed	T4	T3	T2	T1
Total pavement thickness (mm)[1.]	250	200	150	100 [2]

[1] If CBR ≤ 5%, improvement of subgrade needed.

[2] For Feeder roads Traffic level 1 (F-T1), pavement material may not be provided if not necessary

b) Rigid pavement		T4	T3	T2	T1
Min. subbase for rigid pavement		150 mm			Not applicable
Mountainous	> 15 %				
Hilly	10 – 15 %				
Rolling	5 – 10 %			Not needed	
Flat	< 5 %				

Rigid pavement is to ensure accessibility and increase security. It is suggested on arterial roads only.

Strongly recommended to build rigid pavement. Width of 4 m (150 mm thick) (25 MPa reinforced concrete)

Tracks could be suitable in given case: 2 x 0.75 m with or without grouted stone

c) Material properties

Grading

Sieve	Envelope
53	100
37,5	90-100
19	70-100
2,36	35-65
0,425	15-50
0,075	10-30

Note on grading specification
This envelope is assuming that some of the largest particle (37,4-53mm) will break down during compaction. It is also assuming that the spread-water-compact operation is performed adequately. Some quarries may also have harder particles, which wouldn't break down. This could make the wearing surface to become fairly rough after few months of heavy traffic and rain. In that case, it is advised to revise the grading specifications in order to reduce (or eliminate) the coarser content (37,5-53mm), at least for the wearing course. A smaller nominal size would ease spreading and compaction and smoother ride.

Other characteristics that can be relevant to verify are PI, LS and CBR but not yet to become requirements.

Characteristics	Specification	
Grading Coefficient	16 – 34	(%passing 26.5 mm - %passing 2 mm) x %passing 4.75 mm / 100
Grading Modulus	1.5 – 2.5	(200 – (%passing 2 mm + %passing 0.425 + %passing 0.075)) / 100
Fine to sand ratio	0.25 – 0.24	5 passing 0.075 / % passing 2.36
Plasticity Index (PI)	Max 15	If CBR in unknown or < 8 %
Plasticity product	300 - 400	PI x % passing 0.425 mm
Shrinkage Product (Sp)	100 - 365[1]	LS x % passing 0.425 mm
Soaked CBR	Min 30%	

[1] 240 Preferable

9.2.3 DRAINAGE and STRUCTURES Design

<u>Design return period</u>	
Peak discharge for Culverts	1:5 years
Peak discharge for Low Level Structure	1:2 years
Peak discharge for High Level Structure	1:50 years
<u>Pipes and culverts</u>	
Minimum gradient	2 %
Minimum diameter	750 mm
Minimum cover (reinforced concrete)	2/3 of pipe diameter
Minimum cover (galvanized iron ARMCO)	1/2 of pipe diameter
<u>Maximum desirable velocities in un-lined channels</u>	
No vegetation, sandy material	0,5 m\s
Bunch grasses, exposed soil	1,2 m\s
Well established grass	1,8 m\s
Beyond 1.8 m/s line drains and / or scour checks are recommended.	
<u>Table drains [1]</u>	
Trapezoidal drains	1 x 0.5 bottom x 0.5 x 0.4 m deep
V-drains	1 x 1 x 0.4 m deep
<u>Spacing of scour checks</u>	
Gradient of side drain < 4 %	30 m (only if eroded)
4 – 6 %	20 m
6 – 10 %	10 m
> 10 %	5 m
<u>Spacing of mitre drains and relief culverts</u>	
Gradient of side drain < 1 %	50 m (avoid sedimentation)
1 - 4 %	200 m (avoid erosion)
5 – 6 %	160 m (avoid erosion)
7 – 8 %	120 m (avoid erosion)
9 – 10 %	80 m (avoid erosion)
> 10 %	40 m (avoid erosion)
<u>Maximum slope proposed on embankments and channels</u>	
Soil with stone pitching or large earth channel	1:1
Firm Clay, Coronous or small earth channel	1:1,5
Sandy or silty soil, scoria, grassed channel	1:3
<u>Concrete drift</u>	
Minimum thickness [2]	200 mm
Minimum width (when full width)	4 m

[1] A minimum crown height of 0.75 m above the invert level of the side drain is recommended.

[2] Considering the base is well compacted and built properly

PART B

10 PART B DESIGN GUIDE FOR BEST USE OF LOCAL MATERIALS

Purpose

Vanuatu is particularly unique in its archipelago is formed by 80 relatively small islands and therefore, not linked with a “main” road to each other. They are rather isolated from each other. This context makes the use of imported material and/or equipment very expensive.

Fortunately, there are satisfactory materials for construction purposes in abundance on most islands. Sometimes, the materials may not be “ideal” or “perfect” but it is affordable and acceptable for low volume roads.

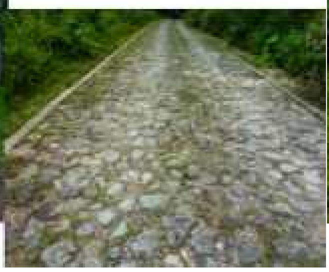
Care and sensible actions can result in the properties of the local material suiting the purposes. As most islands are relatively small, it could be very costly to have heavy equipment available and to keep them in a working state on each isalnd. Therefore, compromise and adaptive actions are necessary.

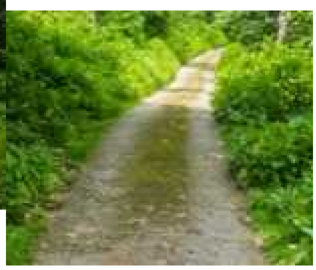
Immediate actions and further actions are proposed to improve local materials. Those proposed actions were mainly based on the overall knowledge of the material type in general. As the knowledge of the specific properties of the local materials is known, the actions to improve the possibilities and requirements may be refined or revised.

Coronous is a good material for base and a wearing course as long as some care is taken in grading and compacting adequately. It can also be a good concrete aggregate but would require heavy processing (crushing, washing and sieving). Test results will be used to assess the potential of the material. Further, an economical study will be needed to evaluate the options and suitability for small-scale processing operation.

Scoria has a good bearing capacity but it is an “average” material for a pavement wearing course as it lacks plastic fines. However, it can be suitable as a base course if the road is sealed (bitumen, chip or concrete). It is hoped that stabilizing scoria with plastic fines to improve its stability, its compaction and its water resistance (less wear, less dust, less corrugate) will improve its use. The behaviour of scoria in concrete in unknown but if the gravel size has enough strength (which could be the case as VTSSP1 used on the Otta Seal trial), it is hoped for good results.

There is little improvement to suggest this for the other local materials. Care would be needed with sand and coral/gravel from beach/stream for concrete to use the correct size in sieving and ensure salt is removed by washing when used in reinforced concrete. Together, they have the ability to make very good concrete.



Actions

Actions proposed to improve the local material or its performances in the roadworks are listed below

Immediate actions

As mentioned above, many actions can be taken in the borrow pit or at the source to improve the material.

1. Sieve gravel or coral (coarse aggregate) for concrete
2. Sieve sand (fine aggregate) for concrete
3. Wash sand and/or gravel/coral if appropriate to remove salt
4. Take note of each mix proportion and behaviour (for further adjustment)
5. Remove manually or build/buy a screen to remove particles bigger than 50 mm (can be built with old steel bars)
6. Prevent segregation in the quarry in ensuring adequate stockpiling procedures
7. Take regular samples and have them analysed by PWD lab
8. Ensure proper operation in the field when using pavement materials: spread / shape / moisture / compact
9. Look for clayey deposit on Ambae, sample and perform tests (grade, LL, PL, IP, LS)

Further actions

1. Develop an easy method to evaluate the water content in the field material
2. Assist in developing a quarry management system (or borrow pit inventory) including all test results for each pits) Department of Geology & Mines are currently working to feed a GIS module on the matter. Help and support may be provided
3. Analyse test results for Coronous material as pavement and revise recommendation
4. Analyse test results for Coronous material as concrete and revise recommendation
5. Analyse test results for scoria material as pavement and revise recommendation
6. Analyse test performed in clayed deposit from Ambae and perform trial in stabilising scoria with plastic fines. This was done as a research on 2 sections in Ethiopia and it showed a great improvement in the behaviour of the scoria.
7. Analyse test results for scoria material as concrete and give recommendation
8. If scoria gravel gives good test results, perform trial mixes using scoria aggregates
9. Analyse options to find the most cost-effective, realistic and applicable technique to process the material (Coronous and/or scoria), which would be accepted by the local community
10. Develop Test/Check forms to record quality activities, process and results (Quality control/Quality assurance).

11 Introduction

11.1 VTSSP and the program

The Vanuatu Transport Sector Support Program (VTSSP) is a partnership between the Government of Vanuatu and the Government of Australia to support the development of Vanuatu's infrastructure, recognising its fundamental role in the provision of economic opportunities and in the delivery of services.

The VTSSP is a long-term program (15 years), which started with Phase 1 in 2009. The road transport infrastructure component is the major part of the program, which main targets are:

- The rehabilitation and maintenance of rural roads on outer islands,
- The stimulation of the private sector and local communities employment to become key providers of road maintenance services to create jobs and income in rural area,
- The establishment of sustainable and affordable institutional arrangements for road maintenance

In Phase 1, baseline and associated processes with roadwork were undertaken along with the rehabilitation of many rural roads on Ambae, Malekula and Tanna. Island based contractors (IBC) were selected and trained to deliver roadwork. Phase 2, which started in July 2013, is the continuation and evolution of various processes initiated on the 3 islands in adding the island of Pentecost.

One of the goals of VTSSP is to ensure the best cost-effective use of the local material needed to supply the work projected has also been part of the planning process of roadwork.

This technical note gives recommendation for the selection and construction practices to ensure the best use of local material in the road works.

The following recommendations are based on an extensive review of the world researches on "Marginal Material" to be use in roadwork as well as on various Manual or Guide for design and/or maintenance on low volume sealed and/or unsealed road. It is also based on the rich local experience of the material use and construction capability available thru Vanuatu.

11.2 Approach

Unpaved gravel roads often constitute around 70 to 90 per cent of the designated road network in developing countries, whilst earth roads and tracks dominate the undesignated network. These roads, generally connecting the productive agricultural areas to the primary road network, play a vital social and economic role in the development of rural areas where the majority of populations live.

> ***Roads will be more affected by rainfall (erosion, landslide, overflows, etc), than by traffic.***

Traditional approach of road design considers mainly the traffic parameters (volume and type) to address security and sustainability aspects. However, for low-volume roads such that in Vanuatu, innovative solutions need to challenge the conventional assumptions regarding road design criteria. The concept of an appropriate, or locally environmentally optimised design approach provides a way forward. Low volume road standards and designs need to support the function that the road is providing as well as recognising the important influences of the deterioration mechanisms. The approach needs also to consider the availability of funds, the local technical capacity and the social impacts.

Research carried out in the latest years has questioned many of the accepted assumptions about the planning, design, construction and maintenance of low-volume roads. This research has quite clearly shown:

- The importance of adopting a more holistic, sustainable approach to the provision of low-volume roads
- The need to revise conventional approaches to planning, economic appraisal and the environment
- The shortcomings of conventional specifications and, to some extent, of test methods, in assessing the adequacy of local materials for use in low-volume roads
- The advantages of adopting more appropriate geometric and pavement design standards
- The economic success of innovative construction methods
- The importance of paying greater attention to the environmental aspects of road provision

Therefore, the use of locally available, but frequently non-standard, pavement construction materials plays a significant role within this concept.

11.3 Road network description

According to the 2014 road inventory, there are a total of 2,241 km of public roads Vanuatu distributed within 24 islands. Out of that, 50% of the road network is found on 3 islands (Santo, Efate and Malekula) and 80% on 8 islands. The distribution is shown on Table 1 and Figure 1 below.

Province	Island	Km
Sanma	Santo	520
Shefa	Efate	337
Malampa	Malekula	267
Penama	Pentecost	199
Penama	Ambae	182
Tafea	Tanna	177
Sanma	Malo	94
Malampa	Ambrym	84
Shefa	Epi	71
Penama	Maewo	46
Sanma	Aore	43
Shefa	Tongoa	37
Tafea	Erromango	31
Malampa	Paama	23
Torba	Vanua Lava	23
Shefa	Nguna	22
Shefa	Emae	20
Torba	Moto Lava	14
Torba	Gaua	13
Sanma	Tutuba	12
Tafea	Aniwa	12
Shefa	Emao	9
Shefa	Tongaoriki	5
Shefa	Pele	4
	Total	2241

Table 17. Road inventory

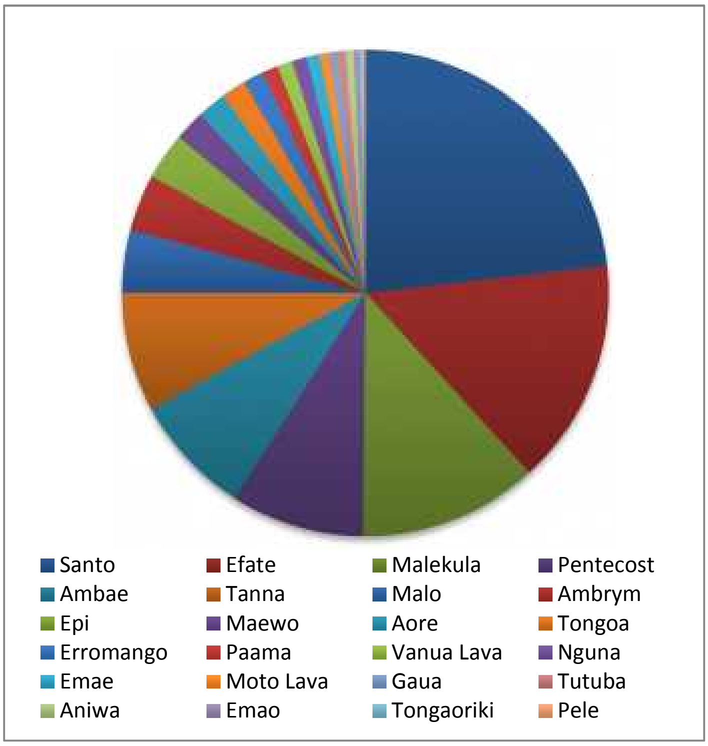


Figure 40. Road distribution

11.4 Road network classification

With the adoption of the Road Act (May 2014), the road network has been divided in 3 functional classes:

The functional classification is used to address the management of accessibility and mobility of the road.

- Arterial,
- Feeder and
- Urban

As most islands have less than 50 km of roads, which are usually the main links between villages, 71% of the network is classified as arterial roads, 20% feeder and 9% urban. Urban roads are found in only 3 islands, Efate (Port-Vila), Santo (Luganville) and Malekula (Lakatoro).

In November 2013, a traffic count was conducted on the main roads on 4 islands:

- Malekula (8 roads, 4 days)
- Pentecost (1 road, 1 day)
- Ambae (5 roads, 2 days)
- Tanna (6 roads, 3 days)

The finding was that:

- The maximum daily traffic recorded on average for one road section was 681 vehicle per day (vpd) on Lakatoro Aoup, in Malekulas
- Four sections had between 200 and 500 vpd (2 on Malekula and 1 in Tanna
- Eleven had between 50 and 200 vpd (3 in Tanna, 4 in Malekula and 4 in Ambae)
- Four had less than 50 vpd (1 on each 4 island)

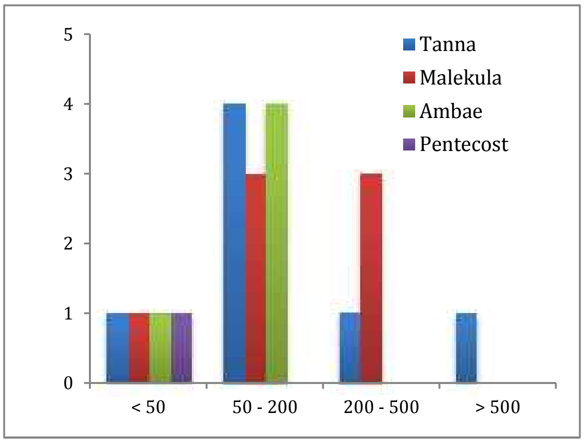


Figure 41. Traffic distribution

Therefore, in order to address the technical and security aspects of the road design (geometry, pavement, drainage), 4 traffic classes were designated for unsealed rural roads in Vanautu:

Traffic classes	TRAFFIC (Vehicles per day (vpd))	Number of lane
T4	> 500	2 lanes
T3	200 – 500	2 lanes
T2	50 – 200	2 lanes
T1	< 50	1 lane

Table 18. Traffic classification

12 Material available in Vanuatu

12.1 Geography

Vanuatu is a mountainous archipelago consisting of 80 relatively small islands but having 2,528 km of coastline. They are geologically new islands of volcanic origin. 65 islands are inhabited and 14 have surface areas of more than 100 square kilometres. There is about 1,300 kilometres north to south distance between the outermost islands.

Most of the islands are steep, with unstable soil and little permanent fresh water. The highest of all the mountains is Mount Tabwemasana on Espiritu Santo at 1,877 meters. Its tropical climate is moderated by southeast trade winds. However, Vanuatu has a long rainy season, with significant rainfall almost every month. The wettest and hottest months are December through April, which also constitute the cyclone season. The driest months are June through November. Rainfall averages about 2,360 millimetres per year but can be as high as 4,000 millimetres in the northern islands. Its natural resources include hardwood forests, coconut, coffee, kava and fish. As of 2011, 2% of its land area is arable, 10% is devoted to crops.

Map of Vanuatu

Natural hazards include tropical cyclones or typhoons from January to April and volcanic activity, which sometimes cause minor earthquakes. Tsunamis are also a hazard. The shoreline is mostly rocky with fringing reefs and no continental shelf, dropping rapidly into the ocean depths

12.2 Geology

The archipelago is on the edge of the Pacific tectonic plate (Pacific Rim of Fire), which is being forced up and over the Indo-Australian Plate. This enormous and relentless pressure causes constant seismic activity in the form of earthquakes and volcanic eruptions, which produce a great deal of basalt.

<u>Materials Commonly Used in Roadworks</u>
Coronous
Coral Beach
Scoria
Beach Sand
Basalt cobble

Therefore, the substrata and most of the exposed bedrock on the islands are made of extrusive volcanic rocks as basaltic and andesite lava, breccia, basalt olivine basalt. Associated with volcanic activity, there is also a series of unconsolidated material as bomb, cobbles, tuff, scoria, pumice and sand. Sand along the coast can be of volcanogenic origin and transported from the interior by the main streams. With the sea surrounding the archipelago, coral have formed around most of the island and as the sea bed is uplifting, some of these coral can now be found in various location on most islands. They are sometimes categorised as Older Raised Limestone, Younger raised Limestone and Recent Raised Limestone by the Department of Geology and Mines. Basically, the older the deposit, the harder and more consolidated the particles will be. However, this material is commonly called “Coronous” gravel. Corals are also found on the beach as coarse gravel size (100 mm) down to fine sand.

12.2.1 Coronous

Typically, the coral-derived material most widely available for use is termed Coronous material; a land-based uplifted coral reef that may contain an abundance of plastic fines and that is usually easily excavated without the use of explosives. The wide occurrence of Coronous in the Pacific region as well as the shortage of “traditional” road aggregates have promoted the study of the use of coral-derived aggregate as an alternative aggregate in pavement engineering works. Although coral-derived materials have been successfully used for pavement construction in the past, traditional engineering tests have generally indicated that it is a substandard product, and material from most pits does not pass typical “traditional” specification tests.

Coronous material

Coronous has been used in road construction for long time. In second WW, airstrips used in the Pacific were made of Coronous. It is widely used in Vanuatu. It is known to perform well under controlled conditions.

12.2.2 Scoria

Scoria is a highly vesicular, dark colour volcanic rock that may or may not contain crystals (phenocrysts). It is typically dark in colour (generally dark brown, black or purplish red), and basaltic or andesitic in composition. Scoria is relatively low in mass as a result of its numerous macroscopic ellipsoidal vesicles, but in contrast to pumice, all scoria has a specific gravity greater than 1, and sinks in water. The holes or vesicles form when gases that were dissolved in the magma come out as it erupts, creating bubbles in the molten rock, some of which are frozen in place as the rock cools and solidifies.

Scoria material

Scoria may form a part of a lava flow, typically near its surface, or as fragmental ejecta (lapilli, blocks and bombs), for instance in Strombolian eruptions that form steep-sided scoria cones. Most scoria is composed of glassy fragments, and may contain phenocrysts.

Scoria has several useful characteristics that influence how it is used. It is somewhat porous, has high surface area and strength for its weight, and often has striking colours. Scoria is often used in landscaping and drainage works. It is also commonly used in gas barbecue grills. Scoria can be used for high-temperature insulation. Scoria is used on oil well sites to limit mud issues with heavy truck traffic. It is also used as a traction aid on ice and snow covered roads.

The quarry of Puna Pau on Rapa Nui/Easter Island was the source of a red coloured scoria which the Rapanui people used to carve the pukao (or topknots) for their distinctive moai statues, and to carve some moai from.

Beside that, scoria can also be used as pavement material. It is known to be very sensitive to water erosion and traffic. It tends to be very dusty and corrugate.

12.2.3 Coral gravel and sand beach/stream

Coral is gravel size dead coral found on beaches. Gravel is loose gravel size rock normally polished by the action of water and normally found on beaches or on streambed. Sand is from terrigenous or coral origin. It is found mainly on beaches but can also be found on stream edges. They are all loose material, normally clean, often rounded and sometimes they may content salt.

All those material have been used in concrete and masonry with great success.

12.2.4 Basalt Cobbles

Basalt gravel and cobbles are known to be found in Ambae. They are rounded or semi-rounded, hard fine-grained volcanic rock. They are found along streams.

Those materials have been used in concrete and masonry with great success. Cobble size can be successfully used for gabion (100-200mm), hand packed stone (150-200mm) and grouted stone (100-200mm).

MM	0.005	0.075	4.75	76 .	300
CLAY	SILT	SAND	GRAVEL	COBBLE	BOULDER

Figure 42. Size definition used in engineering

13 The importance of using local material

As Vanuatu is made of several relatively small islands, the source of the material is very limited. There are three possible sources of material in Vanuatu:

a. From a borrow pit (unconsolidated deposit) from the island where the work is to be
b. From an imported processed material from another island or overseas
c. From a quarry (hard rock to be blasted, crushed and sieved) which can be open on the island

Importing materials or blasting the bedrock would result in an improvement in the quality of the material but the cost of the material from b. and c. would easily be 4 to 20 times the cost of the material found loose on the island.

Many countries struggle with silty and clayed soils which are a disaster in road works. In Vanuatu, it is fortunate that on most islands, several deposit of loose gravel for pavement as well as sand and gravel for concrete can be found. This is the main material needed for road works.

As those materials are naturally occurring, it is normal that there is sometimes a fairly wide variation in the properties. Therefore, some precautions need to be done in the selection of the material and to make the most of it. In addition, gravel is not a renewable resource. It is wise not to waste it.

13.1.1 Gravel

Naturally occurring soils and gravels are an important source of material for use in the construction and maintenance of a Low-Volume Road (LVR). This is because these materials are relatively cheap to use by comparison with processed materials such as crushed rock. Moreover, in many countries such as in Vanuatu, they are often the only source of material readily available, at a low cost and within a reasonable haul distance of the road. Thus, because of the substantial influence that naturally occurring materials exert on the cost of a LVR, typically about 70 per cent, it is essential that the benefits of using them be fully exploited in road construction.

> *The term "natural gravel" refers to a gravelly material occurring in nature as such, (e.g. Coronous or scoria) or which can be produced without crushing. Some processing, to remove or break down oversize may still be necessary. However, a distinction is made between these "natural" gravels, and material produced from crushed hard rock, and is referred to as "crushed stone".*

Importing material on the island to use as wearing course would be a nonsense considering the high cost as well as the availability of suitable local material.

Unfortunately, many of the naturally occurring road building materials in Vanuatu was disparagingly described as being "non-standard", "marginal", "low-cost", or even "sub-standard". This is because such materials are often unable to meet the required specifications, which are usually based on Australian, European or North American practice which does not always make provision for local conditions. There are many examples of naturally occurring materials, such as Coronous, that have performed satisfactorily despite being "sub-standard" with respect to their grading, plasticity or strength. Where failures occurred, investigations often show that poor quality construction or drainage problems were more likely the cause, rather than the material itself.

Pentecost

Malekula

Ambae

The use of local materials requires not only a sound knowledge of their properties and behaviour but also of the traffic volume and loading, physical environment, and their interactions. In addition, it will require the use of appropriate pavement design methods and the application of appropriate design standards and materials specifications, coupled with construction quality that complies with the required standards and specifications.

Naturally occurring gravel is highly variable in size and properties. This requires the use of appropriate and flexible construction techniques and provision of adequate internal and external drainage. Standard methods of test that, for the most part, have evolved as a result of experience of soils in temperate zones, do not always give a true assessment of the performance of locally available materials when used in road construction.

Conventional specifications apply to "ideal" materials and often preclude the use of many naturally occurring materials (Coronous, etc.) despite their good performance in service.

Coronous and scoria are typical examples of natural gravels, which, although occurring throughout the Pacific, had generally been considered to be unsuitable for use in base courses. However, experience and full- scale trials have demonstrated that these materials (at least Coronous) can be used successfully in the upper layers of pavements.

13.1.2 Other material

Other material found on the islands and needed in road construction are:

- Beach Coral Gravel used as concrete aggregates
- Sand deposit (beach and stream) used in concrete, mortar, bedding, etc
- Basalt cobble used in gabions and grouted stone

14 Material requirements

The level of quality of a material is its ability to meet the particular requirements for a given usage. Considering the operations related to roadwork, the material requirements has been divided in 2 main categories,

- Pavement material
- Concrete and masonry

Apart from the quality and particular characteristics of the material, the following factors should always be considered when selecting any material.

Haul distance	Reserves must be within physically and economically feasible haulage distance.
Placeability	The material must be capable of being placed and compacted by the available plant.
Environmental impact	The material reserves must be capable of being won and hauled within any governing environmental impact regulations.

14.1 Requirements for pavement material

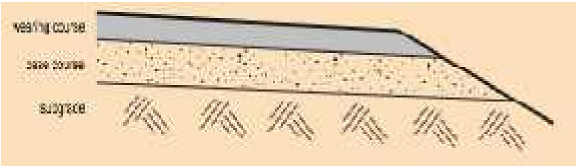
Pavement material traditionally include fill material, sub base, base, wearing course.

A wide range of natural materials including Coronous, scoria, river gravels and other transported and residual gravels, or granular materials resulting from weathering of rocks can be used successfully in the road foundation as fill, sub base, base and/or wearing course.

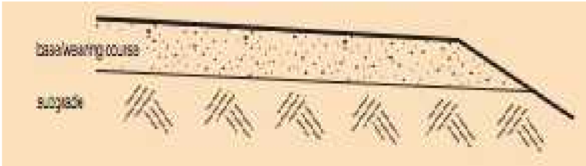
Specific typical requirement considering low volume road in tropical humid climate are described below for the most important usage, as a subbase/base and as wearing course on unpaved road.

As it is often the case in Vanuatu as well as in many other countries with low volume rural roads (New Zealand, Africa, etc), the subgrade is covered with only one or two layers:

- A layer which act as sub-base, and a layer acting as base/wearing course or
- A single layer acting as sub-base, base and wearing course



Preferred layers



Common layers

Figure 43. Pavement layer options

14.1.1 Material requirement for road sub-base/base

The basic role of the subbase is to give strength to the pavement. It is achieved in selecting the right material but also in ensuring that the drainage is efficient and that the water table is not near the ground surface.

The important properties are described in the table below.

Properties	Depends on	Plays a role in	Target basic specifications
Particle size distribution	Mainly on the climate and the traffic	The compaction ability and therefore, the stability of the layer. Drainage.	The maximum size will generally be either 37,5 mm or 53 mm and the maximum fine content between 20 and 30%. A general requirement of five to ten per cent retained on successive sieves may be specified at higher traffic (>0.3 Mesa) .
Strength	Traffic level and climate	Support of the pavement. Prevent deformation	Soaked CBR test is often used to specify the minimum strength of road base material.
Plasticity	Traffic level and climate	Stability of the layer.	Considering the low-volume (< 0.01 mesa), the Ip limit will depend on the stiffness of the subgrade,. - If subgrade CBR is 5 to 8 : Ip max 15 - If subgrade CBR in > 8 : Ip max is 8xGM

Table 19. Important pavement material properties

14.1.2 Material requirements for gravel Wearing course

The role of the wearing course is to give a good and stable surface for the traffic. The wearing course material should be durable and of consistent quality to ensure it wears away evenly. The desirable characteristics of the wearing course of an unsealed road are:

- Resistance to raveling and scouring

- Wet and dry stability
- Low permeability
- Cohesive properties
- Load spreading ability
- Skid resistance
- Smooth riding characteristics

For ease of construction and maintenance, a surface material should also be easy to grade and compact. The material properties having the greatest influence on these characteristics are the particle size distribution and the chemical / physical properties of the fine particles in terms of plasticity. Particle size distribution and its effects may conveniently be described in terms of standard particle size classifications (e.g. gravel, sand, silt and clay) or alternatively, the fractions passing various sieve sizes. Visual evaluation in the field, using these standard classifications, and/or laboratory tests, can therefore be employed to assess a material's potential.

Gravel and sand that are low in fines will be porous, lack stability when dry and will ravel under traffic. However, fines in the form of a sand–clay may be incorporated into these materials to give added stability.

The least desirable materials are those with silty fines, lacking gravel-sized particles, i.e. silts and silty-sands. These materials are likely to be porous and unstable and will ravel under traffic. They also tend to generate considerable dust.

Predominantly clay soils can provide a good dry-weather surface but will be slippery and/or will rut when wet. Sand–clay or sand–silt–clay mixtures can provide a satisfactory surface course for low traffic volume roads.

Either the plasticity index (PI) or the linear shrinkage (LS) can be used to evaluate whether the clay content of a material is appropriate. The PI or LS should desirably fall within minimum and maximum values, depending on climatic conditions, grading of the material and traffic conditions.

Malekula

Tanna

Particle strength and susceptibility to weathering will affect the ultimate grading and plasticity of a paving material. In general, it can be said that the easier a rock is to rip, the more it is likely to break down in construction and service. A material, which breaks down readily or has a history of weathering, should be thoroughly evaluated before use. It may be necessary to expose the material to the elements over a short section of roadway for a while to test its suitability.

The specifications proposed, have been developed to comply with the requirements of “ideal” wearing course materials which also performs as base course, with in mind that the specifications should:

- Be kept as simple as possible, with as few requirements or different test methods as possible.
- Have limits as wide as possible and not restricted to a narrow range of a significant property (e.g. a tight grading envelope), but comprehensive enough to accept suitable materials and reject unsuitable materials.
- Require inexpensive, quick, simple tests, which are repeatable and reproducible and need minimal sophisticated equipment and a relatively low level of operator training.
- Be practical to implement and apply to the total area for which they are intended.
- Adequately define important properties (indirectly if necessary) such as cohesion and strength and eliminate obvious problems such as oversize material.
- Should be in terms of existing test methods or combinations of results from existing methods, although scope exists for the development of simple new methods.
- Be based on performance related studies.
- Be rigidly adhered to; however, the user should appreciate the consequences of use of non-complying materials e.g. increased construction, maintenance and road user costs, increased dust and poor safety standards.

The choice of the gravel surfacing material is most often a compromise between a material, which possesses sufficiently high plasticity to prevent gravel loss in the dry season and sufficiently low plasticity to prevent serious rutting and deformation in the wet season. Choice of materials will also depend, when possible, on haul distances, since this will greatly affect construction costs and rate of progress.

Specifications emphasise the need for these properties combined with a mechanically stable grading with higher fines content for binding action to result. Selection of a suitable range of plasticity is dependent on climate.

The figure below illustrates wearing material quality zones.

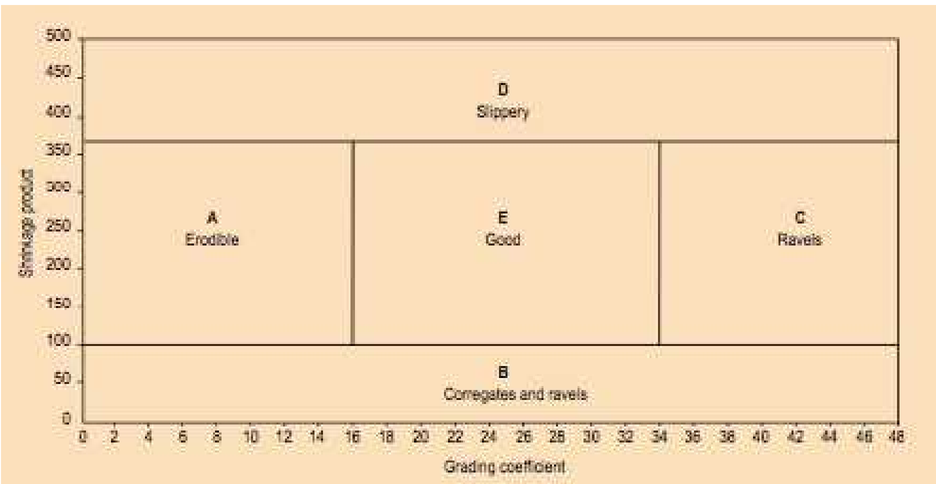


Figure 44. Wearing Material Quality Zones

The characteristics of materials in each zone are as follows:

A. Materials in this area generally perform satisfactorily but are finely graded and particularly prone to erosion. They should be avoided if possible, especially on steep grades and sections with steep crossfalls and super-elevations. Roads constructed from these materials require frequent periodic labour intensive maintenance over short lengths and have high gravel losses due to erosion.

B. These materials generally lack cohesion and are highly susceptible to the formation of loose material (ravelling) and corrugations. Regular maintenance is necessary if these materials are used and the road roughness is to be restricted to reasonable levels.

C. Materials in this zone generally comprise fine, gap-graded gravels lacking adequate cohesion, resulting in ravelling and the production of loose material.

D. Materials with a shrinkage product in excess of 365 tend to be slippery when wet.

E. Materials in this zone perform well in general, provided the oversize material is restricted to the recommended limits.

Dust: Dust is the loss of fines put in suspension by the action of the traffic. To reduce the dust as much as possible near community villages, the material content may have a reduced fine content.

Gravel loss

Dusty road

Gravel loss: Gravel loss is the single most important reason why gravel roads are expensive in whole life cost terms and often unsustainable, especially when traffic level increase. Reducing gravel loss by selecting better quality gravels or improving the construction procedures or modifying the properties of poorer quality materials is one way of reducing long-term costs. Gravel losses can vary from 10 to 45 mm/year/100 vpd for the first phase of the deterioration cycle lasting possibly two or three years. Beyond that period, as the wearing course is reduced in thickness, other developments, such as the formation of ruts, will also affect the loss of gravel material. However, the rates of gravel loss given can be used as an aid to the planning for regravelling in the future. A more accurate indication of gravel loss for a particular section of road can be obtained from periodic measurement of the gravel layer thickness.

14.2 Requirements for concrete and/or masonry

Concrete material includes coarse and fine aggregates along with cement and water. For a good concrete mix, aggregates need to be clean, hard, strong particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete. Aggregates, account for 60 to 75 percent of the total volume of concrete.

Aggregates strongly influence concrete’s freshly mixed and hardened properties, mixture proportions, and economy. Consequently, selection of aggregates is an important process.

14.2.1 Coarse aggregate

Although some variation in aggregate properties is expected, characteristics that are considered include:

- Grading
- Durability
- Cleanliness
- Particle shape and surface texture
- Abrasion and skid resistance
- Unit weights and voids
- Absorption and surface moisture

Grading refers to the determination of the particle-size distribution for aggregates. Grading limits and maximum aggregate size are specified because these properties affect the amount of aggregate used as well as cement and water requirements, workability, pumpability, and durability of concrete. The required amount of cement paste is dependent upon the amount of void space that must be filled and the total surface area that must be covered. When the particles are of uniform size the spacing is the greatest, but when a range of sizes is used the void spaces are filled and the paste requirement is lowered. The more these voids are filled, the less workable the concrete becomes. Therefore, a compromise between workability and economy is necessary. In general, if the water-cement ratio is chosen correctly, a wide range in grading can be used without a major effect on strength.

Cleanliness is an aggregate free of dirt or clay sticking to the particles. Dirt would weaken the bond between paste and aggregates. If aggregates are used in reinforced concrete (using steel bars or wire mesh), the aggregates should be free of salt.

Abrasion and skid resistance of an aggregate are essential when the aggregate is to be used in concrete constantly subject to abrasion as in heavy-duty floors or pavements. Different minerals in the aggregate wear and polish at different rates. Harder aggregate can be selected in highly abrasive conditions to minimize wear.

The shape and texture of aggregate affects the properties of fresh concrete more than hardened concrete. Concrete is more workable when smooth and rounded aggregate is used instead of rough angular or elongated aggregate. Most natural sands and gravel from riverbeds or seashores are smooth and rounded and are excellent aggregates. Crushed stone produces much more angular and elongated aggregates, which have a higher surface-to-volume ratio, better bond characteristics but require more cement paste to produce a workable mixture.

The surface texture of aggregate can be either smooth or rough. A smooth surface can improve workability, yet a rougher surface generates a stronger bond between the paste and the aggregate creating a higher strength.

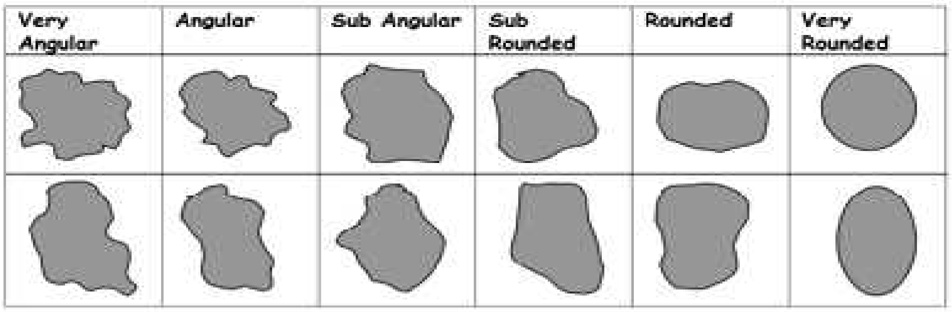


Figure 45. Shape and texture

15 Usage of Coronous in road works

15.1 Coronous as a wearing course

Coronous material is the best widely found material in Vanuatu for wearing course. However, as it is variable in its properties (grading, hardness, plasticity, etc), proper care when selecting can improve the final result. In addition, handling and construction procedures and equipment are as very important to ensure the best possible quality of the final work.

15.1.1 Advantages of Coronous material

- Can be found almost everywhere within ±10 km
- “As dug” pavement aggregate may be exploited to considerable depths by ripping
- When “as dug” material contains an excessive proportion of oversize particles, it can often be effectively treated with a mobile crusher of ’Rockbuster’ type.
- “As dug” Coronous which contains less than 30% of fines, often get CBR > 100
- There is good interlock between angular particles and a hard pavement ’crust’ may develop. Providing advantages listed above for coral beach deposits.
- Carbonate clay is an excellent binder, which produces a good pavement running surface with ’normal’ compaction. Significant breakdown of oversize particles may occur during compaction.
- When well compacted, the surface is hard with minimum dust and impermeable

15.1.2 Disadvantages of Coronous material

- A variable proportion of Coronous particles are fairly weak.
- Rate of pavement wear/loss typically higher than for alluvial gravel pavements. This may become significant on more heavily trafficked roads (> 800 vpd).
- Material quality/performance deteriorates as sand content exceeds gravel content.
- Potholes may form where pavement ’crust’ is broken or softened.

- Material quality/performance deteriorates if carbonate clay (fine matrix) content is excessive.
- Pit materials with high natural moisture content (damp/wet) are difficult to handle and compact, and tend to form a weak pavement when first laid.

15.1.3 Recommended Specifications on the use of Coronous as wearing course

The following specifications are based on the available general research and knowledge of Coronous material adapted to the local environment found in Vanuatu. It was also considered that all roads are low volume and that there is often only one layer above the subgrade. Therefore, to make it simpler and probably more realistic, the proposed specifications applied to all “traditional” layers. (sub base, base and wearing course)

Grading: Coronous and Scoria

Sieve	Envelope
53	100
37,5	90-100
19	70-100
2,36	35-65
0,425	15-50
0,075	10-30

Note on grading specification
This envelope is assuming that some of the largest particle (37,4-53mm) will break down during compaction. It is also assuming that the spread-water-compact operation is performed adequately. Some quarries may also have harder particles, which wouldn’t break down. This could make the wearing surface to become fairly rough after few months of heavy traffic and rain. In that case, it is advised to revise the grading specifications in order to reduce (or eliminate) the coarser content (37,5-53mm), at least for the wearing course. A smaller nominal size would ease spreading and compaction and smoother ride.

Table 20. Grading specification for pavement materials

Considering the variation in the characteristics of the Coronous between quarries and even within the same borrow pit, it is suggested to perform regularly a visual assessment of the fine content of the material during the extraction process and to sample the quarry to build the knowledge of the material. It is also important to sample different zone.

Other characteristics that can be relevant to verify are PI, LS and CBR. Therefore, the specifications would ideally be the following.

Characteristics	Specification	
Grading Coefficient	16 – 34	(%passing 26.5 mm - %passing 2 mm) x %passing 4.75 mm / 100
Grading Modulus	1.5 – 2.5	(200 – (%passing 2 mm + %passing 0.425 + %passing 0.075)) / 100
Fine to sand ratio	0.25 – 0.24	5 passing 0.075 / % passing 2.36
Plasticity Index (PI)	Max 15	If CBR in unknown or < 8 %
Plasticity product	300 - 400	PI x % passing 0.425 mm
Shrinkage Product (Sp)	100 - 365[1]	LS x % passing 0.425 mm
Soaked CBR	Min 30%	

[1] 240 Preferable

Table 21. Other desirable properties for pavement materials

It seems that there is a fairly good relationship between a high fine content and a low CBR. Therefore, it is believed that in having a good grading, limiting the fine content and in verifying its plasticity (specially if the passing 0,075 is higher than 20%), the material is more likely to conform to the CBR requirement.

The limits stated for the characteristics above come from general overseas studies and experiences. These may or may not be suitable for Vanuatu, In order to develop specific requirement for local material, a better knowledge of the material properties are needed. The actual information is almost non-existent and sometimes irrelevant. Therefore, sampling and testing must be done on the local material. Local experience may indicate changes to limits that better distinguish between local materials and their capability of fulfilling requirements for different access road standards.

15.1.4 How to improve Coronous as a wearing course?

In the pit

	Action to improve	How	Why
p1	Avoid material with fine content higher than 30%.	Visual. Perform grading test or consult previous document.	High fines content normally indicate a low CBR. It also indicates a higher plasticity and plasticity modulus, which will make the pavement less stable. It will also generate more dust.
p2	Remove gravel size greater than 50 mm	Manually or with screen and/or crushing,	Coarser material in the wearing course may lead to poor compaction as the interlocking will be harder around large gravel and premature potholing. The larger the gravel, the coarser the wearing surface will become when wearing and loosing its fines.
p3	Prevent segregation in the stockpiling	Stockpile in a continuous layer. Do not push materials over an existing pile	If segregated material is spread on site and compacted as is, the performance expected will not be met; there will be either mainly coarser gravel with a lack of fines or little gravel in a matrix of fine.

Table 22. Proposed improvement actions in the pit

In the worksite

	Action to improve	How	Why
s1	Prevent segregation when loading	Always load a full depth of material and not only the surface of the edge	If segregated material is spread on site and compacted as is, the performance expected will not be met; there will be either mainly coarser gravel with a lack of fines or little gravel in a matrix of fine.
s2	Prevent segregation when spreading	Continuous discharging. Limit passage and vibration on the uncompacted material.	
s3	Remove gravel size greater than 50 mm	Manually or mechanically	See p2 above
s4	Break large particles	Use of a grid rollers can be beneficial under circumstances	If breaking of particles is desirable
s5	Moisture the material uniformly to the optimum moisture content (OMC)	Evaluate the natural water content and add the quantity of water needed to bring it to the OMC (normally between 8 and 11) Use water tank, manual pressure sprayer, watering can, etc	To achieve the optimum compaction. To be able to use the fines as paste and binder. Water will help to bring all particles as tight as possible.
s6	Compact to refusal	Use the more suitable equipment available. Compact with vibration. Minimum of 10 passes or when the compactor leave no more prints "compaction to refusal"	Increase load-bearing capacity Provide better stability Reduce permeability for water Improve traffic resistance
s7	Keep carriageway clean of organics	Avoid putting grass and leaves on carriageway when cutting grass on routine maintenance	It will become humus and may become slippery

Table 23. Proposed improvement actions in the work site

15.1.5 Proposed further actions or study on the use of Coronous as wearing course

1. Develop an easy method to evaluate the water content in the material
2. Help develop a quarry management system (or borrow pit inventory) including all test results for each pits to be sampled
3. Perform at least 2 complete sets of test for each borrow pit (grade, MDD, CBR, limits, shrinkage, LA, etc.)[2]. This will greatly help in the material selection.

15.2 Coronous as concrete aggregate

An aggregate is normally 60-70% of the concrete along with cement and water. If the adherence between the aggregate and the cement paste is strong, the coarse aggregate will help give the strength to the concrete. The fine aggregate (sand) will make the concrete flowing and workable.

Coronous is used as concrete coarse aggregate in ready-mix plants in Port Vila. It is also occasionally used in outer island at small scale for house building or other uses. However, most of the concrete made manually for small quantity will use beach and stream aggregates.

15.2.1 Advantages of Coronous material

- Can be found almost everywhere within ±10 km
- Can be sieved manually or with equipment (sieve, crusher, etc.)
- Often a better environmental option (as the gravel beach/stream)
- Angular particles, if hard, help interlocking and improve strength

15.2.2 Disadvantages of Coronous material

- Fairly weak particles without an operation of crushing may remain as coarse aggregates and weaken the concrete
- Must be well washed to eliminate the fines sticking to the gravel (not with seawater if used in reinforced concrete)
- Angular particles will reduce workability and may require more paste (cement)

15.2.3 Recommended Specifications using Coronous aggregates

In the absence of information regarding the properties of Coronous aggregates (particularly the mechanical properties) for use in concrete, it is suggested to use the specifications stated in the PWD standard specifications or in the Australian Standard AS 2758.1 “Aggregates and rock for engineering purpose – Part 1: Concrete aggregate”.

In material form, the most significant quarries are to be sampled and tested, the knowledge of the Coronous properties should enable the selection of more adapted specification. The normal properties requires are

- Aggregate strength (LA, ACV and/or SSS)
- Aggregate grading
- Impurity, fines and organics

2 Only few laboratory test results have been found for each island. They were all performed in the last two years by the PWD material testing laboratory. However, it was found that two important tests were not performed correctly (sieve analysis and CBR). The material was not tampered and washed during the sieve analysis, leading to an important undervaluation on the fine content. The compaction of the material for the CBR was not at the humidity optimum leading to an under compaction and the surcharge was removed during the test performance loading. This all leads to an under evaluation of the CBR. Therefore, all laboratory test results available could not be trusted to report on the properties.

15.2.4 Proposed further actions or study use of Coronous as concrete aggregate

1. Better knowledge of the characteristics of the aggregates on different quarries. Perform hardness tests on particles size 5-20 of Coronous from several borrow pit (LA, etc.). This will greatly help to determine if a given material is suitable and if it needs crushing.
2. Knowing that Coronous is generally suitable as concrete aggregates, the biggest challenge will be to process the material efficiently on a small scale. Therefore, options should be analyses to find the most cost-effective, realistic and applicable way to process the material, which would be accepted by the local community.

16 Volcanic scoria

16.1 Scoria as a wearing course

Volcanic scoria as wearing course is a less performing material than Coronous. All particles (from fine to coarse) are vitreous and therefore, there are no plastic fines to bind the material. In Ambae and Ambrym, there are no Coronous deposits and scoria is the only material easily available for roadwork. Therefore, as it is variable in its properties (grading, hardness, plasticity, etc), proper care when selecting can improve the final result. In addition, handling and construction procedures and equipment are very important to ensure the best possible quality of the final work.

16.1.1 Advantages of scoria material

- Can be found almost everywhere within ±10 km
- May occur in large relatively uniform exploitable deposits.
- Typically easily excavated by backhoe or wheeled loader.
- Angular gravel produces good interlock of particles when well graded.
- “As dug” materials may often be well graded.
- Larger particles tend to breakdown under normal compaction and may improve the grading by creating sand and silt size particles, which may reduce the need of quarry processing

16.1.2 Disadvantages of scoria material

- Typically lack good plastic binder.
- If the “as dug” materials are uniformly graded and have a significant lack of fines adequate compaction will be difficult to achieve.
- Completely weathered volcanic ash residual soils may form thick overburden deposits.
- Due to vesicular nature of these deposits, weaker materials may breakdown rapidly under compaction and in-service on the road to produce a dusty surface in dry conditions.
- Workable deposits may occur within a sequence, in-bedded with tuff / clayed silt and hard basaltic lavas. Selective extraction at the pit is then necessary.
- Very susceptible to rain. Will tend to ravine and erode.
- Susceptible to corrugate under traffic.
- Dusty

16.1.3 Recommended Specifications for the use of scoria as wearing course

The following specifications are based on the available general research and knowledge of scoria material adapted to the local environment found in Vanuatu. It was also considered that all roads on Ambae and Ambrym are low volume and that there is often only one layer above the subgrade. Therefore, to make it simpler and probably more realistic, the proposed specifications applied to all “traditional” layers (sub base, base and wearing course). Grading is proposed below.

Sieve	Envelope
53	100
37,5	90-100
19	70-100
2,36	35-65
0,425	15-50
0,075	10-30

Note on grading specification
This envelope is assuming that some of the largest particle (37,4-53mm) will break down during compaction. It is also assuming that the spread-water-compact operation is performed adequately. Some quarries may also have harder particles, which wouldn’t break down. This could make the wearing surface to become fairly rough after few months of heavy traffic and rain. In that case, it is advised to revise the grading specifications in order to reduce (or eliminate) the coarser content (37,5-53mm), at least for the wearing course.

Table 24. Grading specification for pavement materials

Considering the visual variation in the characteristics of the scoria between quarries and even within the same borrow pit, it is suggested to perform regular visual assessment of the material during the extraction process and to sample the quarry for testing to build the knowledge of the material. It is also important to sample different zone.

Other important characteristics to verify are:

- Los Angeles
- Soaked CBR min 30

Note: As this type of material does not normally have plastic fines, plasticity limits have not been specified. But if the material happens to have some plasticity, its behaviour would be improved.

16.1.4 How to improve scoria as a wearing course?

In the pit

	Action to improve	How	Why
1	If possible, select material with more fine	Visual. Perform grading test or consult previous document.	More fine content will tend to compact better.
2	Remove gravel size greater than 50 mm	Manually or with screen and/or crushing,	Unless coarser particles are weak and will break under compaction, coarser material in the wearing course will make the compaction more difficult as the interlocking will be harder around large gravel and would normally required heavier equipment. The bigger the gravel is, the rougher the surface pavement will become when wearing and loosing its fines.
3	Prevent segregation in the stockpiling	Stockpile in a continuous layer. Do not push the over the material of an existing pile	If segregated material is spread on site and compacted as is, the performance expected will not be met; there will be either mainly coarser gravel with a lack of fines or little gravel in a matrix of fine.

Table 25. Proposed improvement actions in the pit

In the worksite

	Action	How	Why
1	Prevent segregation when loading	Always load a full depth of material and not only the surface of the edge	If segregated material is spread on site and compacted as is, the performance expected will not be met; there will be either mainly coarser gravel with a lack of fines or little gravel in a matrix of fine.
2	Prevent segregation when spreading	Continuous discharging. Limit passage and vibration on the uncompacted material.	
3	Moisture the material uniformly to the optimum moisture content (OMC)	Evaluate the natural water content and add the quantity of water needed to bring it to the OMC (normally between 8 and 11) Use water tank, manual pressure sprayer, watering can, etc	To achieve the optimum compaction. To be able to use the fines as paste and binder. Water will help to bring all grains as tight as possible.
4	Compact to refusal	Use the heaviest equipment available. Compact with vibration. Compact with a minimum of 10 passes or when the compactor leave no more prints "compaction to refusal"	Increase load-bearing capacity Provide better stability Reduce permeability for water Reduce setting of soil Improve traffic resistance
5	Stabilized with plastic fines	Add plastic fines as clayed material and mix it	It will greatly improve the binding of the material and the compaction. Therefore, will have a better resistance to traffic weathering, be less dusty and corrugate less.

Table 26. Proposed improvement actions in the worksite

16.1.5 Volcanic scoria as base or sub-base

As base or subbase, scoria is confirmed as having good results in overseas studies and trials on low volume roads, particularly on sealed roads. The layer was stable and had an acceptable bearing capacity.

16.1.6 Proposed further actions or study for the use of scoria as wearing course

1. Develop an easy method to evaluate the water content in the material for compaction purpose (same as for Coronous)
2. Help develop a quarry management system (or borrow pit inventory) including all test results for each pits (same as for Coronous) that will be done
3. Perform at least 2 complete sets of test for each borrow pit (grade, MDD, CBR, limits (?), shrinkage (?), LA, etc.). This will greatly help in the material selection.
4. Look for clayey deposit in Ambae / Ambrym and perform trial in stabilising scoria with plastic fines. This was done as a research on 2 sections in Ethiopia and it showed a great improvement in the behaviour of the scoria.

16.2 Volcanic scoria as concrete aggregates

An aggregate is normally 60-70% of the concrete along with cement and water. If the adherence between the aggregate and the cement paste is strong, the coarse aggregate will help give the strength to the concrete. The fine aggregate (sand) will make the concrete flowing and workable.

There is no known use of scoria aggregates in concrete in Vanuatu but there are references from overseas where scoria aggregates were use in lightweight concrete. Information (test results) couldn't be found on the properties of scoria from Ambae/Ambrym, which would be relevant for concrete aggregates (densities, water absorption, durability, etc). However, to be considered, particles would need to be at least as strong as the concrete.

16.2.1 Advantages of scoria aggregates

- Can be found almost everywhere within ±10 km
- Can be sieved manually or with equipment (sieve, crusher, etc.)
- Often a better environmental option (as the gravel beach/stream)
- Angular particles, if hard, help interlocking and improve strength

16.2.2 Disadvantages of scoria aggregates

- Fairly weak particles without an operation of crushing may remain as coarse aggregates and weaken the concrete
- Angular particles will reduce workability and may require more paste (cement)

16.2.3 Recommended Specifications for the use of scoria as a concrete aggregate

In the absence of information regarding the properties of scoria aggregates (particularly the mechanical properties) for use in concrete, it is suggested to use the specifications stated in the PWD standard specifications or in the Australian Standard AS 2758.1 "Aggregates and rock for engineering purpose – Part 1: Concrete aggregate".

However, as the material form the most significant quarries are to be sampled and tested, the knowledge of the scoria properties should enable the selection of more adapted specification.

16.2.4 How to improve scoria as a concrete aggregate?

In the absence of any test results to assess the raw material, it is hazardous to propose any improvement. However, grading is surely essential.

	Action	How	Why
1	Ensure grading as specified	Sieve (and crushed) manually or with equipment (sieve, crusher, etc)	To ensure workability in respecting the water/cement ratio. The formula took in account the grading of aggregates and its proportion.

Sieving scoria in Ambae 2012

16.2.5 Proposed further actions or study to improve scoria as concrete aggregate

1. Build basic knowledge of the properties of the scoria aggregates. Perform lab tests relevant to concrete aggregates on several samples, at least from Ambae. This will greatly help to determine if a given material has the basic properties to be considered, and if so, what are its limitations and how can it be improved. Proposed testing regime is attached in appendix.
2. Perform trial mixes using scoria aggregates
3. If the scoria gravel happened to be appropriate for concrete aggregates, the biggest challenge will be to process the material efficiently on a small scale. Therefore, options should be analyses to find the most cost-effective, realistic and applicable way to process the material, which would be accepted by the local community.

17 Stabilisation

Pavement stabilisation is employed in unsealed roads usually to reduce maintenance costs, improve material properties and to provide a better all-weather surface. By rectifying deficiencies in materials, stabilisation allows otherwise unsuitable materials to be used to advantage in road pavements.

Stabilisation has the benefits of improved surface condition through less dust, rutting, potholes and corrugating. In addition to reduced maintenance costs, vehicle-operating costs may also be reduced. However, some forms of stabilisation may be inappropriate or too costly for use in unsealed road construction. Problems can arise from either the selection of a stabilisation method, which is inappropriate for the local material and conditions, or the use of incorrect techniques in an appropriate application.

The principal factors to be considered when selecting the most suitable method of stabilisation are as follows:

- Type of material to be stabilised
- Proposed use of the stabilised material
- Relative costs.

Cost is a particularly important factor in relation to unsealed roads. Stabilisation is therefore only worthy of consideration if it is economical when compared to all other alternatives. For unsealed roads, it is more likely to be justified at particular problem locations. Other factors that influence the choice of method of stabilisation include:

- The capabilities and experience of the construction personnel
- Availability of the equipment
- The availability of testing facilities for investigations and subsequent quality control.

The most common methods of stabilisation used in roadworks include:

- Mechanical stabilisation
- Lime stabilisation
- Cement stabilisation
- Bituminous stabilisation including emulsions
- Geotextiles
- Chemical stabilisation.

The proposed addition of clayed soil (plastic fines) to scoria as wearing course is a mechanical stabilisation. Other type of stabilisation will be discussed in the SEALING OPTIONS report.

18 Summary of actions proposed for improvement

18.1 Immediate actions

As mentioned above, many actions can be taken in the borrow pit or at the source to improve the material.

1. Sieve gravel or coral (coarse aggregate) for concrete
2. Sieve sand (fine aggregate) for concrete
3. Wash sand and/or gravel/coral if appropriate to remove salt
4. Take note of each mix proportion and behaviour of the concrete (for further adjustment)
5. Remove manually or build/buy a screen to remove particles bigger than 50 mm (can be built with old steel bars)
6. Prevent segregation in the quarry in ensuring adequate stockpiling procedures
7. Take regular samples and have them analysed by PWD lab (refers to TN04_Sampling/Testing of Borrow Pits)
8. Ensure proper operation in the field when compacting pavement materials: spread / shape / moisture / compact (refers to appendix “Control of Compaction”)
9. Look for clayey deposit on Ambae, sample and perform tests (grade, LL, PL, IP, LS)

18.2 Further actions

1. Develop an easy method to evaluate the water content in the material (refer to appendix “Possible Methods to evaluate Moisture content on-site”)

2. Help develop a quarry management system (or borrow pit inventory) including all test results for each pits) Department of Geology & Mines are currently working to feed a GIS module on the matter. Help and support may be provided
3. Analyse test results for Coronous material as pavement and revise recommendation
4. Analyse test results for Coronous material as concrete and revise recommendation
5. Analyse test results for scoria material as pavement and revise recommendation
6. Analyse test performed in clayed deposit from Ambae and perform trial in stabilising scoria with plastic fines. This was done as a research on 2 sections in Ethiopia and it showed a great improvement in the behaviour of the scoria.
7. Analyse test results for scoria material as concrete and give recommendation
8. If scoria gravel gives good test results, perform trial mixes using scoria aggregates
9. Analyse options to find the most cost-effective, realistic and applicable technique to process the material (Coronous and/or scoria), which would be accepted by the local community (refer to appendix “Material processing options”)
10. Develop Test/Check forms to record quality activities, process and results (Quality control/Quality assurance).

19 Conclusion

Vanuatu has a particular context in which it is an archipelago formed with 80 relatively small islands and therefore, they are not linked with a “main” road one to each other. They are rather isolated one to each other. This context make the use imported material and/or equipment very expensive.

Fortunately, there are satisfactory materials for construction purpose in abundance on most islands. Sometimes, the materials may not be “ideal” or “perfect” but it is affordable and acceptable for low volume roads.

Care and few sensible actions can realise properties of the local material at its best and/or improve. As most islands are relatively small, it could be very costly to have heavy equipment available and in a working state in all of them. Therefore, compromise and adapted actions are necessary.

Immediate actions and further actions are proposed to improve local materials. Those proposed actions were mainly based on the overall knowledge of the material type in general. However, as the knowledge of the specific properties of the local materials is better known, the improvement action possibilities and requirements may be refined or revised.

Coronous is a good material for base and wearing course as long as some care is taken in grading and compacting adequately. It can also be a good concrete aggregate but would probably need heavy processing (crushing, washing and sieving). Test results will be used to assess the potential of the material. Further, an economical study will be needed to evaluate the options and suitability for small-scale operation.

Scoria has a good bearing capacity but it is medium material for pavement earing course as it lacks of plastic fines. However, it can be suitable as base course when the road is sealed (bitumen or concrete). Good hope is in stabilizing scoria with plastic fines to improve it (more stable, less wear, less dust, less corrugate). The behaviour of scoria in concrete in unknown but if the gravel size has enough strength (which could be the case as the VTSSP1 use it on the Otta Seal trial), there is a possible use.

There is little evidence to suggest problems with the other local materials. Sand and coral/gravel from beach/stream for concrete would require the correct size in sieving and ensure removal of salt by washing when used in reinforced concrete. Together, they have the ability to make very good concrete.

20 APPENDICES

Appendix 1 Summary of Material Suitability

Appendix 2 Better control of Compaction

Appendix 3 Possible Methods to evaluate Moisture Content of Material on site

Appendix 4 Better Control of Concrete

Appendix 5 Quarry Materials Process Options

20.1 APPENDIX 1

20.1.1 SUMMARY of MATERIAL SUITABILITY

20.1.1.1 Knowledge and Local Experience on the use of various material

Unconsolidated natural deposits where available, has been historically used on the islands for various purposes. Most of these natural material are designated as: Coronous (or raised reef), scoria (or cinder gravel), basalt cobble, beach coral, volcanogenic and coral sand. They were and/or can be used for

	Coronous	Scoria	Cobble	Beach coral	Sand
Embankment					
Subgrade					
Subcase					
Base (if sealed)					
Wearing course					
Surfacing (Otta seal)					
Surfacing (other)					
Concrete aggregates					
Masonry					
Gabion					
Stone pitching / grouted stone					

Successfully used in the past
Good potential with some processing but need further study
Would need major process (crushing, etc) or extensive research
Not suitable

20.1.1.2 Use of Coronous

Coronous material or raised coral reef deposit is found on all islands having public roads except on Ambae and Ambrym. It can be described as a poorly consolidated rippable rock producing - moderately to well graded, irregular to angular carbonate GRAVEL with some to many cobbles of sandy plastic ’putty’ CLAY or sandy SILT. The status of the knowledge on its use is mapped in the table below.

		General comment on usage	Issues or precaution needed – Material selection	Issues or precaution needed – Construction	Proposed study
Embankment		Make suitable and stable fill.	Larger size of gravel not more than 2/3 of the thickness of the compacted layer.	Need to be shaped and compacted properly to refusal.[1]	No
Subgrade		Make a good and stable subgrade.	Not applicable	Need to be shaped and compacted properly to refusal.[2]	No
Sub base		Make a good and stable sub base (as long as the subgrade is stable).	Material with high fine content may not be stable and have low CBR. Need less than 30% fines. If too plastic, stability may decrease. Need to remove gravel larger than 53 mm and keep not more than 10% larger than 37,5 mm. May be improved by processing in the quarry. Almost all deposits suitable for “as dug” or screened sub base material.	Good construction procedure is a MUST. Cross fall of 5% to drain water, spread, shape and compact properly to refusal [2].	No
Base [1]		Can make a good and stable base			No
Base/ Wearing		Can make a good base/wearing course for low volume roads. Stable, “waterproof” and traffic resistant. Proper proportion of plastic fines will “bind” the material. “As dug” and screened materials typically compact well to form a dense interlocking structure. Some breakdown of particles.			Need to monitor the performance and to relate it with the particle characteristics. Search for option of processing in the quarry and the possible use of a small crusher
Surfacing (Otta seal)		Has been used successfully in Tonga.	Would need some processing. Screening and perhaps crushing.	Knowledge, experience and equipment also needed	Yes
Surfacing (other sealing)		Never been tried	Particles strength could be an issue		If need arise
Concrete / coarse aggregate		Currently used in batch plant in Port Vila. Also used in many islands to build houses	Need processing: screening and perhaps crushing for large volume. Need to care for fines that could stick on aggregates		Cost of processing options
Masonry		Not recommended. Need non plastic sand and fine gravel < 5mm..	Would need too much processing.		No
Gabion		Suitable but need processing	Important screening need to be done 100-200 mm needed	Some particles could be week and break down with interlocking	Cost of processing options
Stone Pitching or grouted stone		Suitable but need processing	Important screening need to be done 150-200 mm needed	Some piece could be week and break down	Cost of processing options

1 Base course for seal roads

2 Layers not exceeding 150 mm, respect OMC (± 2%), compact with heavy roller with 8 to 12 passes depending on the weight of the roller. Refusal is when an extra pass leaves no print.

20.1.1.3 Use of Scoria

Scoria or cinder gravel or volcanic cinder is found on few islands, but on Ambae and Ambrym it is the only "gravelly" material available. It can be described as a loose natural gravel – typically comprising variably graded silty sandy to very sandy angular to subangular vesicular GRAVEL with some to many cobbles (volcanic bombs) and with a lack of plastic fine.

The status of the knowledge on its use is mapped in the table below.

		General comment on usage	Issues or precaution needed – Material selection	Issues or precaution needed – Construction	Proposed study
Embankment		Make suitable and stable fill but slope should be reduce as the cohesion is low	Size of gravel larger than 2/3 of the compacted layer has to be removed	Need to be shaped and compacted properly	No
Subgrade		Make a good and stable subgrade.	Not applicable	Need to be shaped and compacted properly	No
Sub base		Make a good and stable sub base (as long as the subgrade is stable).	The grading and particle strength properties of coarse deposits may be significantly improved by crushing. The more uniformly graded fine to medium gravel deposits are typically unsuitable for use in base construction but will represent useful sources of selected subgrade fill and sub base.	Good construction procedure is a MUST. Spread, shape and compact properly to refusal [2]. Mechanical stabilization with plastic fines can greatly help.	No
Base [1]		Can make a good and stable base in lightly trafficked roads			Monitor the performance and to relate it with the particle characteristics. Processing in the quarry and the possible use of a small crusher. Perform trial in adding plastic fines
Base/ Wearing		Gives a suitable support but corrugate and wears very quickly. Considering its poor "as dug" grading, relatively low particle strength and lack of plastic fines, these materials can rate poorly when used for base/wearing course and need higher maintenance.			
Surfacing (Otta seal)		Trial performed in Ambae in 2012. Results were promising. .	Would need some processing. Screening and perhaps crushing.	Knowledge, experience and equipment also needed	Continue trial in building on experience
Surfacing (other sealing)		Never been tried			Need to know the particles strength
Concrete / coarse aggregate		No known use on Vanuatu. Used overseas in light weight concrete	Would need processing (screening and perhaps crushing)		Cost of processing options
Masonry		No known use on Vanuatu			Need to investigate the grading of fine content
Gabion		No known use on Vanuatu.	Important screening need to be done (100-200 or 150-200)	Some piece could be week and crumble	Particles strength would need to be investigate
Stone Pitching or grouted stone		Where there is scoria, there is basalt cobble which are preferred			

[1] Base course for seal roads

[2] Layers not exceeding 150 mm, respect OMC (± 2%), compact with heavy roller with 8 to 12 passes depending on the weight of the roller. Refusal is when an extra pass leaves no print.

20.1.1.4 Use of Basalt cobbles

		General comment on usage	Issues or precaution needed – Material selection	Issues or precaution needed – Construction	Proposed study
Embankment		Not applicable			
Subgrade		Not applicable			
Sub base		Not applicable			
Base [1]		Not applicable			
Base/ Wearing		Not applicable			
Surfacing (Otta seal)		Not applicable			
Surfacing (Other sealing)		Never been tried	Would need crushing. Usually good strength. Crushed basalt is known to make elongated shape.		If need arise. Would need to crush and perform various testing
Concrete / coarse aggregate		Never been tried	Would need crushing. Usually good strength. Crushed basalt is known to make elongated shape.		If need arise. Would need investigate for crushing
Masonry		No known use on Vanuatu			Need to investigate the grading of fine content
Gabion		No known use on Vanuatu.	Important screening need to be done (100-200 or 150-200)	Some piece could be week and crumble	Particles strength would need to be investigate
Stone Pitching or grouted stone		Where there is scoria, there is basalt cobble which are preferred			

[1] Base course for seal roads

20.1.1.5 Use of Beach Coral and gravel

		General comment on usage	Issues or precaution needed – Material selection	Issues or precaution needed – Construction	Proposed study
Embankment		Not applicable			
Subgrade		Not applicable			
Sub base		Not applicable			
Base [2]		Not applicable			
Base/ Wearing		Not applicable			
Surfacing (Otta seal)		May be possible, but never tried.			If need arise
Surfacing (other sealing)		Never been tried	Would need crushing. Could have a valuable strength.		If need arise. Would need to crush and perform various testing
Concrete / coarse aggregate		It is the primary source of concrete coarse aggregates on the islands. Make suitable results.	Need to be sieved and washed.		No
Masonry		Not applicable			
Gabion		Not applicable			
Stone Pitching or grouted stone					

[2] Base course for seal roads

20.1.1.6 Use of Sand (Beach and volcanogenic)

		General comment on usage	Issues or precaution needed – Material selection	Issues or precaution needed – Construction	Proposed study
Embankment		Not applicable			
Subgrade		Not applicable			
Sub base		Not applicable			
Base [2]		Not applicable			
Base/ Wearing		Not applicable			
Surfacing (Otta seal)		Not applicable			
Surfacing (other sealing)		Never been tried. Could maybe be use in sand seal.			If need arise.
Concrete / coarse aggregate		It is the primary source of concrete fine aggregate. Make suitable results.	Need to avoid fine sand. Need to be sieved and washed.		No
Masonry		Suitable for use in masonry	Need to avoid fine sand.		No
Gabion		Not applicable			
Stone Pitching or grouted stone		Suitable for use in mortar or grout	Need to avoid fine sand. Need to be sieved and washed.		No

[2] Base course for seal roads

20.2 APPENDIX 2

20.2.1 BETTER CONTROL of COMPACTION

To be used whenever pavement material is to be imported, spread, water and compact (for all roadwork including IBC, NCB and force account)

20.2.1.1 WORK SPECIFICATION

(If applicable, ensure to include the following requirement in the existing Work Specification)

- Gravel and gravel source to be approved by the supervisor prior to spreading.
- Gravel must be free of particles larger than 50 mm (remove or crushed oversize)
- Spread uniformly at the required thickness (+10% before compaction) and ensure there is no segregation
- Evaluate the initial moisture content of the material and select the amount of water to add per square meter (m^2)
- Water the material to its Optimum Moisture Content (OMC) before compacting
- Compact with at least 8 passes of approved compactor equipment or until no roller imprint on the surface can be recognised.

20.2.1.2 QUALITY CONTROL

Test / Check	Measure	Method	Frequency	Tolerance
Gravel source approved	Quarry Permit required	Check document	Each source	Na
Gravel material approved	Max. 50 mm	Visual (or sieve or tape)	Each day	± 5 mm
Spread uniformly, no segregation	Na	Visual	All	Na
Thickness of the layer	As required	Tape / gauge	Each 20 m or each spot	± 10 mm
Evaluate initial moisture content	Na	Hand test, hydrometer, speedy	Every 10 -15 m or at least 3 location	± 2 %
Add water to OMC [1]	Amount of water needed per m^2	Tape, volume of water	Each section	Na
Compact gently with NO vibration	Na	Visual	All	Na
Leave it for 2-3 h	2 - 3 h	Time	Each section	_
Ensure material at OMC	Target OMC 8-11 %	Hand test, hydrometer, speedy	Every 10 -15 m or at least 3 locations	± 2 %
Compact with roller vibrating	8-10 passes or to refusal [2]	Visual count, check imprints of roller	All	Na

[1] Check initial moisture and add amount needed to reach 12% if dry and sunny weather (10% if wet and cloudy weather)

[2] Compaction to refusal is when the compactor leaves no more imprint on the material.

Table 27. Quality Control checks

Water to add to the granular material to bring the moisture at its optimum for compaction (addition in litre of water per square meter – L / m^2)

Target Moisture: 12% (Dry and sunny weather)

Initial state	Increase in MC	Thickness of the layer to compact (mm)				
		50	**75**	**100**	**125**	**150**
Dry (± 2 %)	**+ 10**	10	15	20	25	30
Slightly Moist (± 5 %)	**+ 7**	7	10.5	14	17.5	21
Moist (± 8 %)	**+ 4**	4	6	8	10	12

Target Moisture : 10% (Wet and cloudy weather)

Initial state	Increase in MC	Thickness of the layer to compact (mm)				
		50	**75**	**100**	**125**	**150**
Dry (± 2 %)	**+ 8**	8	12	16	20	24
Slightly Moist (± 5 %)	**+ 5**	5	7.5	10	12.5	15
Moist (± 8 %)	**+ 2**	2	3	4	5	6

Table 28. Moisture Test Targets

20.3 APPENDIX 3

20.3.1 POSSIBLE METHODS TO EVALUATE MOISTURE CONTENT OF MATERIALS ON SITE

It is very important to ensure that the material is close to its Optimum Moisture Content (OMC) when compacting on site. Therefore, simple methods are proposed below.

Method	Pros	Cons	Note
Sampling and lab test	Accurate	Takes too long. No facilities on outer island	
Moisture Roll Meter (Speedy)	Accuracy ± 1% ; fast on-site result (10 min) ; Fairly easy to use (1 h training)	Need to manage equipment and supply of reagent powder. Some cost.	1
Agricultural Moisture meter	Easy and fast. Direct reading	Accuracy and durability unknown. Cost unknown.	2
Hand squeeze test	Fast and no cost	Not accurate. Very subjective.	3

Table 29. Evaluate Moisture content

1. Four Moisture Roll Meters were bought during VTSP1. Reagent lost. Need to be supplied.
2. More research should be done regarding this method. Could be promising.
3. Experience and much "calibration" with known moisture content to ensure reasonable estimates. Also depend greatly on the fines content.

Out of those methods, the **Moisture Roll Meter** has proven its efficiency and its use is recommended.

However, an interesting suggestion as to use an **Agricultural Moisture Meter** came late in the study. Considering the low cost and simplicity of the equipment, this method would definitely need further research.

20.4 APPENDIX 4

20.4.1 BETTER CONTROL of CONCRETE

To be used whenever for all roadwork including IBC, NCB and force account

20.4.1.1 WORK SPECIFICATION

(Ensure to include the following requirement in the existing Work Specification)

- Sand for concrete mixing shall be clean river/beach sand free from dust, salt, lumps, soft or flaky particles or organic
- Aggregates shall be well graded and free from organic material and salt
- Water shall be clean, free of oil, free of salt and shall not contain any impurity that may affect concrete durability
- The water / cement ratio shall not be more than 0.5
- Compact of vibrate concrete (care must be taken regarding segregation)
- Cast element shall be protected from direct sunshine for 14 days
- Concrete slabs and walls crowns shall be kept wet for 7 days
- No concrete shall be cast unless the formwork, reinforcement and hardcore bed have been checked and approved by the supervisor

Test / Check	Measure	Method	Frequency	Tolerance
Sand and Gravel/Coral source approved	Quarry Permits required	Check document	Each source	Na
Sand material approved	5 mm	Visual (or sieve)	Each day	Na
Gravel/Coral material approved	5 – 20 mm (unless instructed)	Visual (or sieve or tape)	Each day	+ 5 mm
Compliance with mix design[1]	Quantity	Visual	Each batch	Na
Water/cement ratio	Max 0.5	Check	Each batch	
Time of mixing	2 min	Watch	Each batch	
Time for pouring	45 min	Watch	Each batch	+10 min
Workability (if required)	Normally 80-100 mm	Slump cone	As required	-
No segregation	Na	Visual	All	Na
Time for wet curing	7 days	Visual	Daily	Na
Quality of cast concrete	No honey combs / No cracks	Visual	All	Na
Concrete strength evaluation	As specified, 15, 20 or 25MPa	Schmidt Hammer	When needed	

[1] Unless otherwise specified, Concrete Mix by volume should be as follow

- Class 10 MPa: 1:4:4
- Class 15 MPa: 1:3:6
- Class 20 MPa: 1:2:4
- Class 25 MPa: 1:1.5:2.5

Table 30. Requirement for concrete mix

20.5 APPENDIX 5

20.5.1 QUARRY MATERIAL PROCESS OPTIONS

Pavement material is actually the principal material extracted from quarries on outer islands. It has to be processed as the material should be free from particles bigger than 50 mm. This is addressed in options 1 and 2.

Concrete aggregates and cobbles come naturally from sources like beaches and streambeds. This type of extraction is not well accepted from an environmental point of view and therefore, opportunity to extract them from a Coronous/scoria quarry need to be evaluated. In addition, from an environmental point of view, some islands may not agree to remove beach/stream material.

Therefore, technical options are given below. However, all islands would need a small-scale operation, which can be itinerant between islands. An economical evaluation will be essential to complete the study.

Size definition

MM	0.005	0.075	4.75	76	300
CLAY	SILT	SAND	GRAVEL	COBBLE	BOULDER

Range of Material Size Needed

Pavement materials	Max. 50 mm
Concrete aggregates: min 5 / max 20 mm .	5-20
Cobbles for gabion / grouted stone : min 100 mm / max 200 mm .	100-200

Table 31. Size definition of material

Option	Process	Local work	Machinery	Issues
1	- Try to remove > 50 mm as much as possible with the excavator - Remove more > 50 mm with people when stockpiling - When reloading, remove bigger pieces - On site, have site workers remove big gravel before compacting	Give work to 2 MD/100m3 Removing big part on 50 m3 / d PAVEMENT MATERIAL ONLY. Ø < 50 MM	Use of excavator or loader. Move only once	Unused material > 50 mm (waste)
2	- Try to remove > 50 mm as much as possible with the excavator - Pass material through a grizzly (wire screen used to separate larger from smaller) (50 mm) - Stockpile	No manual workers PAVEMENT MATERIAL ONLY. Ø < 50 MM	Use of excavator or loader. Move twice	Unused material > 50 mm (waste)
3	- Try to remove > 50 mm as much as possible with the excavator - Pass material unto a double grizzly if possible (200 and 50) - Stockpile < 50 mm - Have workers manually crush gravel 50-100 to incorporate onto pavement material < 50 mm - Stockpile the rest 100-200 for gabion/grouted stone, etc.	Give work to 75 MD/100m3 Crushing 0,75 m3/d - PAVEMENT MATERIAL, Ø < 50 MM + - COBBLE 100-200	Use of excavator or loader. Move twice for pavement/cobbles	Unused material > 200 mm (waste)
4	- Could sieve natural material to get the pavement material - The oversize material can be crushed manually of with crusher to make concrete aggregates.	- PAVEMENT MATERIAL < 50 MM +		
5	- Use of big sieve or grizzly	- COARSE CONCRETE AGGREGATES 5 -20 +		

Grizzly can be bought for a few thousands dollars or can be homemade. Small crusher on tracks can worth around 80,000$ (less if not on tracks)

Table 32. Process of gravel selection

Further technical and economical research needs to be done of various options available.

Figure 46. Pictures from a worksite. 1. Grizzly bar; 2. Sorting gravel; 3. Shifting gravel with an Excavator; 4. Gravel Sieve

PART C

21 PART C - SCREENING INFRASTRUCTURE FOR CLIMATE RESILIENCE

22 Philosophy of Design

22.1 A climate resilient road

"A climate resilient road correctly designed now is no different to a climate resilient road in 2050." [3]

The figure below shows what can be considered a "good" design for a climate resilient road. In an "ideal world" this is the design that would be followed. In Vanuatu the situation is far from ideal.

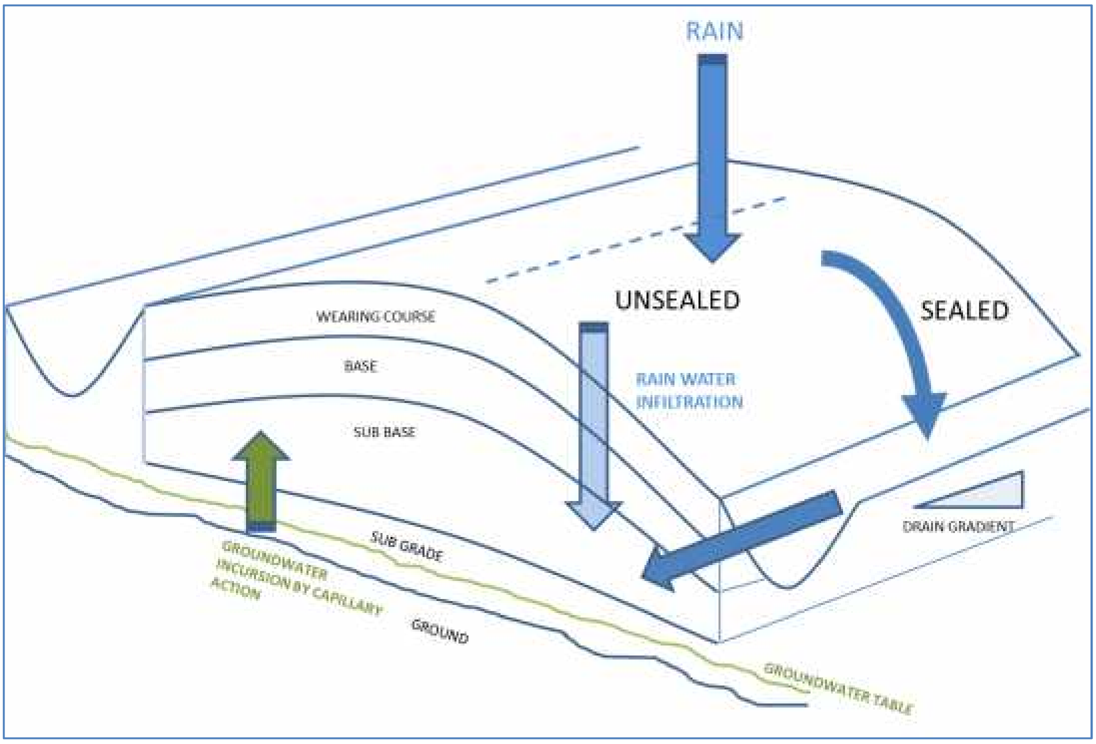


Figure 47. Conventional Design of Climate Resilient Road

22.2 Maintenance

There are three types of maintenance followed by MIPU PWD :

- Routine or periodic maintenance - repairing potholes, clearing blocked drains, fixing embankments about to collapse
- Emergency - road damaged or has collapsed
- Planned upgrading

It is generally accepted that "$1 of preventive maintenance equals $5 of repairs".[4]

[3] World Bank "Making Transport Climate Resilient" Country Report: Ethiopia, August 2010
[4] Infrastructure Maintenance in the Pacific, Pacific Region Infrastructure Facility, 2013

22.3 Interventions
There are two kinds of intervention:- response to failure; and planned.

- If response to failure – must “build back better”
- If planned work then works are rehabilitation of existing roads

22.4 New Roads
In Vanuatu nearly all roads are ring roads around the islands. There are some exceptions - Tanna has a cross island road; Ambae has some inland roads.

For connectivity purposes a new road may be justified. However, it is a long process involving land acquisition. Even “new” roads are usually built on existing paths or tracks which people have established. Main emphasis is on rehabilitating existing road networks to a workable condition.

A special case is coastal erosion. Moving the road a short distance has been used on Ambae to avoid coatal erosion but it is is a “quick fix’.

One must make a long term strategic choice :

1) Move road a significant distance inland. Given that some areas in Vanuatu are experiencing coastal erosion approaching a rate of 1 metre per year a minimum distance of 100 metres would be appropriate.
2) Use natural defences for example building the new road behind mangroves which provide excellent sea defences
3) Build a sea wall. This is the most expensive option and may not be economically justifiable

The priority task now is to :

- Modify ongoing works if possible.
- Influence new works, both rehabilitation of existing, and new construction. This should apply to roads and coastal infrastructure, such as wharves or jetties.

22.5 Constraints
There are many recognised constraints on road rehabilitation at the moment. These include (but are not limited to) :

- budget and financing
- materials not fit for purpose
- equipment
- labour
- Contractor’s abilities.

These factors are exacerbated by :

- Lack of consistent standards
- Inadequate design not recognising climate change impacts

- Lack of quality control on winning stockpiling and placement of materials
- Fundamental design parameters missing in construction. Drainage is a major factor. This applies to lateral drains and cross drainage frequently being missing.
- Roads constructed at grade not elevated on embankments.
- No contouring of roads to give cross for drainage.
- Lack of indication of safe depths for pedestrians or vehicles.[5]

All of these issues are addressed in this manual.

22.6 The challenge

The challenge is to produce climate resilient roads which are "sustainable". That is to say, they exist for the full duration of their intended design life (20 years). Roads currently being maintained in Vanuatu are far below the structural integrity and design needed to be climate resilient. The "Standard road" design currently being adopted must be improved even if thus falls short of the "ideal" situation. This is shown in the diagram below.

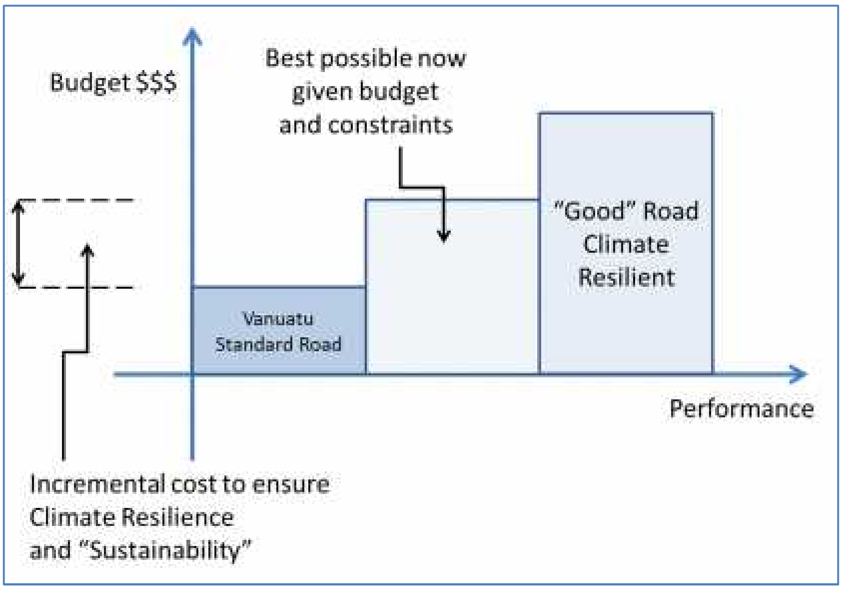


Figure 48. Performance versus budget of Climate Resilient Roads

23 Performance

23.1 Connectivity

The performance of a road can be defined in terms of its connectivity. Ideally a road should be an all-weather road, passable in all weathers, including extreme weather events.

In Vanuatu, at present, this is an unrealistic expectation. Given the present constraints it must be accepted that roads may be closed at times. If this closure time is limited to a few hours, this should be acceptable to the community.

[5] There are reports in newspapers in Vanuatu of people and vehicles being swept away when trying to cross roads in flood.

23.2 Climate Resilience

If a road is permitted to be closed for a short period of time due to flooding, it must be structurally sound when the floodwaters recede. This is “Climate Resilience”.

23.3 Fit for Purpose

The road design and construction must be fit for purpose. This is directly related to the number and type of vehicles using the road. Economic considerations normally preclude overdesign. Given the low number of vehicles using roads in Vanuatu, and the low axle weights, in most cases roads will be unsealed.

23.4 Extreme weather events and over design

Notwithstanding the points made above, roads should be designed to withstand extreme weather events. This may require some overdesign (and increased costs) now but this is offset against potentially higher costs avoided later.

23.5 Do Nothing - Allowed to Fail

One scenario is to allow a road to fail structurally if there is confidence that it can be repaired quickly. This requires skilled labour and materials to be available locally. This is an option but is contrary to Resilience and is not encouraged as a design basis.

23.6 Existence value

In many cases it is hard to justify expenditure on roads based on present and future traffic flows. Conventional economic appraisal would return a negative value. However roads perform many functions other than direct vehicular access. There are social and economic spin-off benefits in having communities interconnected: access to schools, hospitals, markets, jobs; emergency response to accidents; disaster response to major incidents; provision of utilities such as electricity, telephone, internet connections, gas; job opportunities for the workforce and generation of a local revenue from tourism.

In this manual it is not relevant to consider further economic justification for road rehabilitation. If a road exists it should be passable. The existence of a road is sufficient self-justification in its own right.

23.7 Use of Roads for Emergency Services

A key usage of roads is to provide access routes for emergency service first responders. In an ideal world that requires a road to be open 24/7/365. As indicated above in Vanuatu at the moment this is not practicable. Under the present constraints roads should not be relied upon as a means of access in emergency situations under worst case scenarios. Other alternatives must be sought.

23.8 Alternative Alignments

As referred to above if road closure cannot be avoided then an alternative route should be identified, if it exists. Even if it involves longer travel time it will still provide an alternative route in a medical emergency or for disaster relief.

23.9 Pedestrian Bridges

Provision for emergency response is a key consideration. If temporary road closure for vehicles is anticipated due to flooding a combination of a pedestrian bridge in the vicinity of a stream crossing may be viable.

If a road is not passable to vehicles, then it is even more hazardous for pedestrians to attempt to cross and they should be discouraged from doing so. Signage (to be discussed later) will act as a warning but a footbridge will still allow connectivity in an emergency without entailing excessive additional cost.

UNDP are currently preparing a project V-CAP (budget US$ 6 million for infrastructure) for the VTSSP2 islands which incorporates foot bridges. VTSSP2 should liaise with V-CAP consultants to ensure footbridges are provided adjacent to the most vulnerable road crossings. Such bridges do not have to be immediately adjacent to the road-stream crossing but can be conveniently located upstream or downstream.

24 Main Climate Resilience Considerations

The main considerations for climate resilient infrastructure are vulnerability to:

- Sea level rise. This is currently measured to be 6 mm per year throughout Vanuatu and this will probably continue at, or around, this rate in the future.
- Time horizon. Due to the permanent nature of coastal infrastructure such as walls or jetties, a life cycle of 50 years should be considered. For coastal roads a life cycle of at least 20 years should be considered.
- Storm surges. Storm surges cause overtopping of coastal roads. Wave heights are driven by wind speed and “fetch” so are hard to predict but any locations currently experiencing flooding during storms will experience more severe events in the future.
- Rainfall will become more intense, of shorter duration but may happen more often.
- Temperatures will increase. Longer periods of drought can be expected. Anticipate less water availability. Also a 1^{o}C rise in temperature may cause a 10% increase in precipitation.

25 Preliminary Screening

25.1 Vulnerable Areas Screening

To identify vulnerable areas one should check if roads are in areas of :

- Close proximity to shoreline where erosion is self-evident.
- Close proximity to shoreline where overtopping by storm waves is known to occur.
- Flat areas prone to flooding which take long time to dry out.
- Steep gradient > 10%.
- Road below steep slopes prone to landslides.
- Roads crossing water courses.

Reference should be made to the vulnerability maps produced under the CRRS project.

25.2 Priority Screening

To identify priority areas one should check if :

- Road close to hospitals, clinics.
- Road links centres of population.
- Road close to Airport.
- Road close to port, shipping wharf, jetty.
- Road close to schools.

25.3 Priorities and Scheduling

Notwithstanding the points raised above, budgets and cash flow limitations require the setting of priorities. Priorities for road rehabilitation with respect to climate change induced effects should take note of:

- Proximity to eroding shorelines when the sea is already noticeably moving inland
- Coastlines which are gently shelving and exposed to sea level rise
- Coastlines which are not naturally sheltered by bays and promontories and are exposed to storm surges, high tides and wave overtopping.
- Roads which lie at the lowest point of a natural catchment “bowl” with no exit drainage point and so will flood in heavy rain, and remain inundated for lengthy periods of time.
- Roads which cross a dry stream bed and lie in an extended catchment, so making them vulnerable to flash floods.
- Roads which cross a wet stream bed with an existing flow which is known to flood.
- Roads climbing an extreme gradient.
- Roads which have overhanging steep slopes above them making them vulnerable to landslides falling on the roads.
- Roads overhanging a stream bed which is undermining the road by scouring.
- Roads in areas of potential natural hazards for example volcanoes, tsunami.
- Coastal infrastructure such as jetties having insufficient free board and so vulnerable to extreme tide events.
- Roads subject to inundation and high social and economic value for example access to airport, connection between hospital and community.

Such priority roads will be more exposed to climate change impacts in the future.

26 Screening Methodology of Road Rehabilitation

26.1 Checklists

The items give in Section 25.3 above should be regarded as a “Checklist” for PWD to use in preliminary screening of climate change aspects of road design and construction. A screening methodology with proposed solutions is given in text form below. Roads Located Near the Coastal Shoreline.

Check for wave overtopping:

- Road located within 50 m of coastline - slightly vulnerable.
- Road within 20 m of coastline - moderately vulnerable.

- Road within 10 m of coastline - highly vulnerable.

Check for coastal erosion: visual evidence of beach retreat / sea advance

- Loss of trees.
- Tree stumps in sea.
- Interview local residents. Ask about situation 10, 20 years ago.

Figure 49. Evidence of Coastal Erosion

Although coastal erosion is not necessarily attributable to climate change its makes coast lines more vulnerable to sea level rise and wave overtopping.

Figure 50. Wave Run Up and Over topping

Mitigation:

- Realign inshore. Do not make minor re-alignments for example 10 m. Make major move, 100 - 200m inland.
- Raise road height above level of inundation by at least 0.5 m.
- If road raised on embankment, incorporate pipe culverts for cross drainage to allow water drainage back to sea.
- Provide Beach protection. Place boulders, wire mesh gabions, or textile mesh gabions to

form seawall on beach side of road. Provide concrete vertical seawall if funds allow.

- Select alignment to exploit natural protection such as mangroves
- Check local residents are not removing mangroves for other purposes
- Determine highest astronomical tide (HAT) from hydrographic charts, tide tables for nearest port or highest high tide recorded. Check with MGHD.
- Check for tide gauge on wharf
- for projections 50 years into future; assume SLR = 0.5m
- Set freeboard (height above sea level) at 0.5 m.
- Take HAT + SLR + 0.5 as height of upper surface of platform.


Figure 51. Wharf with low freeboard at high tide. Tide Gauge

26.2 Roads on Flat Gradient.
Check for:

- Crossfall. Surface of the road should have slope of 4% to 6% from crown of road to shoulders. Alternatively allow slope of 3% from crown of road to carriageway edges and 4% to 6% across shoulders (3% equals one in 40 gradient).
- Compacting of surface must be effective during construction to ensure sealing of wearing course.
- Lateral drains should be installed alongside road. Make sure drains have slope > 0.3% to be self-cleaning.
- Lift Road on embankment to avoid upwards ingress of moisture by capillary action from water table and sideways ingress from standing water.

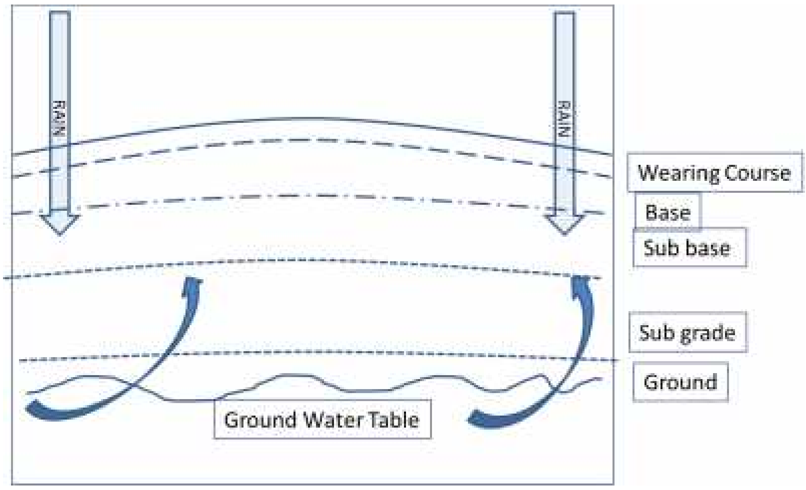


Figure 52. Moisture ingress from Water Table

Mitigation :

- Use material alongside road for embankment and create drains.
- Line drains with vegetation, short grasses.
- Provide cross drainage at least once in every 500 meters.
- If no embankment then increase subgrade from 75/100 mm to 150 mm.

26.3 Roads on steep gradient.

Check for :

- Steep inclines
- Soil and muddy surface
- Lack of drainage
- Not passable in wet weather
- Concrete strips

Mitigation :

- Use concrete across full width of road.
- Ensure longitudinal side drains.
- Direct the drainage flow to watercourse.
- Do not allow to discharge to non-draining area.
- Concrete strips save money but can lead to rutting.
- If strips used continue up full incline, do not stop halfway up.
- Continue concrete up full height of road.

Figure 53. Concrete strips

Figure 54. Vulnerable steep muddy road

Figure 54(A). Climate resilient road

27 Climate Resilience

27.1 Remedial Measures

If the above screening identifies weaknesses in the design then remedial measures must be considered and incorporated. A good road design is climate resilient and if the measures described in the earlier sections of this manual are followed than few problems should be encountered.

However, extreme weather events, such as very heavy rainfall, may exceed the normal design parameters and this must be allowed for in the chosen design. A balance must be struck between financial considerations and resilience.

Although the drainage system may be overloaded and the road temporarily unpassable, if the road remains undamaged after the event, then its construction is acceptable.

The following sections highlight construction measures presented previously in this manual as good design and construction techniques. Their inclusion is necessary for a good design. Their inclusion is essential for a Climate Resilient road.

27.2 Crossfall

27.2.1 Lack of adequate crossfall

Lack of adequate crossfall is considered to be the most common defect in unsealed roads as this does not provide adequate drainage of the road surface. As flat roads are most prone to potholes forming, if the shoulder has adequate crossfall there should be no evidence of potholes on the road surface.

Sufficient crossfall should be provided to allow the easy run off of water from the surface and to prevent potholes developing. If too steep crossfall is applied, the surface material will be prone to scouring and erosion.

For ease of construction and maintenance operations, shoulders can have the same surface crossfall as the traffic lanes for unsealed roads so that they may be constructed and maintained in the same manner.

27.2.2 Type of Crossfall

The crossfall which should be used depends on the local conditions and material properties. Crossfalls in the range of 4-6% are appropriate. In practice it is recommended that the road crossfall be initially constructed at 6% as over time it will flatten to around 4%. In terms of fall from the crown to the edge of the roadway the values for different crossfalls and road widths are given in Table 12.

Crossfall	Road width 4 m	5 m	6 m	8 m
4%	80 mm	100 mm	120 mm	160 mm
5%	100 mm	120 mm	150 mm	200 mm
6%	120 mm	150 mm	180 mm	240 mm

Table 34. Crossfalls and road widths

The correct shape of a two-lane road is shown in this figure.

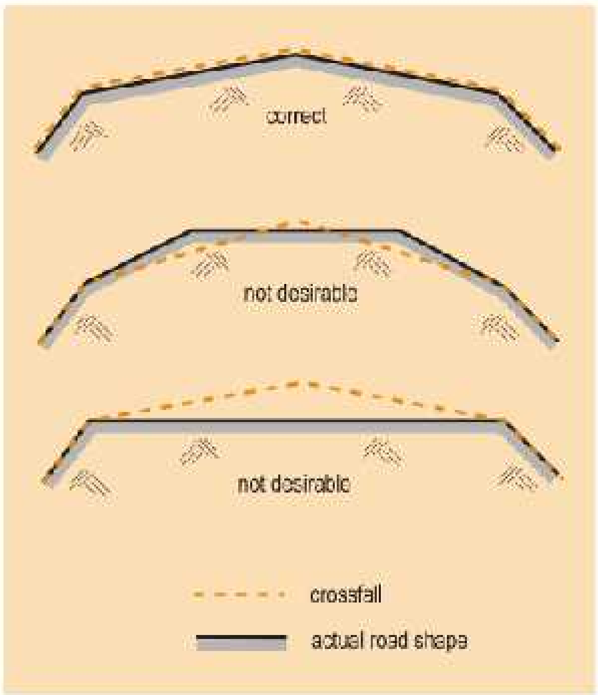


Figure 55. Correct shape of a two-lane road

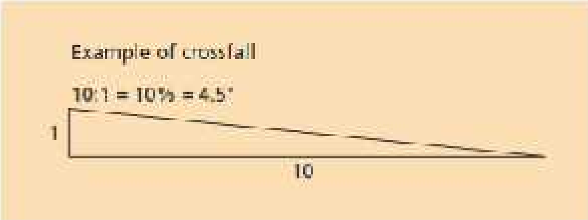
For single-lane carriageways, it may be best to have a single crossfall for ease of grading during regular maintenance.

27.2.3 Measuring Slopes and Gradients

Gradient measurement can be expressed in various ways as listed below:

- By **ratio** (**slope** or **gradient**) such as 10:1 (10 refers to the horizontal H and 1 refers to vertical V distance m/m)
- By **percentage** such as 10% (vertical divided by horizontal distance and multiplied by 100%)
- By **degrees**.

It is important not to mix up units. For example, slopes can be stated as 10:1 = 10% = 4.5°



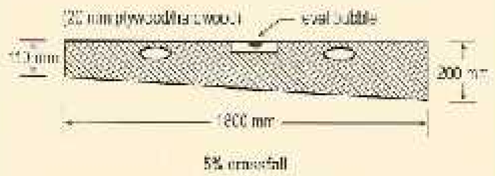
Ratio values m/m (H:V)*	Percentage values	Degrees values
100:3	3%	1.35°
100:4	4%	1.80°
100:5	5%	2.25°
100:6	6%	2.70°
100:7	7%	3.15°
100:8	8%	3.60°
100:9	9%	4.05°
100:10	10%	4.50°

Figure 56. Ways to specifying Crossfall

Crossfalls in the field can be measured in various ways. Some graders have levelling devices that provide the crossfall of the road. Care should be taken that the rear wheels on which the level is based are on the actual roadway being measured and the tyres are all correctly inflated.

A 'smart level' can be used which provides a digital readout, in either percentage values or degrees, of the actual crossfall of the road being measured. An alternative is to use a camber board which is cut to the required crossfall and has a spirit level on top to show when the desired crossfall is achieved (Figure 57).

Use of a smart level to measure road crossfall which provides a digital readout in either percentages or degrees.



Use of a specially made up camber board for a given crossfall.

Figure 57. Ways of Measuring Crossfall

Figure above shows use of a smart level to measure road crossfall which provides a digital readout in either percentages or degrees.

Smartphones can be loaded with Apps to measure inclination. These can be placed on a straight edge on the road.

Hand held inclinometers can be used to measure longitudinal road gradients, crossfall and stream gradient which occur at right angles to a stream flow.

27.3 Drainage

27.3.1 Importance of Drainage

The importance of drainage cannot be over-emphasised.

In extreme weather events, drainage is the single most important factor in Climate Resilient Roads. Drainage provision should always account for three components:

- water falling onto the road surface (provision of crossfalls and side drains)
- water approaching the road on the high side (provision of catch bank drain)
- water from below the road due to high watertable or capillary action (provision of subsoil drains or elevated formation).

These components are illustrated in Figure 58.

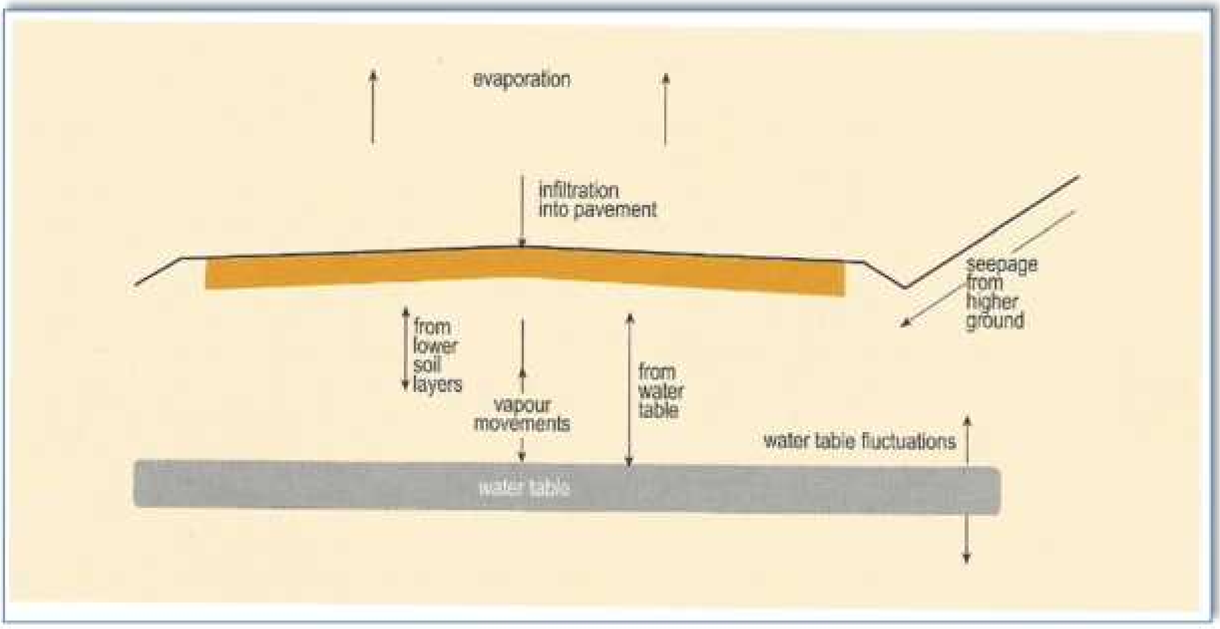


Figure 58. Three Components of road drainage

The methods employed to account for the three key drainage components are:

- Water that falls onto the road surface must be shed off as quickly as possible by the use of a crowned crossfall of 4-6% on straight sections.
- Water flows approaching a road from the higher adjoining countryside must be intercepted and prevented from flowing toward the road by catch drains or banks, diverted into natural watercourses and directed across the road by suitable culverts/floodways.
- Water collected alongside the road must be drained away from the road as soon as possible by the use of deep table drains to intercept water.

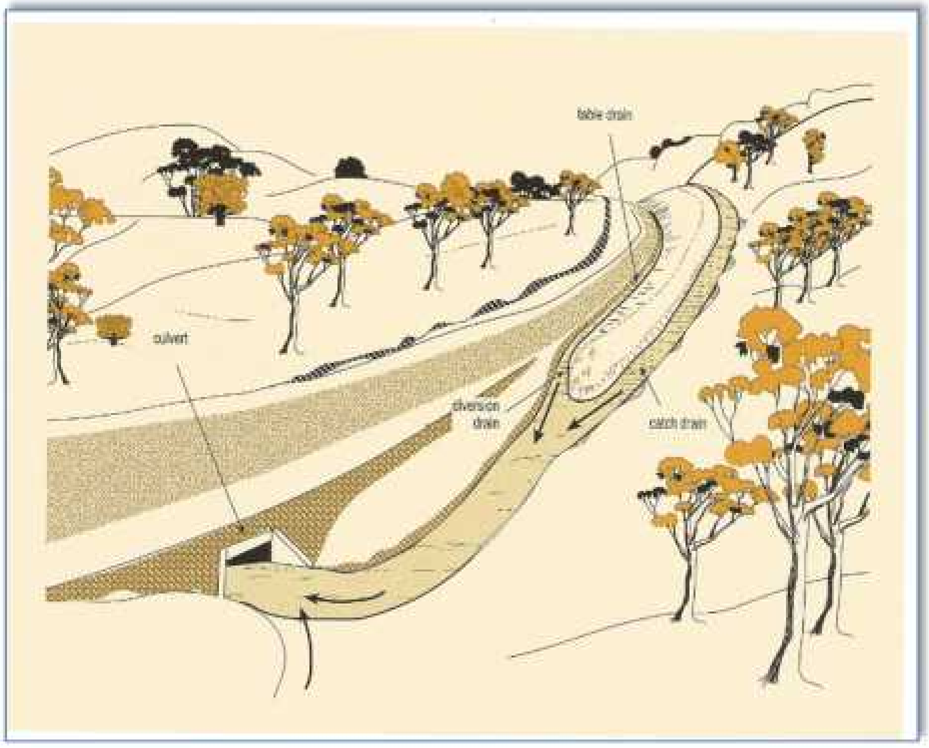


Figure 59. Schematic road drainage system

27.3.2 Key Drainage Factors in Unsealed Roads

Two factors make drainage of higher importance in unsealed roads than in sealed roads.

- Firstly, the materials used in low-volume unsealed roads tend to be of lower quality than those used in sealed roads and are more likely to be susceptible to water damage.
- Secondly, due to the lack of a seal, the combination of traffic and water is able to erode the pavement structure much more easily and do more damage than for sealed roads.

Drainage for unsealed roads falls into two groups: surface and subsurface. The purpose of surface drainage is to remove water that falls on the road surface and to protect the road from water which falls on the surrounding areas. Subsurface drainage protects the pavement against water that has entered through the road surface, and against subsurface water that enters from surrounding areas or the watertable.

Key Principles are :

- ***Keep the water off the road by having a crossfall of between 4-6 % and the road built to a crown.***
- ***Take the water away from the road as quickly as possible by having good table drains, mitre and cross drains.***
- ***Keep the water from reaching the road by having catch banks***.

The **importance of drainage must always** be emphasised.

27.3.3 Lateral drains/cross drains.
These should be designed for 1: 2 year event.

Assume the following.

- Rainfall equals 60 mm/hour; 260 mm/day (now)
- Calculate drain size based on local run-off area.
- Make gradient of lateral drains greater than 0.3%.
- Lateral drains must drain to common discharge point.
- Cross drains gradient follows natural gradient of slope at right angles to road direction.

If necessary refer to the Quick Method for culvert calculation given in Section 8.16.9.

27.3.4 Slope stabilisation.
Slope stabilisation can be an issue both above and below the road.

- Check for unsound slopes above road.
- Check for deforestation.
- Check for evidence of slope collapse.

If necessary consider :

- Cut and slope stabilisation techniques
- Cut off drains above the road section
- Energy dissipation below the road

27.4 Roads crossing Streams.

27.4.1 Methodology for calculating flood height across a drift
Where it is known that a drift will carry a flow the flood height can be calcuated. This requires use of the Manifold GIS files and the EXCEL Spreadsheet. Manifold will give the Catchment Area, and Fall across the catchment. EXCEL will give the flood height.

- Adopt a design standard now of 1 in 2 year event. This is a rainfall of 60mm /hour or 250mm per day.
- Assume rainfall is same all over Vanuatu.
- Calculate for a 1 in 10 year event now. This is a rainfall of 100 mm/hour or 400 mm / day.
- Check there is no apparent deforestation on the slope above the road surface. The model assumes heavy vegetation everywhere.
- The model is based on a simplified (by the consultants) version of the rational method. Heavy vegetation and steep slopes are assumed throughout Vanuatu.

Figure 59. Drift under flowing water

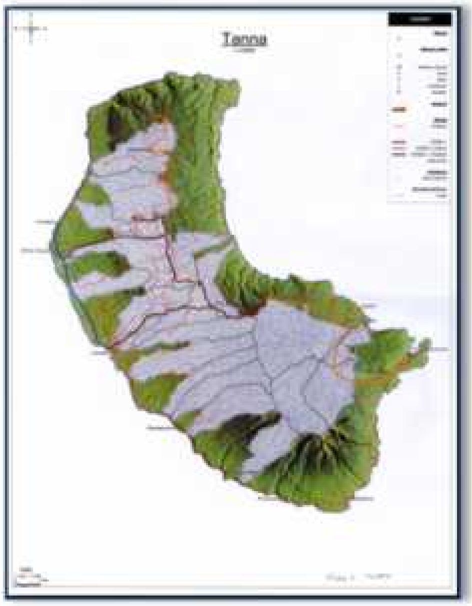


Figure 60. Catchment areas

27.4.2 Procedure

- Identify the location of a stream crossing.
- Determine the GPS coordinates of the intersection of the stream and the road. Use latitude and longitude. Not UTM. If you use UTM draw attention to this.(as the "*page number*" must be stated.)
- Measure the length of the drift along the centre line of the road.
- Access the Manifold GIS "Map '*island-name*'" and enter GPS coordinates.
- Identify the catchment
- Measure the catchment length, fall and area.
- Enter these data into EXCEL spreadsheet.
- For selected return period calculate flows.
- Enter length of drift and set flows for differing return periods (2 years, 5, 10, 20, 50, 100) to obtain likely height of the Flood (H_F)
- Compare with standard
- H_F less than 150mm = non-hazardous for pedestrians.
- 150mm < H_F < 300 mm = hazardous for pedestrians - nonhazardous for vehicles.
- H_F > 300mm = hazardous for vehicles - all forms of crossing prohibited.

[*At this point refer to the Manifold GIS files and the EXCEL Spreadsheet*]

The procedure s shown in graphic form below.

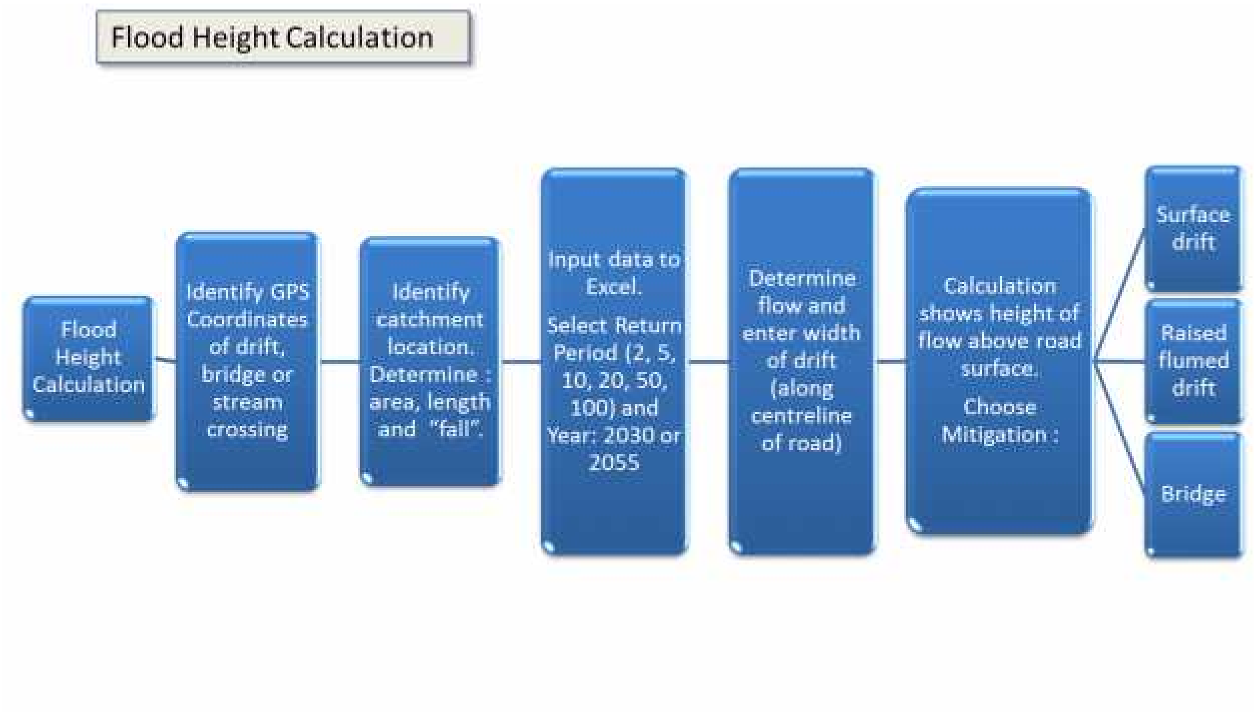


Figure 61. Flow Chart for calculating height of flood over drift

A screen shot of the EXCEL file is shown below. Varying the length of the drift will alter the flood height and this, combined with the selection of various Return Periods, will allow "What-if" Scenarios to be simulated.

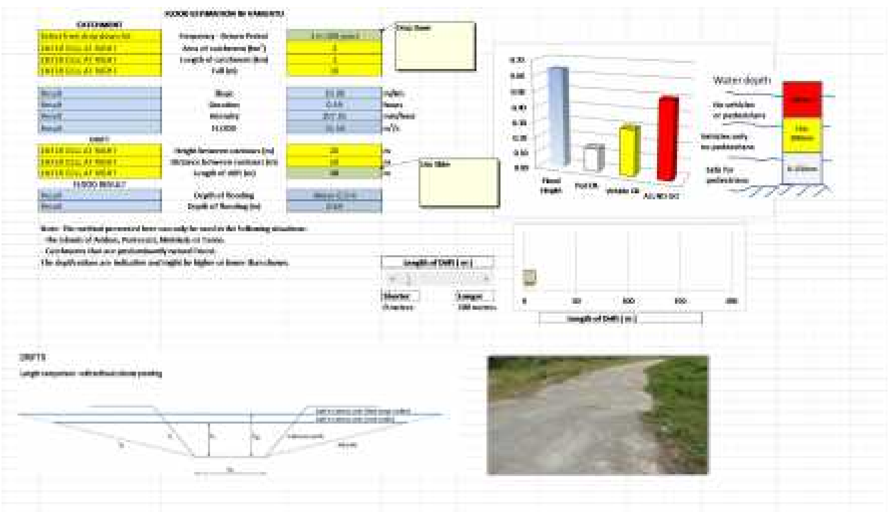


Figure 62. Screen shot of the EXCEL file

Having determined the flood height one can assess possibility of an extreme weather event rendering the crossing not passable. For this, one should refer to the safe crossing heights desribed below.

If the road is designated a priority road, but a vehicular bridge crossing cannot be justified, then then the provision of a pedestrian footbridge can be considered. This methodology will permit calculation of the needed height of a bridge crossing allowing a safety factor for extreme weather events.

28 Safety in Low-water Crossings

28.1 Level of Service

Whilst the aim of climate resilience is to produce all-weather roads which remain open 24/365 this is unlikely to be attained at present. Indeed experience shows that even in highly developed economies this level is never actually reached.

If it is accepted that the road may be blocked by flooding for a certain period then it must also be accepted that person will attempt to cross. Safety considerations should be taken into account and if necessary pedestrian footbridhes should be provided.

28.2 Safety Criteria

The use of drifts for flood management introduces the risk that pedestrians and vehicles could be swept away. There were in fact reports of both of these happening in the past. It is suggested that the aim should be to minimise this risk for the mean annual flood and to allow potential users, pedestrians or drivers, to assess the risk.

The following table gives figures for safe water heights, velocities and the cross product in still and flowing waters. In still water modern vehicles, which are more water-tight and buoyant than older vehicles, are more prone to buoyancy and flotation. In fast moving waters the risk is higher and so the safe depth is lower. In extreme weather events the risks associated with attempting to cross flowing streams will increase.

Table 35 – Proposed DRAFT INTERIM criteria for stationary vehicle stability

Class of vehicle	Length (m)	Kerb weight (kg)	Ground clearance (m)	Limiting still water depth[6]	Limiting high velocity flow depth[7]	Limiting velocity[8]	Equation of stability[9]
Small passenger	4.3	1250	0.12	0.3	0.10	3.0	DV <= 0.30
Large passenger	4.3	1250	0.12	0.4	0.15	3.0	DV <= 0.45
Large 4WD	4.5	2000	0.22	0.5	0.29	3.0	DV <= 0.60

For pedestrians a safe depth-velocity product is 0.4 ms^{-1}. These guidelines are presented graphically below.

[6] At velocity = 0 ms-1
[7] at velocity = 3ms-1
[8] at low depth
[9] DV is Depth x Velocity

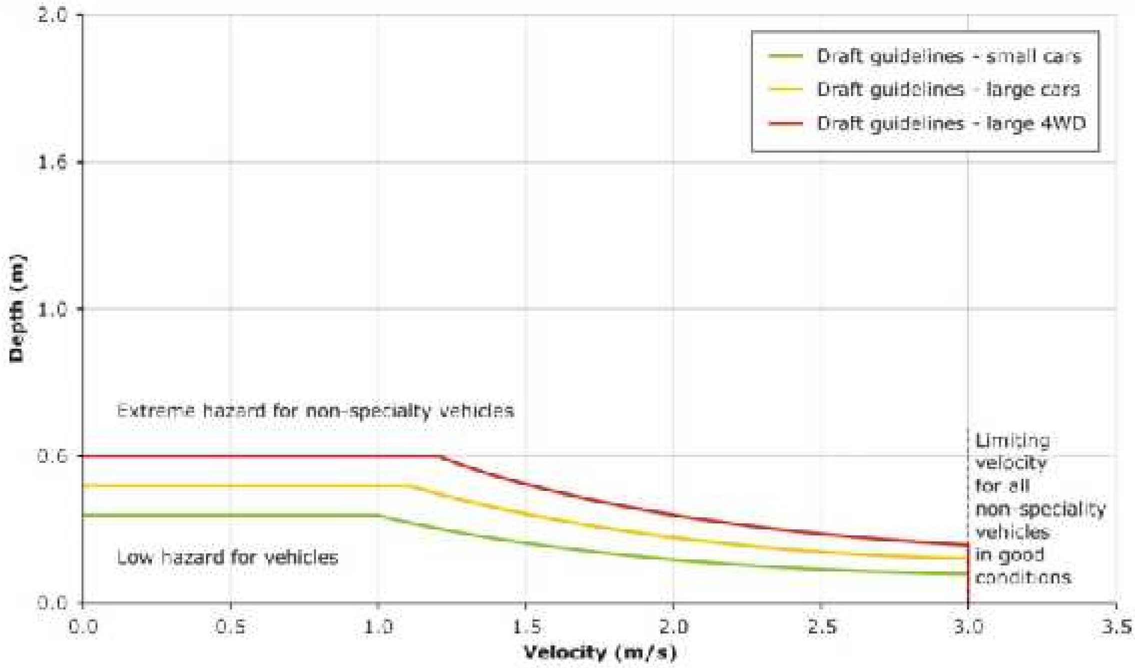


Figure 63 - Thresholds for Vehicle Stability in Floods (after Shand et al 2011)

The Automobile Association in the UK give guidance to drivers for flooding condition and suggest that a flood of 0.3m could move a car and 0.6 m could float a car. They also give a figure of 0.15 m as the safe limit for pedestrians.

Safety criteria for people stability are recommended for all flood hazard assessments where the stability of people in flood flows is relevant.

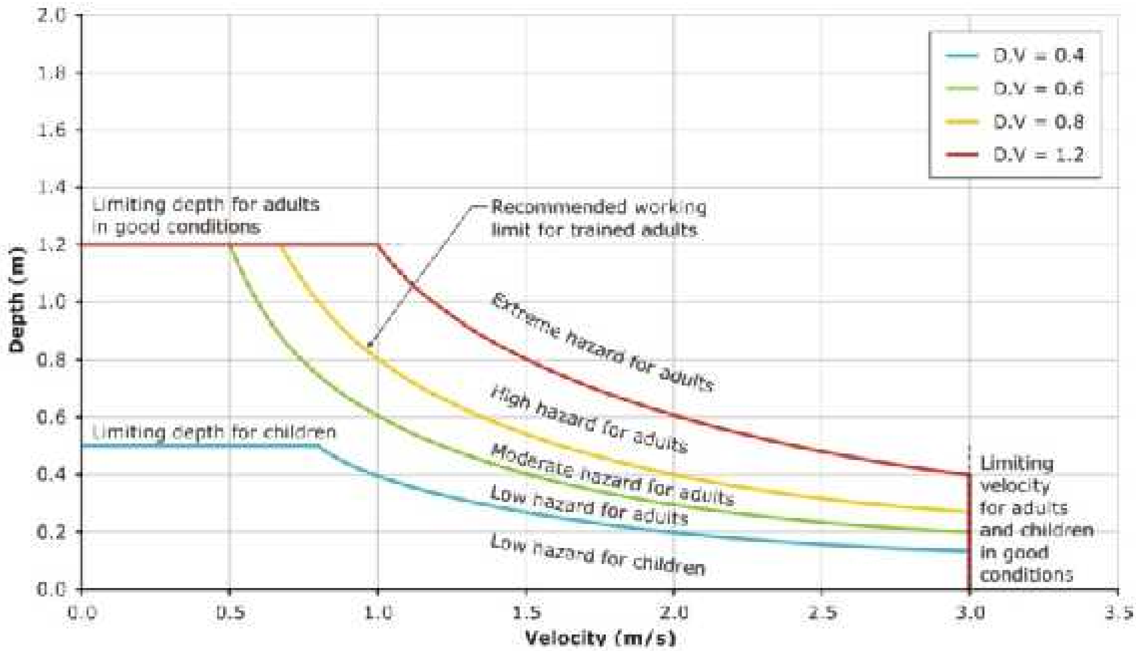
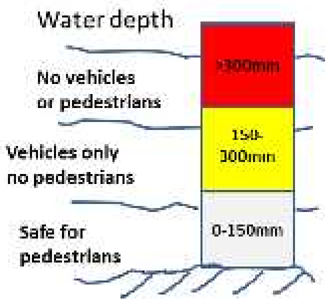


Figure 64 - Thresholds for People Stability in Floods (after Cox et al 2011)

It is not of course realistic to expect pedestrians or drivers to estimate the flow velocity and depth and act accordingly. What is done in some countries is to use painted marker posts. For example, if you can see the lower white part it is safe to cross but if you can only see the red upper part it is not safe. This may require a public awareness campaign so that travellers understand the significance of the signage.

It is essential to erect guide posts and flood gauges so that the edges of the causeway are defined and water depth can be determined.



On some drifts concrete blocks are used on the downstream side of drifts. These help to prevent vehicles being washed downstream and, if made to appropriate height could be used for warning – if one can see them it is safe to cross – if one cannot, it dangerous.

Figure 65 – Warning signage in event of flood

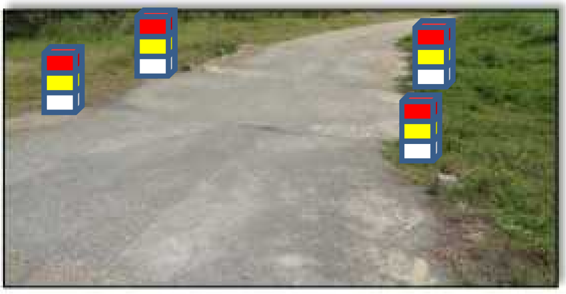
 

Figure 66 – Concrete warning blocks on drift

28.3 Maintenance

If road crosses a flowing stream create a flumed drift ONLY if confident maintenance will be adequate. Road crossings in remote areas cannot be expected to receive regular maintenance.

Drift culverts should be sized at a minimmum of 600mm and prefereabley 900 mm for ease of maintenance.

If projected calculated flood indicates crossing will be hazardous, and road priority is HIGH provide a bridge. Single span bridge or double span with central pillar requires minimal maintenance

Figure 67 – Flumed drift (culvert under drift) requiring maintenance

If maintenance is NOT adequate construct drift at grade and anticipate road closure. Provide alternate crossing such as footbridge and identify alternate route.

28.4 Countering lack of maintenance

If necessary drainage systems should be adopted which do not rely on regular maintenance, such as proving crossing drifts at grade and allowing stream water to flow over them.

Provide energy dissipation below crossing and scour protection above crossing. Increasing length of drift along road centerline can lower flood height.

Figure 68 – Scouring under road and gabions for energy dissipation

Roads can be constructed at grade with no culverts. If the drift is strengthened then at a later date a box culvert can be added with decking laid on top to form a bridge.

A drift with no culverts has no maintenance requirements yet the opportunity to install a boxculvert based causeway at a late date has not been lost.

This would be a **no regrets** decision.

29 No Regrets Decisions.

All decisions made on the level of intervention must be based on the principle of no regrets. Whatever decision is made should allow for further modifications to be made in the future without excess cost or difficulty. The climate change design interventions should be reviewed every 5 to 10 years.[10]

30 Decision Tree Analysis

The steps described above are given in the Decision Trees below. These should be followed by PWD engineers and decision makers as a guide and checklist when designing new roads, or rehabilitating existing roads, to be climate resilient.

[10] Wharfs: Increasing sea levels are causing engineers to rethink the design parameters required to design wharf and port structures. However, to design a port that will work in 20 - 30 years time means that it will not work now. In Vanuatu, on an ADB ports project, the solution was to reinforce the pilings which supported the wharf so that as the sea level rose the height of the platform could be raised using additional concrete. The added weight of the concrete could be supported by the existing pilings. “Infrastructure and Climate Change in the Pacific”, GHD Report for Ausaid, 2012.

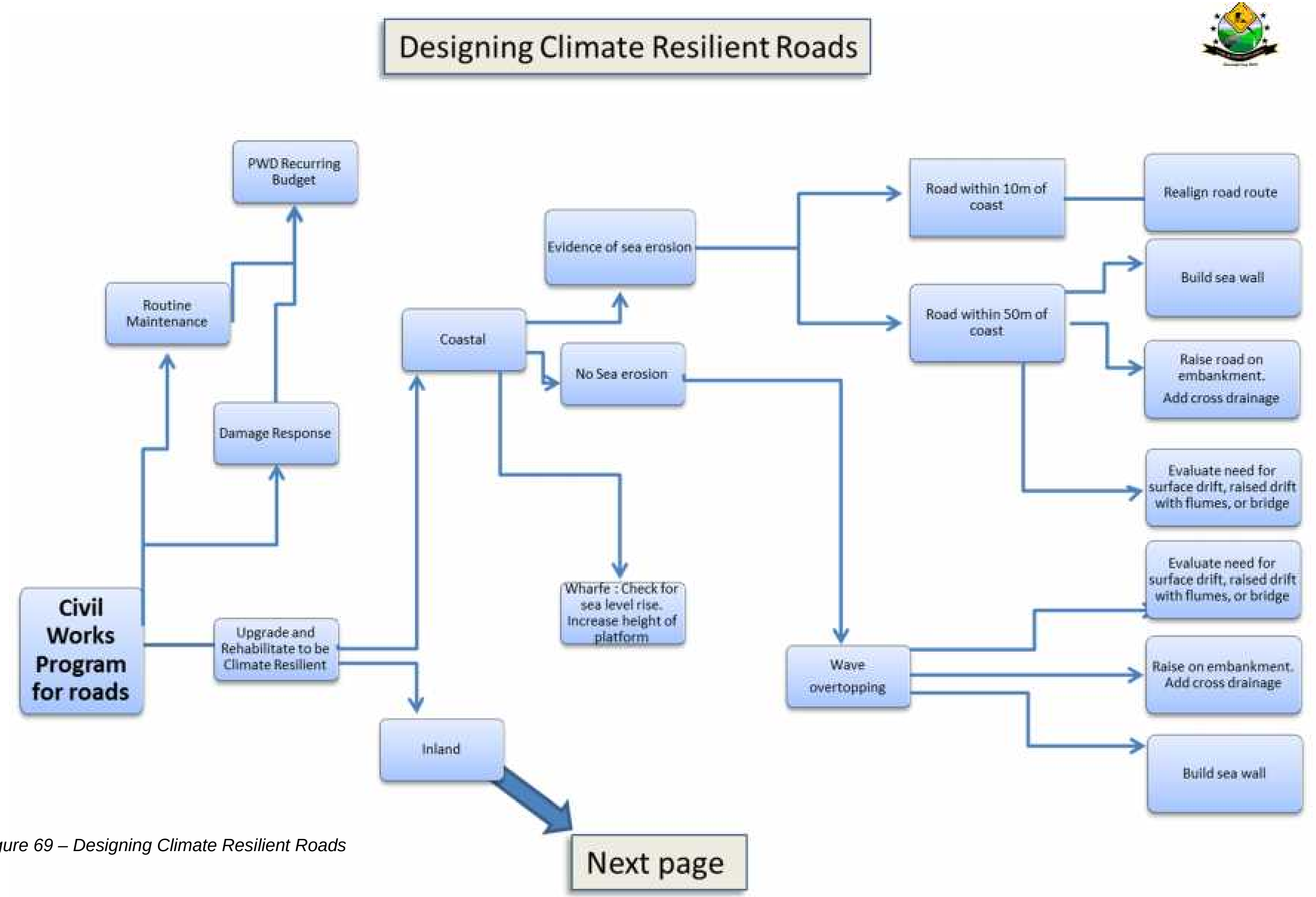


Figure 69 – Designing Climate Resilient Roads

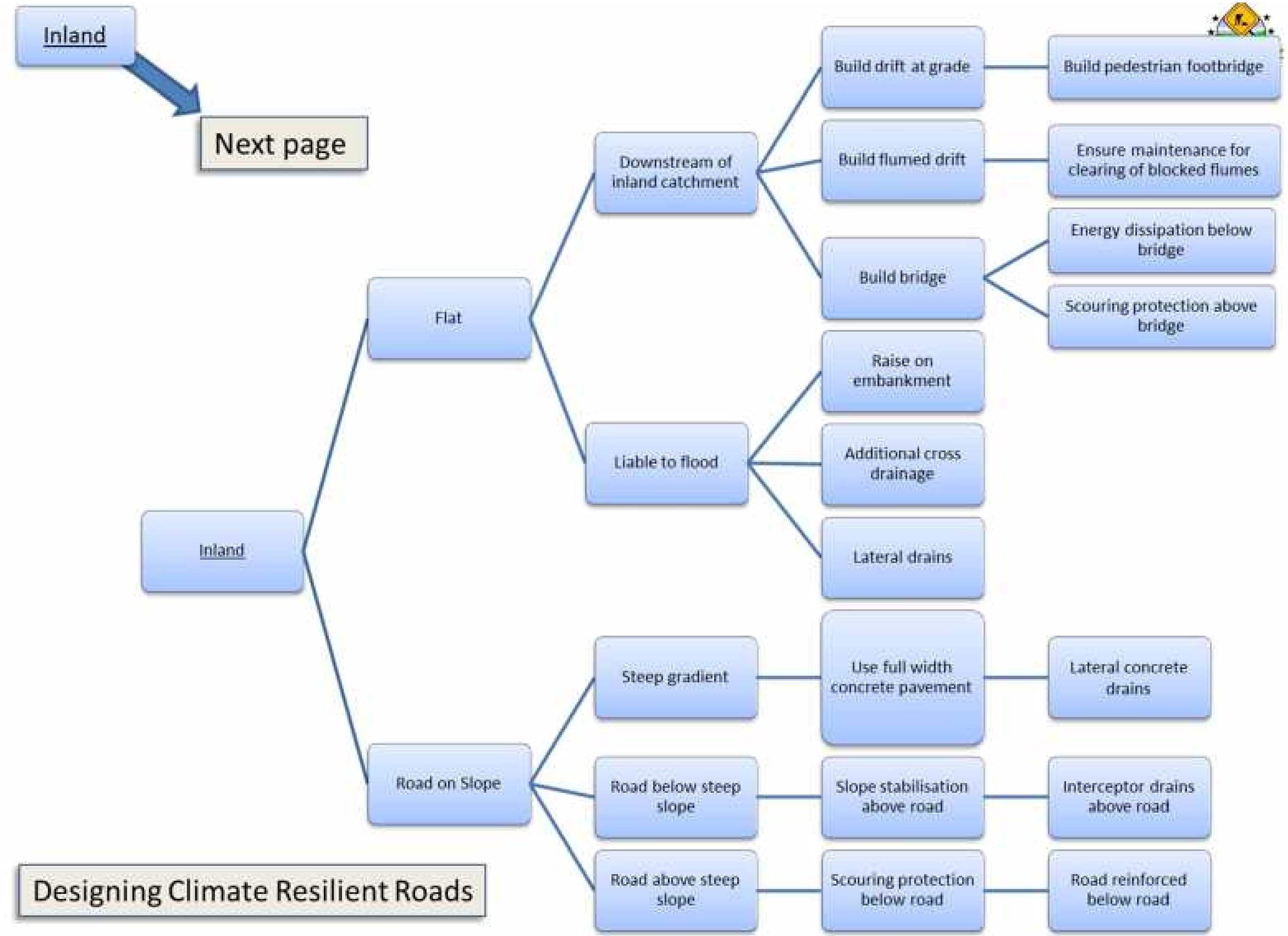


Figure 70 – Designing Climate Resilient Roads (Continued)

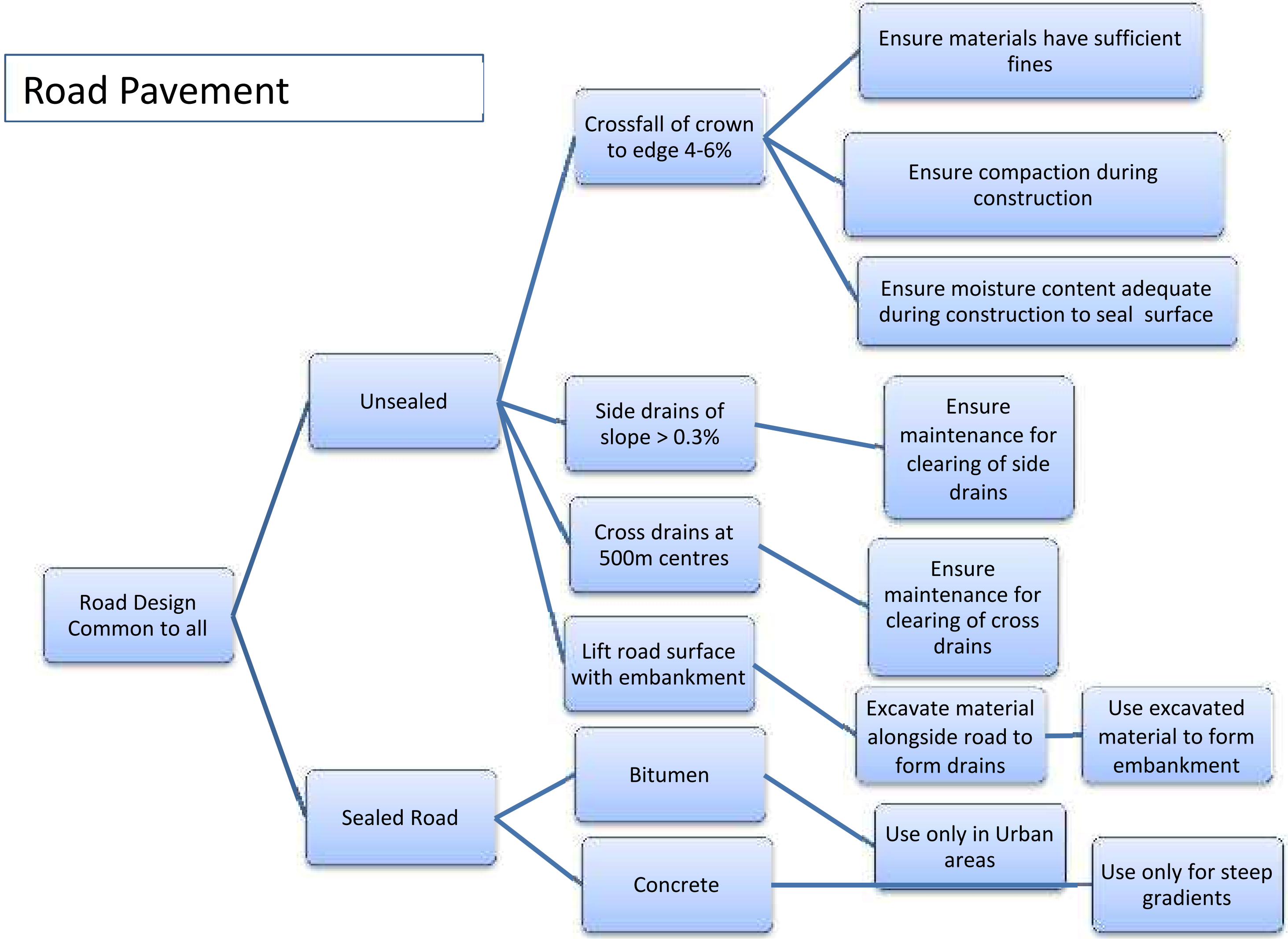


Figure 71 – Geometry of Climate Resilient Roads

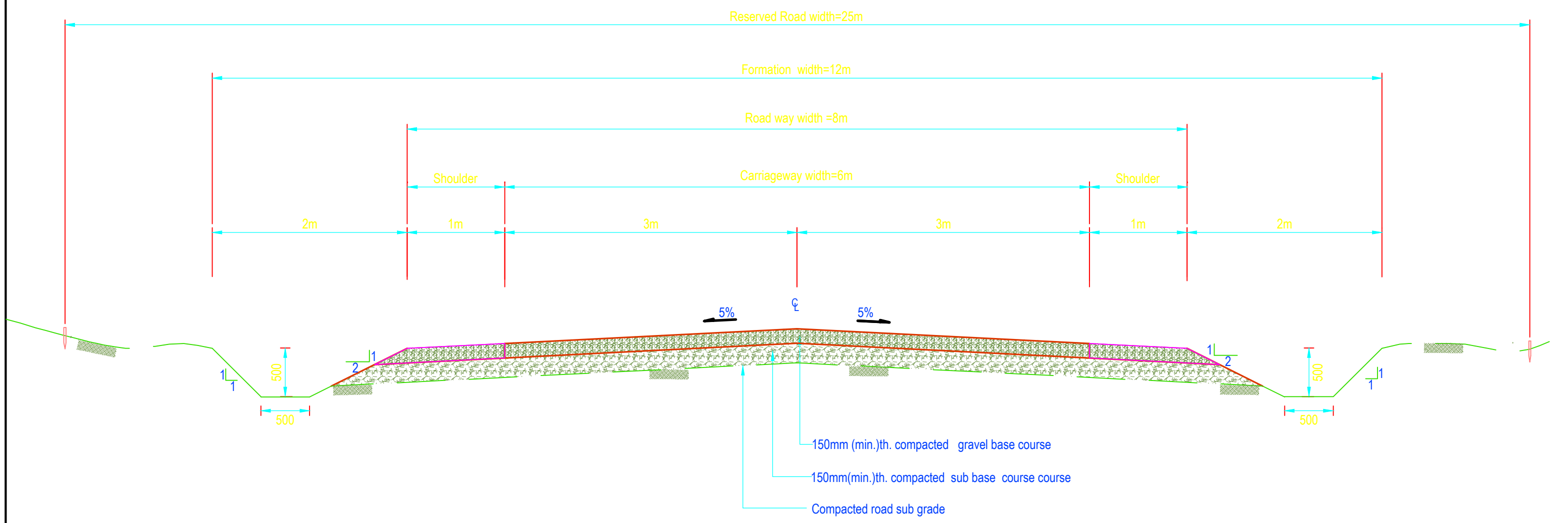
PART D

31 PART D – PWD STANDARD DRAWINGS

32 MIPU / PWD / DWGS

GENERAL NOTES:

1. All dimensions are in millimetres unless otherwise stated
2. Do not scale from drawing
3. Road reserved shall be 25m for Arterial , Urban and Feeder roads.
4. All gravel material shall be approved by engineer prior to delivery to site
5. Base course and sub base course shall be conformed with California Bearing Ratio (CBR) value.
6. Sub-base shall have a 4 day soaked CBR of not less than 50% at 98% Maximum Dry Density (MDD) and road base shall have a 4 day soaked CBR of not less than 80% at 98% of MDD. Subgrade CBR shall not be less than 8% CBR at 95% MDD.
7. Miter drain shall be provided at least 100m interval in both side of raod



TYPICAL CROSS SECTION

(1000-2000Vpd)

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:	JH
CAD BY:	DM
REVISED BY:	WW
APPROVED BY:	SN

Public Works Department

Private Mail Bag 004

Tel: 22889 Fax: 24495

PWD Standard Drawings

DRAWING TITLE : Gravel Wearing Course(8m) Arterial Road

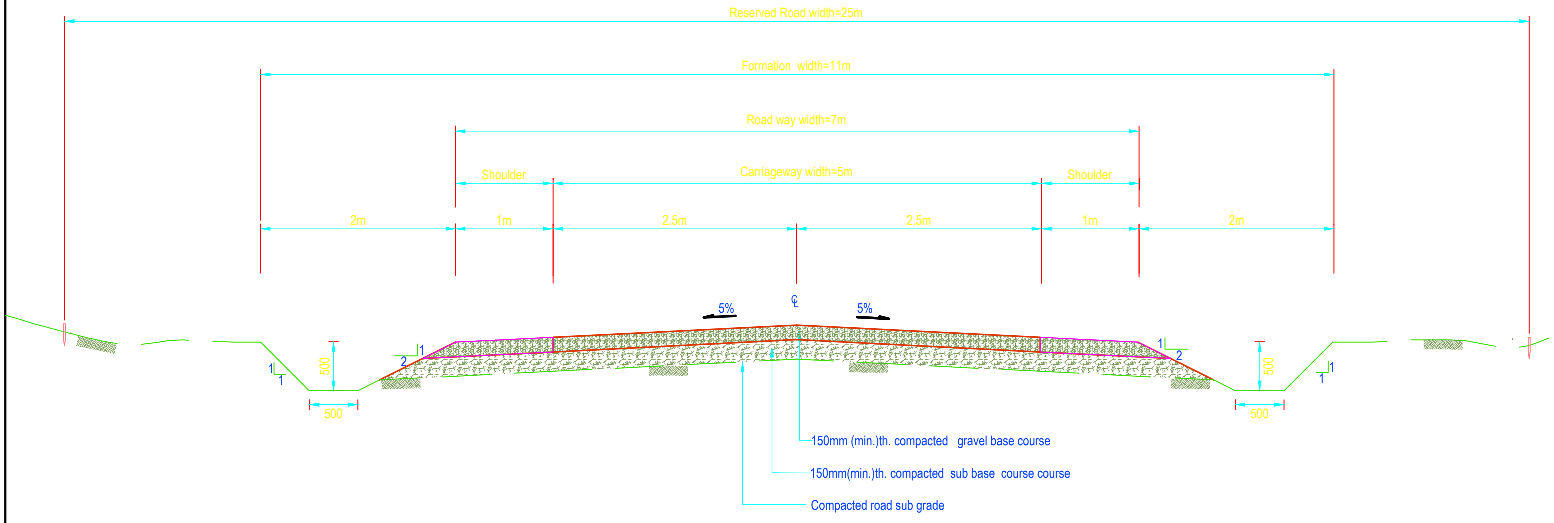
SCALE : 1:50

DATE : March 2012

DRAWING NUMBER **SD01**

GENERAL NOTES:

1. All dimensions are in millimetres unless otherwise stated
2. Do not scale from drawing
3. Road reserved shall be 25m for Arterial , Urban and Feeder roads.
4. All gravel material shall be approved by engineer prior to delivery to site
5. Base course and sub base course shall be conformed with California Bearing Ratio (CBR) value.
6. Sub-base shall have a 4 day soaked CBR of not less than 50% at 98% Maximum Dry Density (MDD) and road base shall have a 4 day soaked CBR of not less than 80% at 98% of MDD. Subgrade CBR shall not be less than 8% CBR at 95% MDD.
7. Miter drain shall be provided at least 100m interval in both side of raod



TYPICAL CROSS SECTION

(400-1000Vpd)

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:		JH
CAD BY:		DM
REVISED BY:		WW
APPROVED BY:		SN

Public Works Department

Private Mail Bag 004

Tel: 22889 Fax: 24495

PWD Standard Drawings

DRAWING TITLE : Gravel Wearing Course(7m) Arterial Road

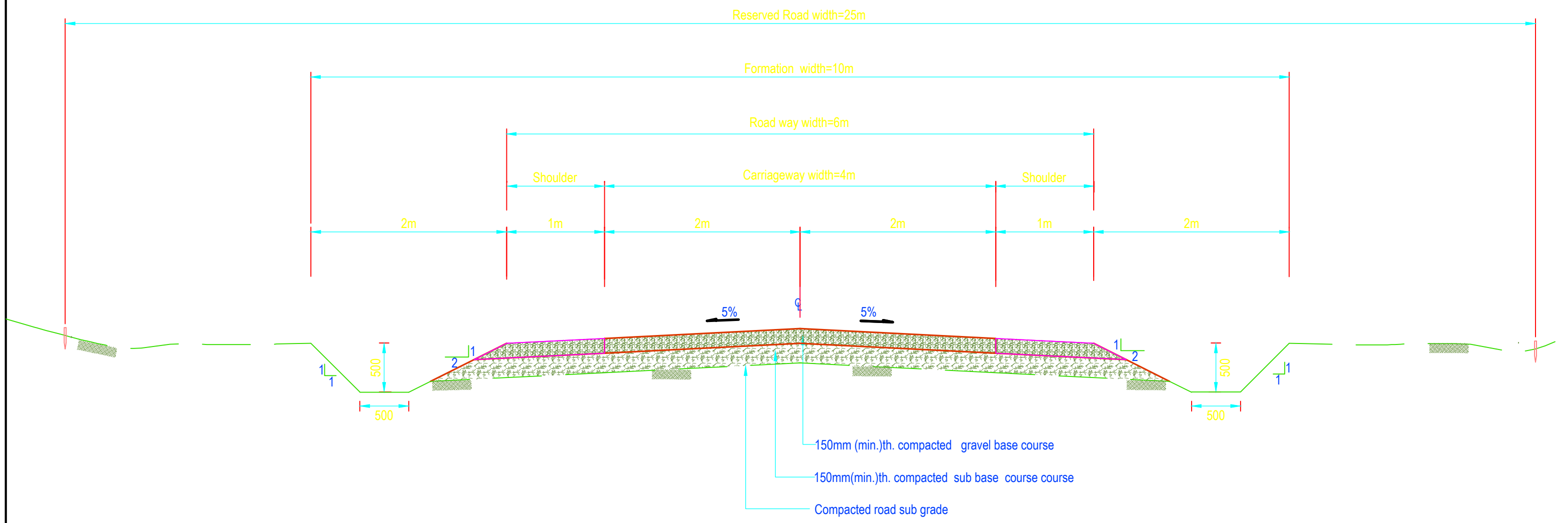
SCALE : 1:50

DATE : March 2012

DRAWING NUMBER **SD02**

GENERAL NOTES:

1. All dimensions are in millimetres unless otherwise stated
2. Do not scale from drawing
3. Road reserved shall be 25m for Arterial , Urban and Feeder roads.
4. All gravel material shall be approved by engineer prior to delivery to site
5. Base course and sub base course shall be conformed with California Bearing Ratio (CBR) value.
6. Sub-base shall have a 4 day soaked CBR of not less than 50% at 98% Maximum Dry Density (MDD) and road base shall have a 4 day soaked CBR of not less than 80% at 98% of MDD. Subgrade CBR shall not be less than 8% CBR at 95% MDD.
7. Miter drain shall be provided at least 100m interval in both side of raod



TYPICAL CROSS SECTION

(100-400Vpd)

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:	JH
CAD BY:	DM
REVISED BY:	WW
APPROVED BY:	SN

Public Works Department

Private Mail Bag 004

Tel: 22889 Fax: 24495

PWD Standard Drawings

DRAWING TITLE : Gravel Wearing Course(6m) Arterial Road

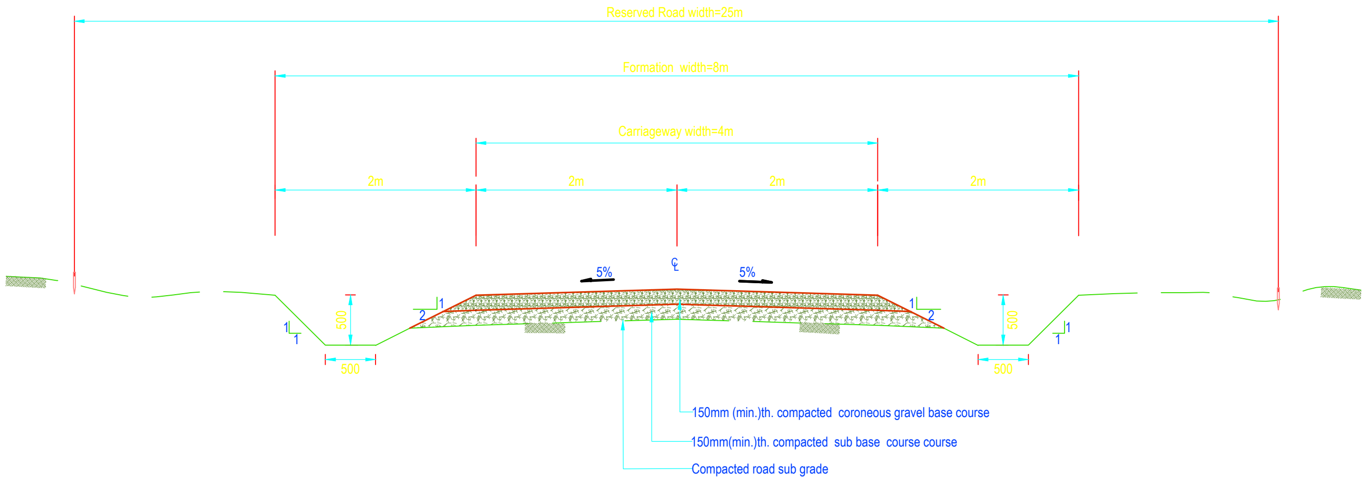
SCALE : 1:50

DATE : March 2012

DRAWING NUMBER **SD03**

GENERAL NOTES:

1. All dimensions are in millimetres unless otherwise stated
2. Do not scale from drawing
3. Road reserved shall be 25m for Arterial , Urban and Feeder roads.
4. All gravel material shall be approved by engineer prior to delivery to site
5. Base course and sub base course shall be conformed with California Bearing Ratio (CBR) value.
6. Sub-base shall have a 4 day soaked CBR of not less than 50% at 98% Maximum Dry Density (MDD) and road base shall have a 4 day soaked CBR of not less than 80% at 98% of MDD. Subgrade CBR shall not be less than 8% CBR at 95% MDD.
7. Miter drain shall be provided at least 100m interval in both side of raod



TYPICAL CROSS SECTION

(<50Vpd)

			DESIGNED BY:		JH
			CAD BY:		DM
			REVISED BY:		WW
1.			APPROVED BY:		SN
No.	DESCRIPTION	DATE			

Public Works Department

Private Mail Bag 004

Tel: 22889 Fax: 24495

PWD Standard Drawings

DRAWING TITLE : Gravel Wearing Course(4m) Feeder Road

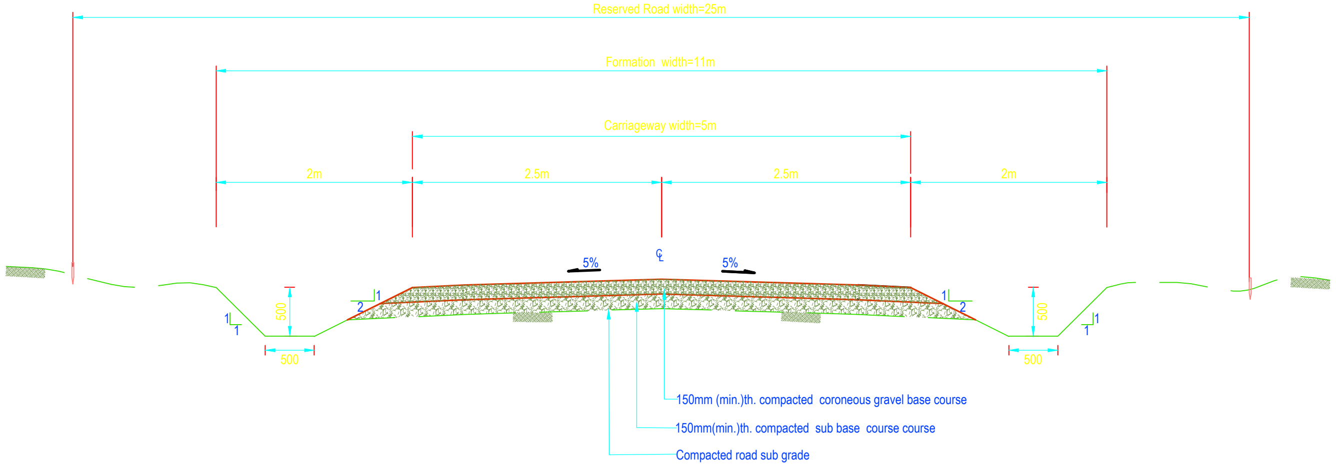
SCALE : 1:50

DATE : March 2012

DRAWING NUMBER **SD04**

GENERAL NOTES:

1. All dimensions are in millimetres unless otherwise stated
2. Do not scale from drawing
3. Road reserved shall be 25m for Arterial , Urban and Feeder roads.
4. All gravel material shall be approved by engineer prior to delivery to site
5. Base course and sub base course shall be conformed with California Bearing Ratio (CBR) value.
6. Sub-base shall have a 4 day soaked CBR of not less than 50% at 98% Maximum Dry Density (MDD) and road base shall have a 4 day soaked CBR of not less than 80% at 98% of MDD. Subgrade CBR shall not be less than 8% CBR at 95% MDD.
7. Miter drain shall be provided at least 100m interval in both side of raod



TYPICAL CROSS SECTION

(50-100Vpd)

			DESIGNED BY:		JH
			CAD BY:		DM
			REVISED BY:		WW
1.			APPROVED BY:		SN
No.	DESCRIPTION	DATE			

Public Works Department

Private Mail Bag 004

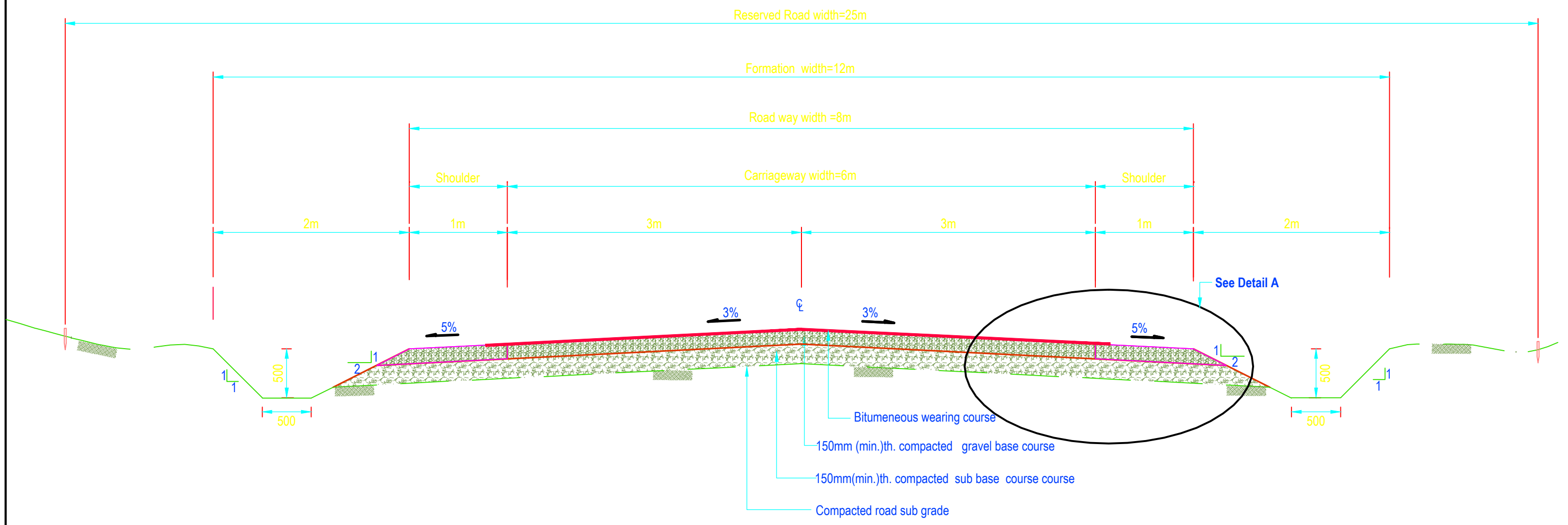
Tel: 22889 Fax: 24495

PWD Standard Drawings

DRAWING TITLE :	Gravel Wearing Course(5m) Feeder Road		SD05
SCALE : 1:50	DATE : March 2012	DRAWING NUMBER	

GENERAL NOTES:

1. All dimensions are in millimetres unless otherwise stated
2. Do not scale from drawing
3. Road reserved shall be 25m for Arterial , Urban and Feeder roads.
4. All gravel material shall be approved by engineer prior to delivery to site
5. Base course and sub base course shall be conformed with California Bearing Ratio (CBR) value.
6. Sub-base shall have a 4 day soaked CBR of not less than 50% at 98% Maximum Dry Density (MDD) and road base shall have a 4 day soaked CBR of not less than 80% at 98% of MDD. Subgrade CBR shall not be less than 8% CBR at 95% MDD.
7. Miter drain shall be provided at least 100m interval in both side of raod



TYPICAL CROSS SECTION

(3000-5000Vpd)

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:		JH
CAD BY:		DM
REVISED BY:		WW
APPROVED BY:		SN

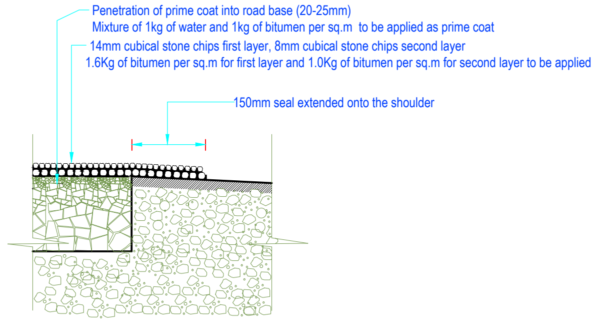
Public Works Department

Private Mail Bag 004

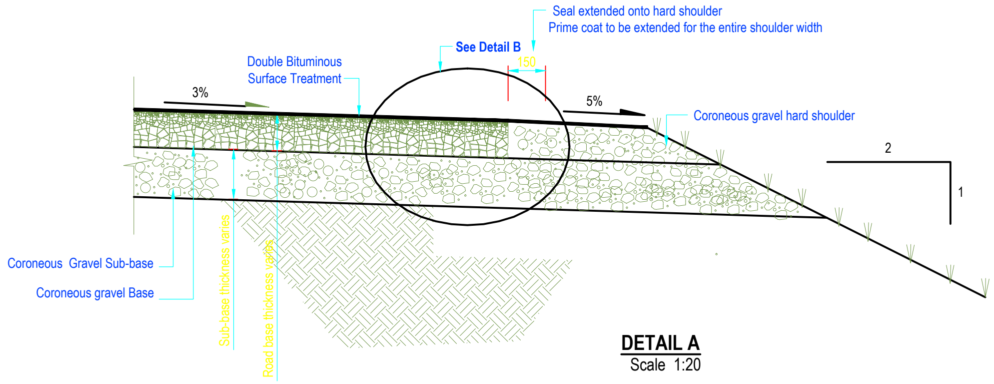
Tel: 22889 Fax: 24495

PWD Standard Drawings

DRAWING TITLE :	Bitumen Wearing Course(8m) Urban Road
SCALE :	1:50
DATE :	March 2012
DRAWING NUMBER	SD06



DETAIL B
Scale 1:10



DETAIL A
Scale 1:20

NOTES:

1. All dimensions are in millimetres unless otherwise stated
2. Do not scale from drawing
3. SS65 bitumen emulsion with 35% water shall be used and it should be approved by the Engineer prior using .
4. Emulsion prime coat shall be applied at a spread rate of 1.0kg per square metre.
5. Stone chips to be used for the surface treatment are to be cubical in shape, single sized, free of earth, dust and water before application. Flaky stone chips are to be rejected.
6. The first layer of surface treatment shall be rolled with a pneumatic wheeled roller without vibration and opened to construction traffic until the chips are firmly bedded into the bitumen layer. Following this the additional stone chips are to be brushed off the surface of the layer and the surface is to be cleaned by hand or mechanical brooming or with an air hose such that no dust, water or soil remains on the surface. The second layer is to be applied in the same manner as the first.
7. All shoulders shall be treated with prime coat with SS65 bitumen emulsion blinded with coarse sand.
8. Bitumen shall be sprayed at a normal temeperature
9. Shoulders shall be constructed prior to the placement of road base or sub-base material using a pedestrian roller with vibration and trimmming off excess material from the pavement area such that the shoulders will restrain the sub-base and road base layers during compaction
10. A gradation test is shall be carried on site and approved by the Engineer prior to approval being issued for the delivery of road base material
11. Sub-base shall have a 4 day soaked CBR of not less than 50% at 98% Maximum Dry Density (MDD) and road base shall have a 4 day soaked CBR of not less than 80% at 98% of MDD. Subgrade CBR shall not be less than 8% CBR at 95% MDD.
12. Coroneous material shall be used for subbase and shoulders is to be in strict accordance with the technical specifications for Coroneous base of sub base material.
13. **Base and sub base thickness shall be specified in the schedule of work**

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:		JH
CAD BY:		DM
REVISED BY:		WW
APPROVED BY:		SN

Public Works Department
Private Mail Bag 004
Tel: 22889 Fax: 24495

PWD Standard Drawings

DRAWING TITLE : Bitumen Wearing Course(8m) Urban Road

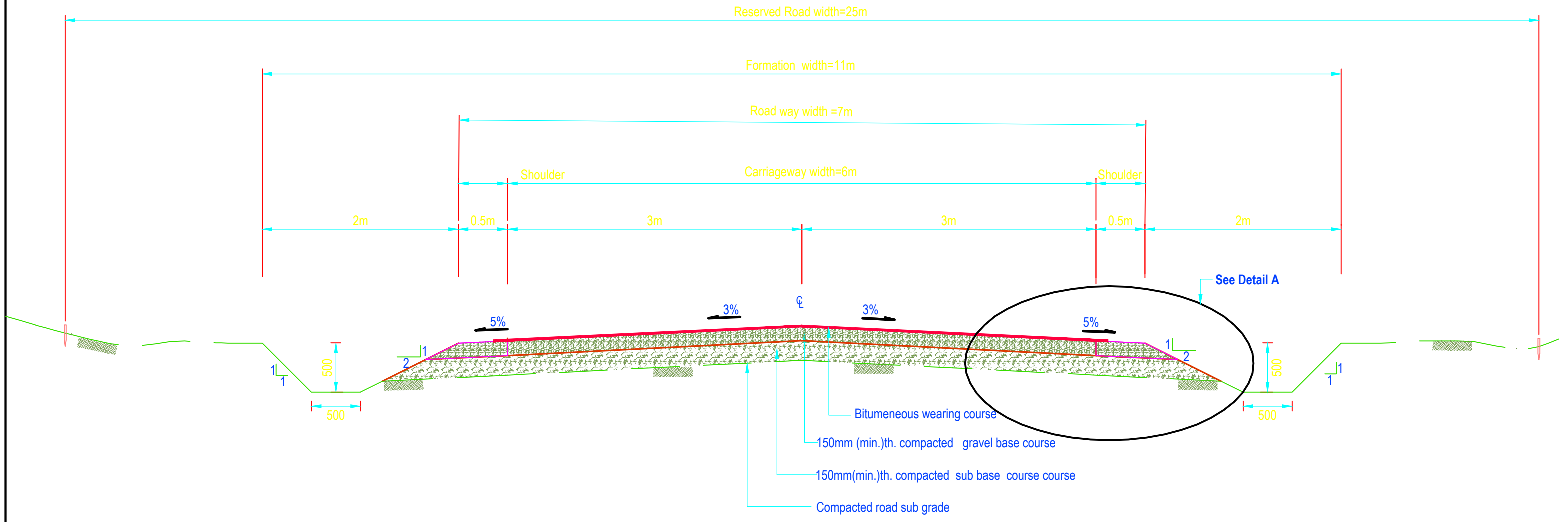
SCALE :

DATE : March 2012

DRAWING NUMBER **SD06/a**

GENERAL NOTES:

1. All dimensions are in millimetres unless otherwise stated
2. Do not scale from drawing
3. Road reserved shall be 25m for Arterial , Urban and Feeder roads.
4. All gravel material shall be approved by engineer prior to delivery to site
5. Base course and sub base course shall be conformed with California Bearing Ratio (CBR) value.
6. Sub-base shall have a 4 day soaked CBR of not less than 50% at 98% Maximum Dry Density (MDD) and road base shall have a 4 day soaked CBR of not less than 80% at 98% of MDD. Subgrade CBR shall not be less than 8% CBR at 95% MDD.
7. Miter drain shall be provided at least 100m interval in both side of raod



TYPICAL CROSS SECTION

(2000-3000Vpd)

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:		JH
CAD BY:		DM
REVISED BY:		WW
APPROVED BY:		SN

Public Works Department

Private Mail Bag 004

Tel: 22889 Fax: 24495

PWD Standard Drawings

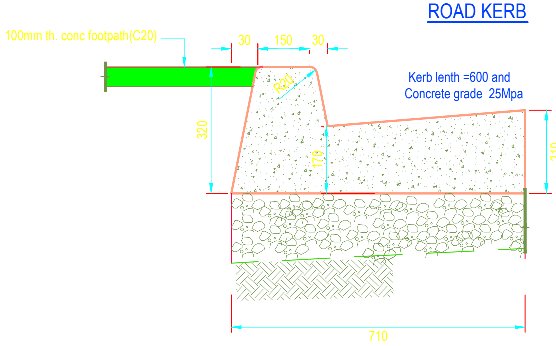
DRAWING TITLE : Bitumen Wearing Course(7m) Urban Road

SCALE : 1:50

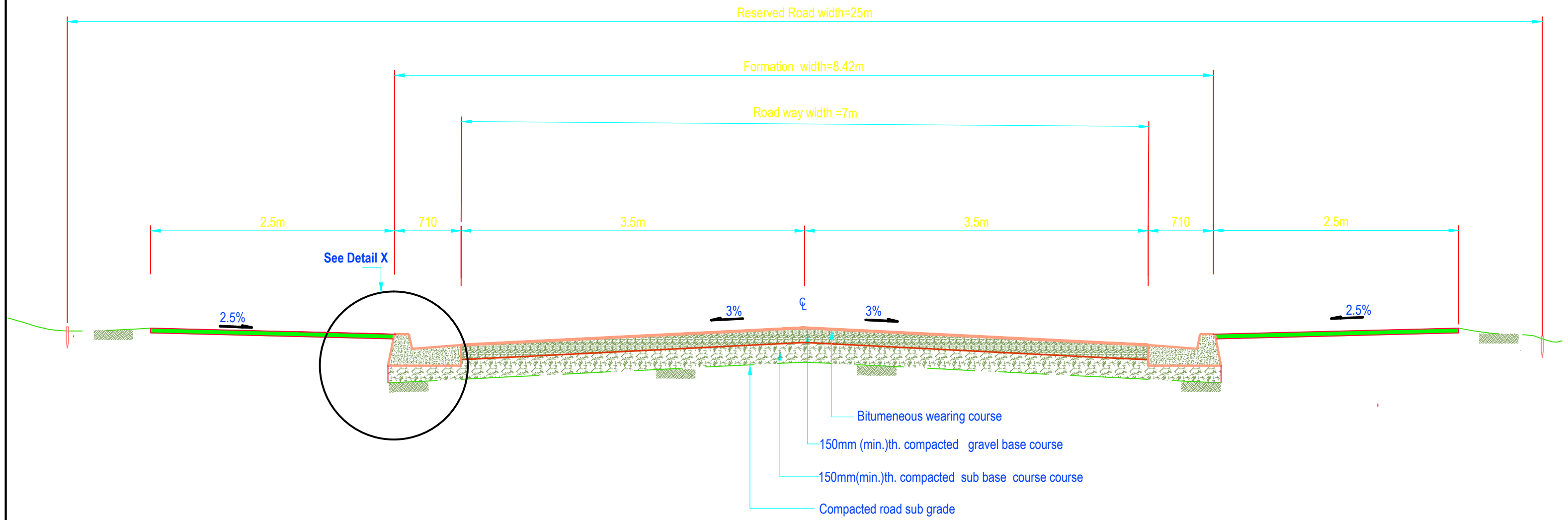
DATE : March 2012

DRAWING NUMBER **SD07**

ROAD KERB



DETAIL X
Scale 1:20



TYPICAL CROSS SECTION

1:50
(1000-2000Vpd)

GENERAL NOTES:

1. All dimensions are in millimetres unless otherwise stated
2. Do not scale from drawing
3. Road reserved shall be 25m for Arterial , Urban and Feeder roads.
4. All gravel material shall be approved by engineer prior to delivery to site
5. Base course and sub base course shall be conformed with California Bearing Ratio (CBR) value.
6. Sub-base shall have a 4 day soaked CBR of not less than 50% at 98% Maximum Dry Density (MDD) and road base shall have a 4 day soaked CBR of not less than 80% at 98% of MDD. Subgrade CBR shall not be less than 8% CBR at 95% MDD.
7. Miter drain shall be provided at least 100m interval in both side of raod

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:		JH
CAD BY:		DM
REVISED BY:		WW
APPROVED BY:		SN

Public Works Department
Private Mail Bag 004
Tel: 22889
Fax: 24495

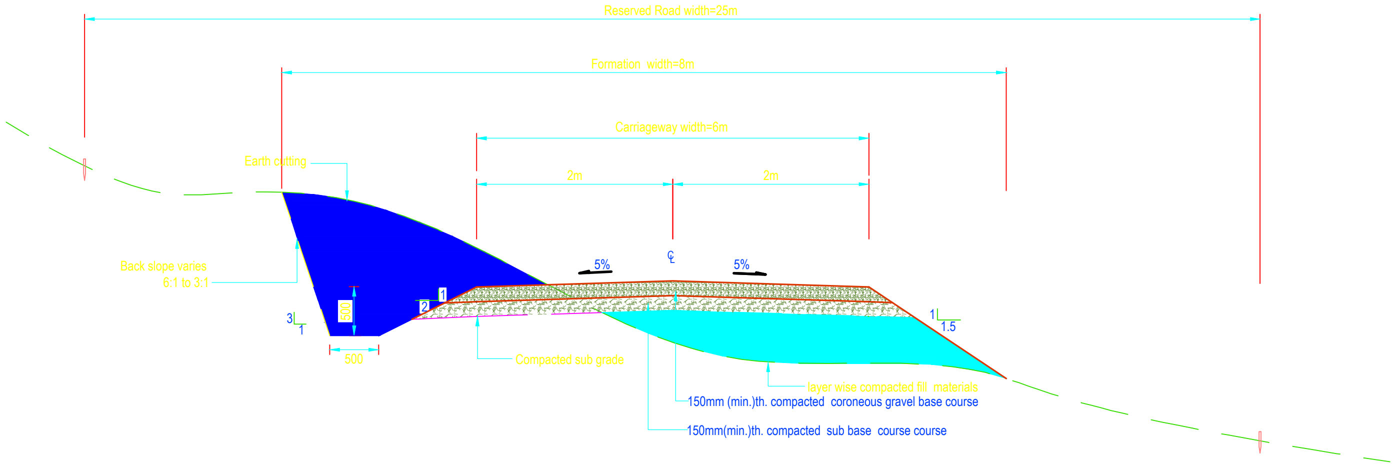
PWD Standard Drawings

DRAWING TITLE : Bitumen Wearing Course(7m) Urban Road with kerb

SCALE : 1:50

DATE : March 2012

DRAWING NUMBER **SD08**



TYPICAL CROSS SECTION

GENERAL NOTES:

1. All dimensions are in millimetres unless otherwise stated
2. Do not scale from drawing
3. Road reserved shall be 25m for Arterial , Urban and Feeder roads.
4. All gravel material shall be approved by engineer prior to delivery to site
5. Base course and sub base course shall be conformed with California Bearing Ratio (CBR) value.
6. Sub-base shall have a 4 day soaked CBR of not less than 50% at 98% Maximum Dry Density (MDD) and road base shall have a 4 day soaked CBR of not less than 80% at 98% of MDD. Subgrade CBR shall not be less than 8% CBR at 95% MDD.
7. Miter drain shall be provided at least 100m interval in both side of raod

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:		JH
CAD BY:		DM
REVISED BY:		WW
APPROVED BY:		SN

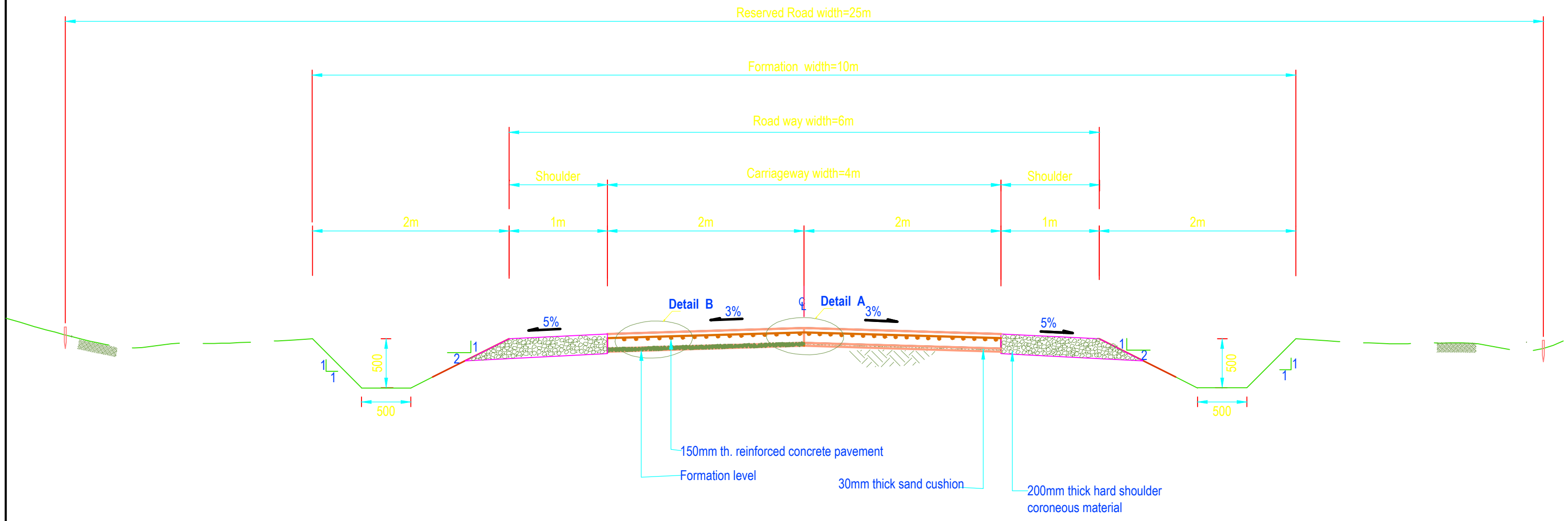
Public Works Department

Private Mail Bag 004

Tel: 22889 Fax: 24495

PWD Standard Drawings

DRAWING TITLE :	Hill road (8m) Feeder Road
SCALE :	1:50
DATE :	March 2012
DRAWING NUMBER	SD09



TYPICAL CROSS SECTION

GENERAL NOTES:

1. All dimensions are in millimetres unless otherwise stated
2. Do not scale from drawing
3. Concrete shall comply with PWD Technical Specification for road and bridge.
4. Reinforcement shall comply with PWD Technical Specification for road and bridge.
5. Curing of concrete shall comply with PWD Technical Specification for road and bridge .
6. Concrete cover shall comply with PWD Technical Specification for road and bridge .

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:	JH
CAD BY:	DM
REVISED BY:	WW
APPROVED BY:	SN

Public Works Department

Private Mail Bag 004

Tel: 22889 Fax: 24495

PWD Standard Drawings

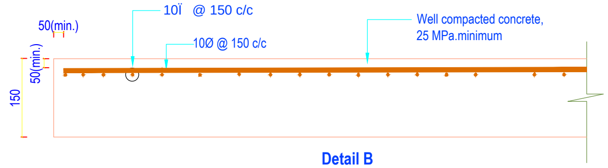
DRAWING TITLE : Concrete Pavement

SCALE : 1:50

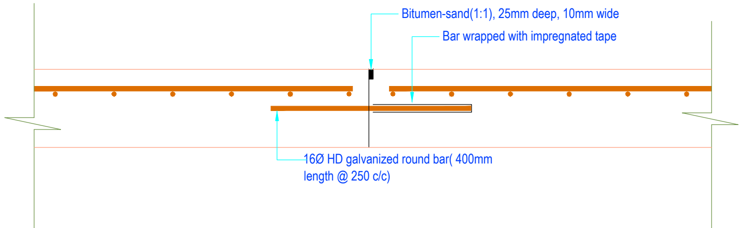
DATE : March 2012

DRAWING NUMBER

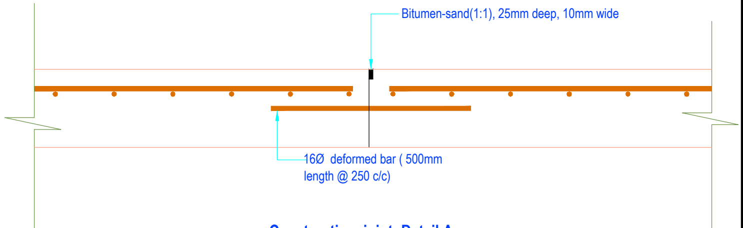
SD10



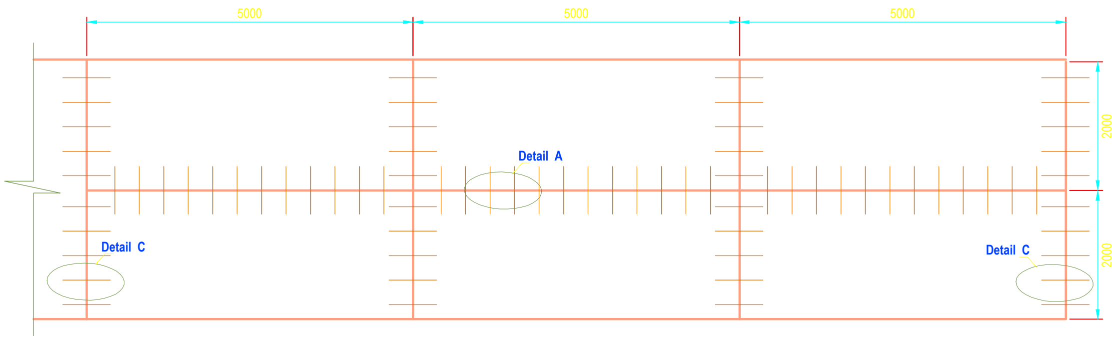
Detail B



Expansion joint @15m-Detail C



Construction joint -Detail A



Plan of concrete pavement with dowel details

GENERAL NOTES:

1. All dimensions are in millimetres unless otherwise stated
2. Do not scale from drawing
3. Concrete shall comply with PWD Technical Specification for road and bridge.
4. Reinforcement shall comply with PWD Technical Specification for road and bridge.
5. Curing of concrete shall comply with PWD Technical Specification for road and bridge .
6. Concrete cover shall comply with PWD Technical Specification for road and bridge .

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:		JH
CAD BY:		DM
REVISED BY:		WW
APPROVED BY:		SN

Public Works Department

Private Mail Bag 004

Tel: 22889 Fax: 24495

PWD Standard Drawings

DRAWING TITLE : Concrete Pavement

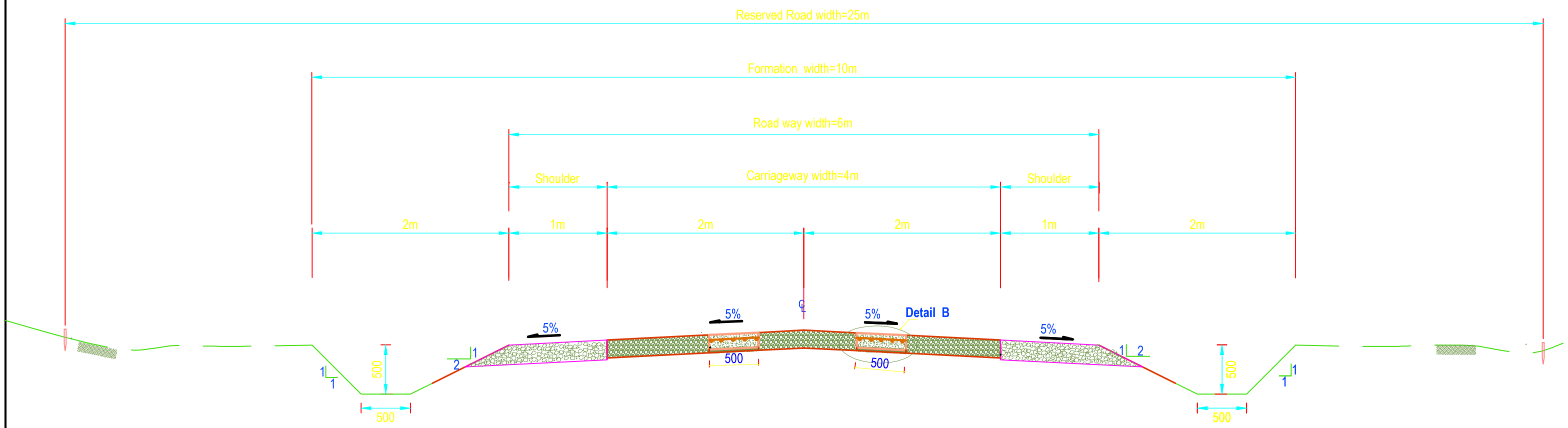
SCALE : 1:50

DATE : March 2012

DRAWING NUMBER **SD10/a**

GENERAL NOTES:

1. All dimensions are in millimetres unless otherwise stated
2. Do not scale from drawing
3. Concrete shall comply with PWD Technical Specification for road and bridge.
4. Reinforcement shall comply with PWD Technical Specification for road and bridge.
5. Curing of concrete shall comply with PWD Technical Specification for road and bridge .
6. Concrete cover shall comply with PWD Technical Specification for road and bridge .



TYPICAL CROSS SECTION

			DESIGNED BY:		JH
			CAD BY:		DM
			REVISED BY:		WW
1.			APPROVED BY:		SN
No.	DESCRIPTION	DATE			

Public Works Department

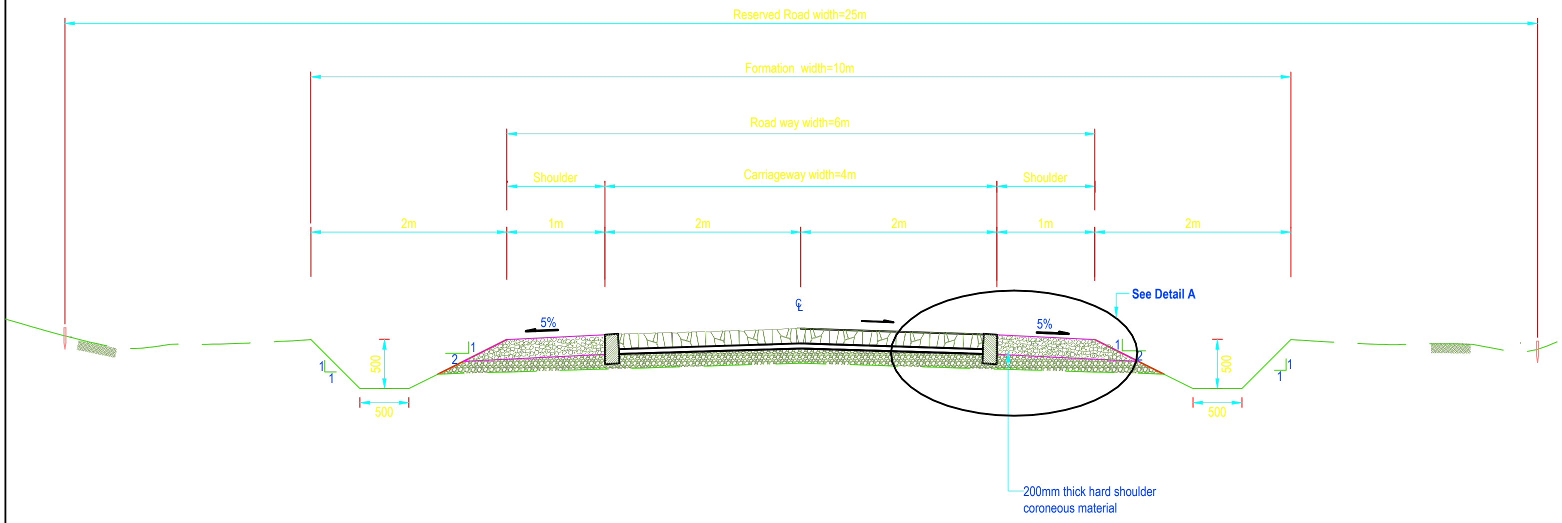
Private Mail Bag 004

Tel: 22889 Fax: 24495

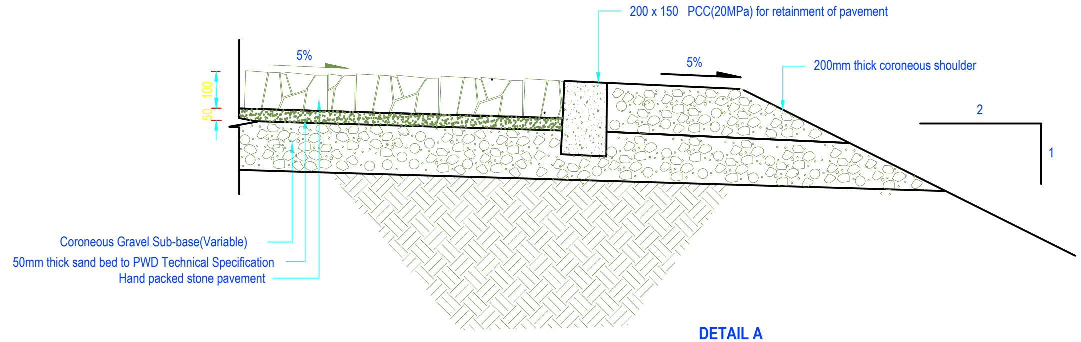
PWD Standard Drawings

DRAWING TITLE :	Strip concrete pavement		SD11
SCALE : 1:50	DATE : March 2012	DRAWING NUMBER	

NOTES:
1. All dimensions are in millimetres unless otherwise stated
2. Do not scale from drawing
3. Material shall comply with PWD Technical Specification for road and bridge
4. Compaction shall comply with PWD Technical Specification for road and bridge
5. Coroneous material shall comply with PWD Technical Specification for road and bridge



TYPICAL CROSS SECTION



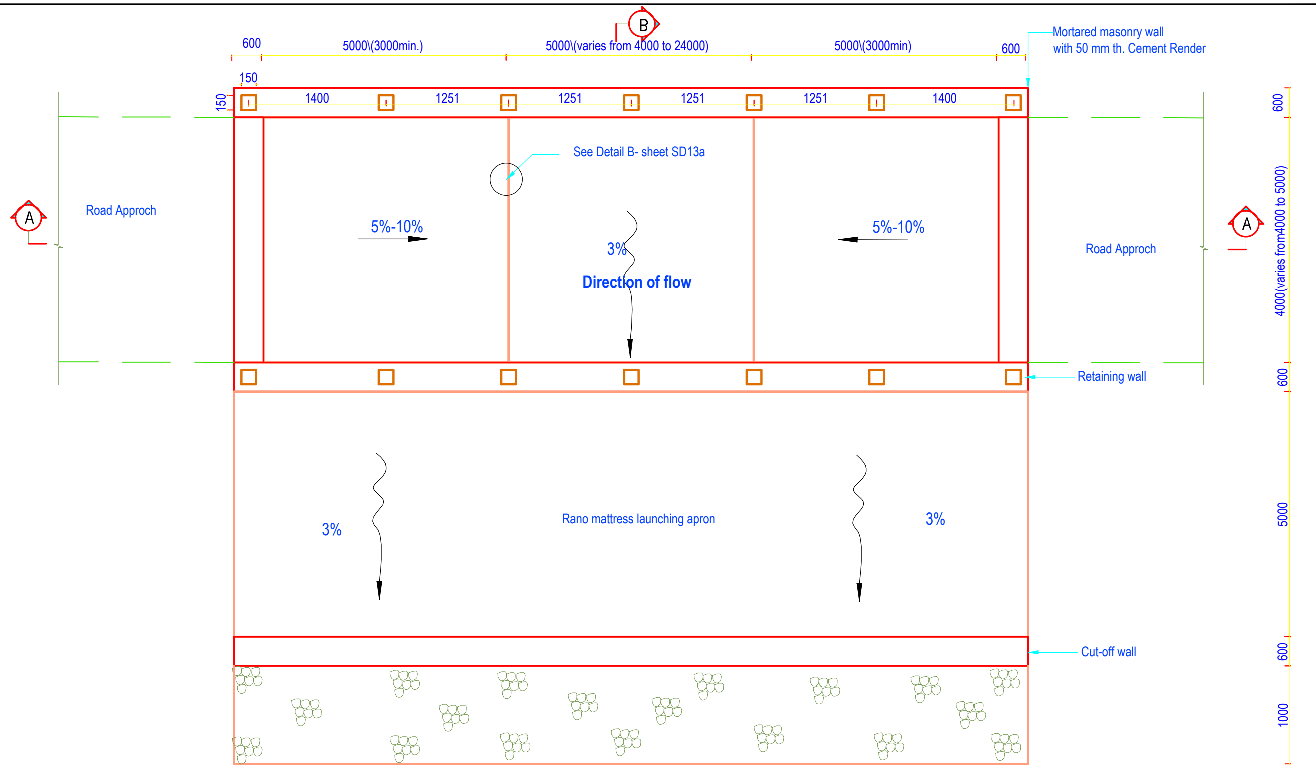
DETAIL A
Scale 1:20

			DESIGNED BY:		JH
			CAD BY:		DM
			REVISED BY:		WW
1.			APPROVED BY:		SN
No.	DESCRIPTION	DATE			

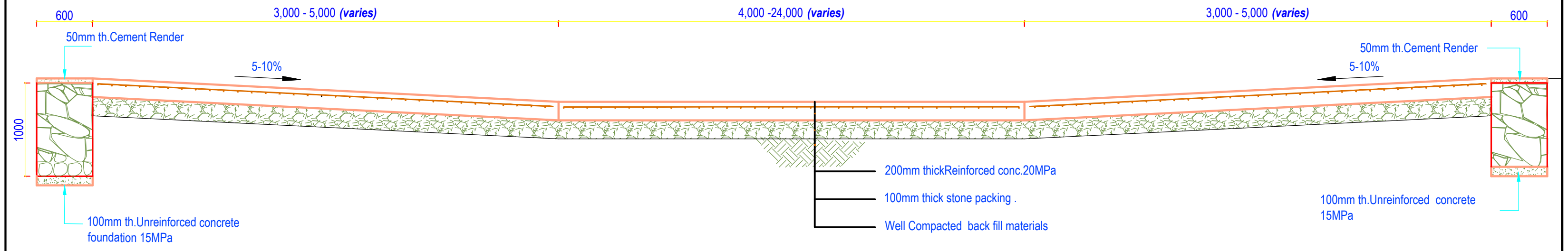
Public Works Department
Private Mail Bag 004
Tel: 22889 Fax: 24495

PWD Standard Drawings

DRAWING TITLE :	Stone Pavement		SD12
SCALE : 1:50	DATE : March 2012	DRAWING NUMBER	



Plan View of Wash



Section AA - Typical wash

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:	JH
CAD BY:	DM
REVISED BY:	WW
APPROVED BY:	SN

Public Works Department

Private Mail Bag 004

Tel: 22889 Fax: 24495

PWD Standard Drawings

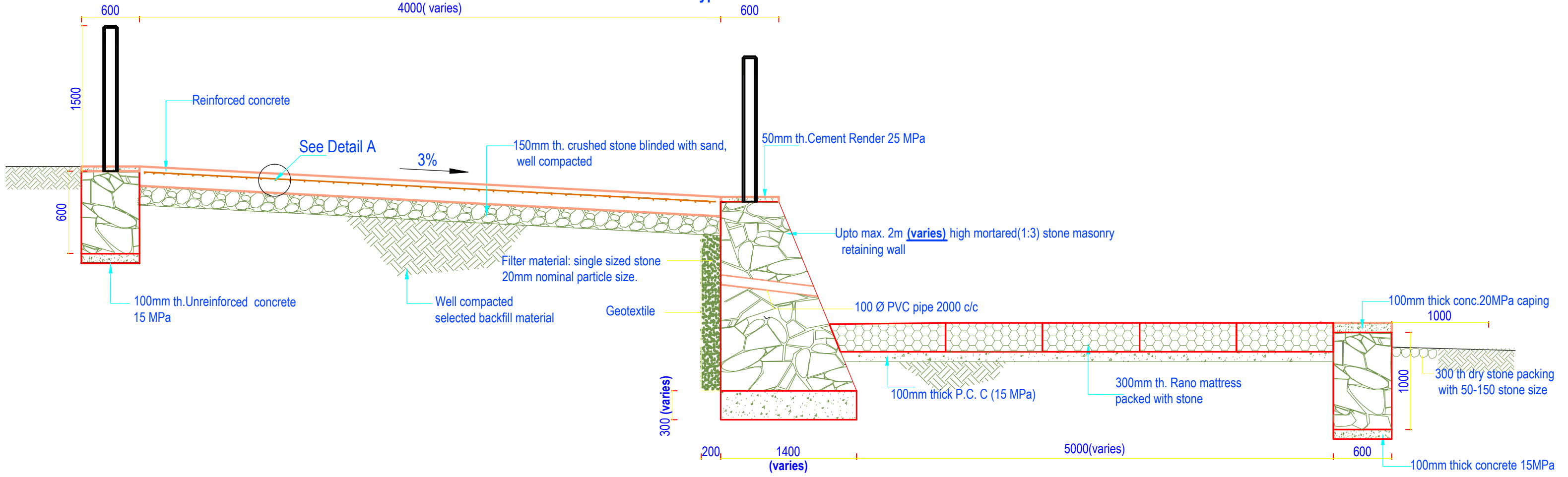
DRAWING TITLE : Typical plan and L.section for Wash CONCRETE SURFACE

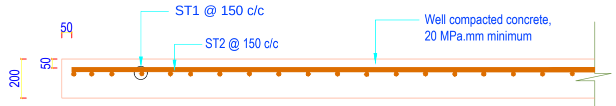
SCALE : 1:50

DATE : March 2012

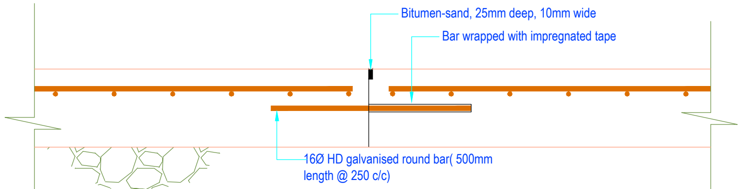
DRAWING NUMBER **SD13**

Section BB - Typical Wash





Detail A



Detail B- sheet SD 10a

Bar Schedule (No. of bars presented are for single 5m x 4m slab)

Member	Bar Diameter	Shape Code		No. of Bars	Segment length a	Segment length b	Total length - ***varies*** (metres)
Deck	10	ST1	a		3900		
Deck	10	ST2	a		4900		

NOTES:

1. All dimensions in millimetres unless otherwise stated.
2. Material shall comply with PWD Technical Specification for road and bridge
3. All masonry work shall comply with PWDTechnical Specification for road and bridge
4. Depth of mortared masonry retaining wall and cut-off wall to be designated by the Engineer taking account of site conditions
5. Steel reinforcement shall comply with PWD Technical Specification for road and bridge.
6. Concrete shall comply with PWD Technical Specification for road and bridge.
7. Concrete curing shall comply with PWD Technical Specification for road and bridge.
8.The central slab(s) of the wash shall be constructed with a crossfall not greater than 3%
9. The run-on slabs shall be constructed with a crossfall not less than 5% and not greater than 10%
10.See conc.pavement detail for construction joints for RCC slab.
11.Down stream gabion protection will be detailed in the schedule of structure where required.Other wise or downstream gabion erosion protection is to be constructed.

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:		JH
CAD BY:		DM
REVISED BY:		WW
APPROVED BY:		SN

Public Works Department

Private Mail Bag 004

Tel: 22889 Fax: 24495

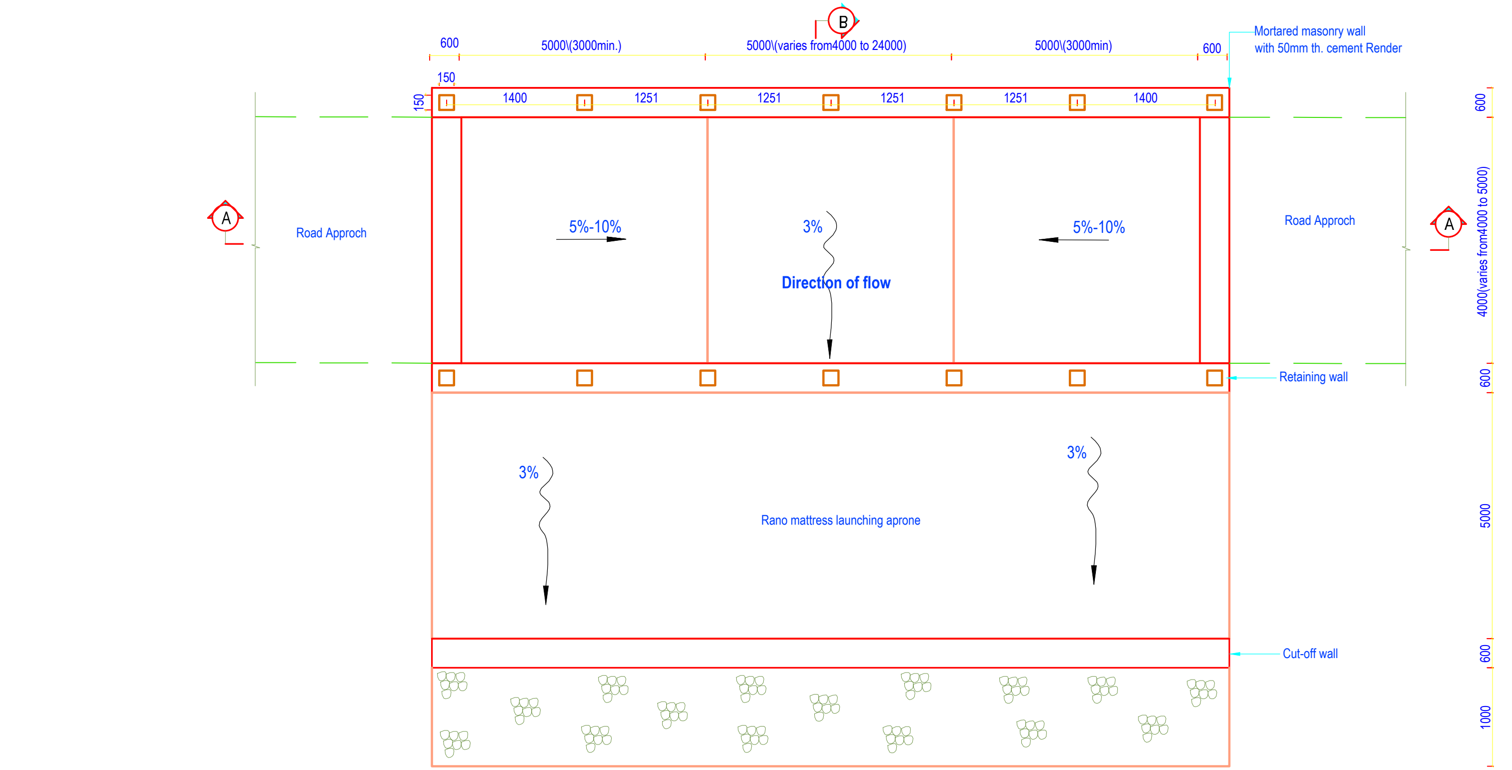
PWD Standard Drawings

DRAWING TITLE : Typical plan and L.section for Wash CONCRETE SURFACE

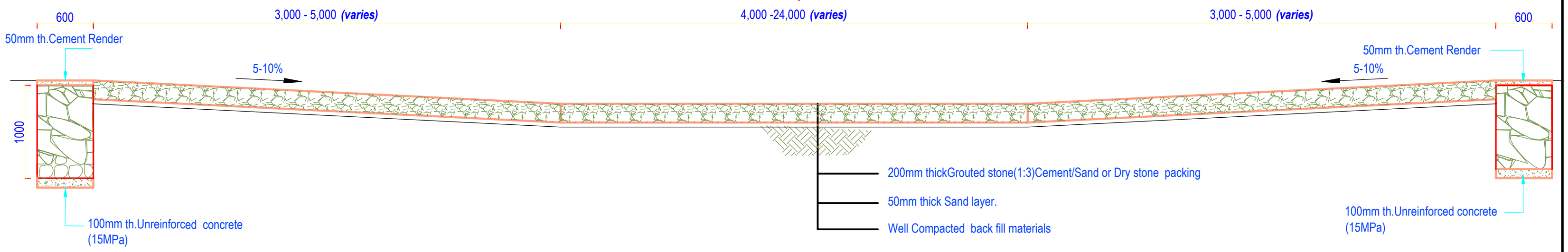
SCALE : 1:50

DATE : March 2012

DRAWING NUMBER **SD13a**



Plan View of Wash



Section AA - Typical wash

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:		JH
CAD BY:		DM
REVISED BY:		WW
APPROVED BY:		SN

Public Works Department

Private Mail Bag 004

Tel: 22889 Fax: 24495

PWD Standard Drawings

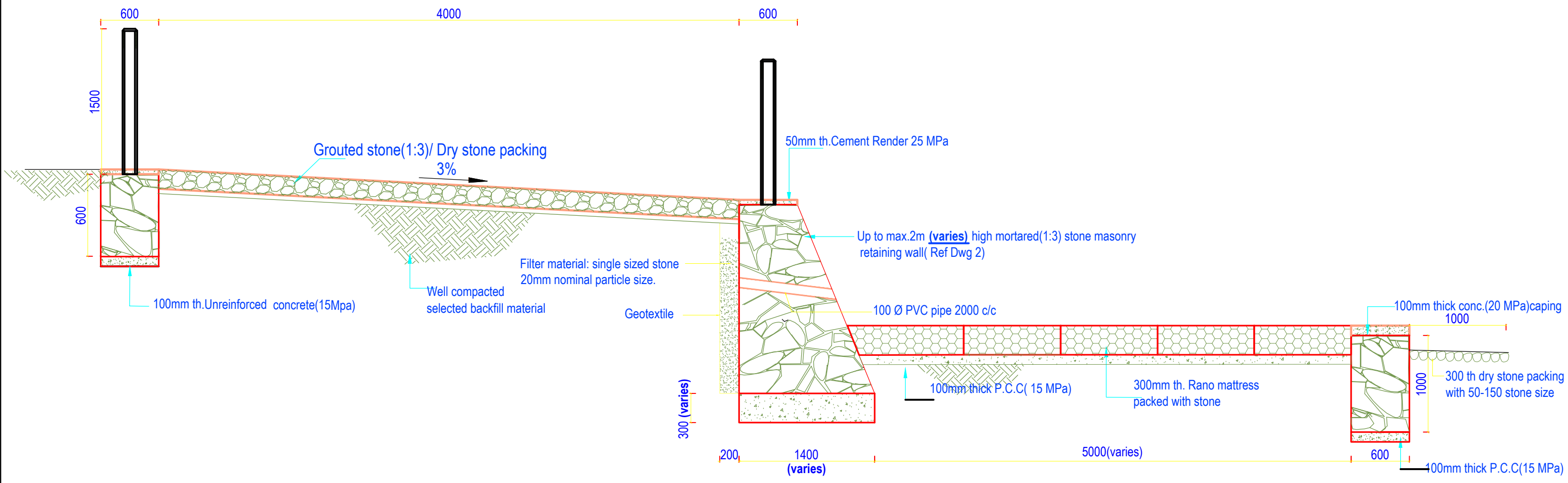
DRAWING TITLE : Typical plan and L.section for Wash
GROUTED STONE or DRY STONE PACKING SURFACE

SCALE : 1:50

DATE : March 2012

DRAWING NUMBER **SD14**

Section BB - Typical Wash



NOTES:

1. All dimensions in millimetres unless otherwise stated.
2. Material shall comply with PWD Technical Specification for road and bridge.
3. All masonry work shall comply with PWD Technical Specification for road and bridge.
4. Depth of mortared masonry retaining wall and cut-off wall to be designated by the Engineer taking account of site conditions.
5. Concrete shall comply with PWD Technical Specification for road and bridge.
6. The central leaf(s) of the wash shall be constructed with a crossfall not greater than 3%
7. The run-on leafs shall be constructed with a crossfall not less than 5% and not greater than 10%
8. **Down stream gabion protection will be detailed in the schedule of structure where required.Other wise or downstream gabion erosion protection is to be constructed.**

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:		JH
CAD BY:		DM
REVISED BY:		WW
APPROVED BY:		SN

Public Works Department

Private Mail Bag 004

Tel: 22889 Fax: 24495

PWD Standard Drawings

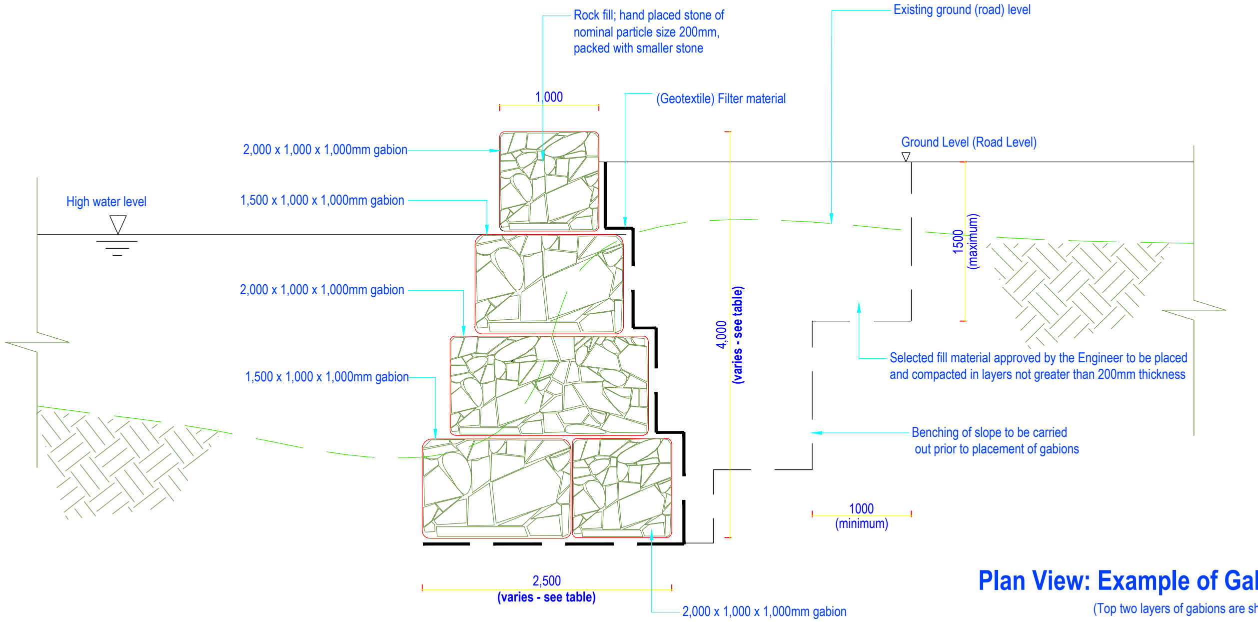
DRAWING TITLE : Typical plan and L.section for Wash
GROUTED STONE or DRY STONE PACKING SURFACE

SCALE : 1:50

DATE : March 2012

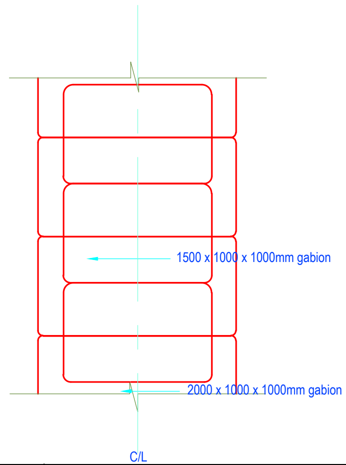
DRAWING NUMBER **SD14a**

Typical Cross Section
Gabion Retaining Wall & Land Protection



Plan View: Example of Gabion Placement

(Top two layers of gabions are shown only)



Retaining Wall Height, Base Width & Ground Pressure

Wall Heigth (m)	2	3	4	6	8	10	12
Base Width (m)	1.5	2	2.5	3.5	4.5	5.5	6.5
Ground Pressure (kPa)	20	70	90	120	150	190	230

NOTES:

1. Do not scale from drawing.
2. All dimensions in millimetres unless otherwise stated.
3. Material shall comply with PWD Technical Specification for road and bridge works.
4. Back fill material shall comply with PWD Technnical Specification for road and bridge works .
5. Earthwork excavation shall comply with PWD Technical Specification for road and bridge works.

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:		JH
CAD BY:		DM
REVISED BY:		WW
APPROVED BY:		SN

Public Works Department

Private Mail Bag 004

Tel: 22889 Fax: 24495

PWD Standard Drawings

DRAWING TITLE : Gabion Retaining Wall and Land Protection

SCALE : 1:50

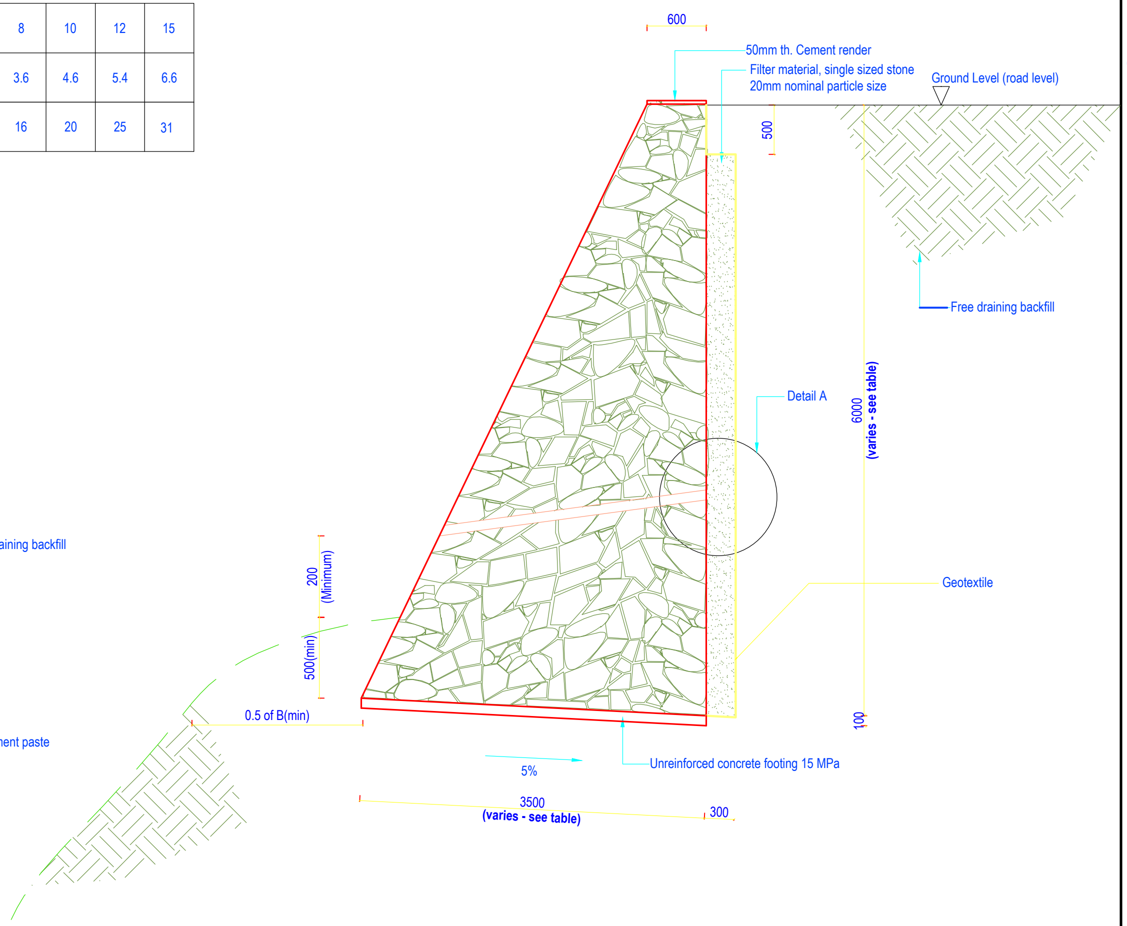
DATE : March 2012

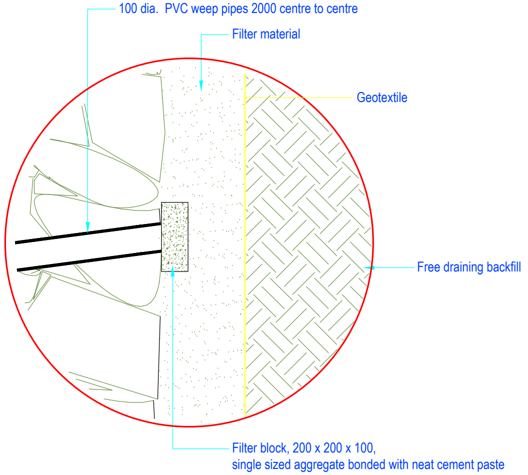
DRAWING NUMBER **SD15**

Typical Cross Section
Mortared Random Rubble Masonry Retaining Wall

Retaining Wall Height, Base Width & Ground Pressure

Wall Heigth (m)	2	3	4	6	8	10	12	15
Base Width(B) (m)	1.4	1.8	2.2	3.0	3.6	4.6	5.4	6.6
Ground Pressure (kPa)	4	6	8	12	16	20	25	31





Detail A

NOTES:

1. Do not scale from drawing
2. All dimensions in millimetres unless otherwise stated
3. Material shall comply with PWDTechnical Specification for road and bridge.
4. Concrete shall comply with PWD Technical Specification for road and bridge.
5. Mortar mix shall comply with PWD Technical Specification for road and bridge.
6. Earthwork excavation shall comply with PWD Technical Specification for road and bridge.

No.	DESCRIPTION	DATE
1.		

DESIGNED BY:		JH
CAD BY:		DM
REVISED BY:		WW
APPROVED BY:		SN

Public Works Department

Private Mail Bag 004

Tel: 22889 Fax: 24495

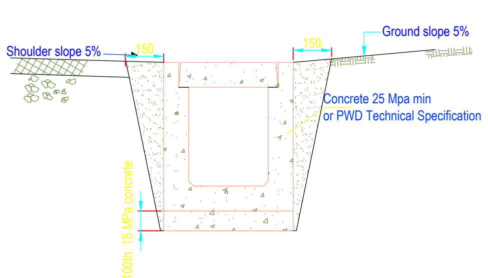
PWD Standard Drawings

DRAWING TITLE : Typical Mortared Random Rubble Masonry Retaining Wall

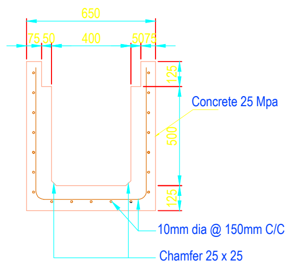
SCALE : 1:50

DATE : March 2012

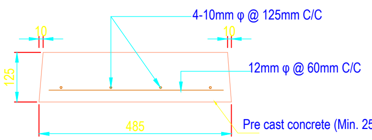
DRAWING NUMBER **SD16**



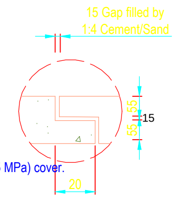
U-CONCRETE DRAIN: TYPE A



SECTION 1 - 1



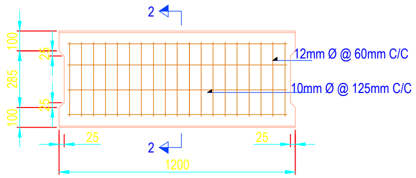
SECTION 2 - 2



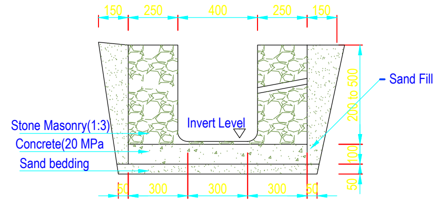
SECTION 3 - 3

NOTES

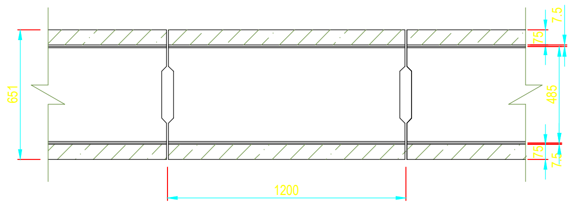
1. All dimensions are in millimeters unless otherwise specified
2. Concrete shall comply with PWD Technical Specification for road and bridge.
3. Reinforcement shall comply with PWD Technical Specification for road and bridge
4. Mortar shall comply with PWD Technical Specification for road and bridge.
5. Masonry side wall shall comply with PWD Technical Specification for road and bridge
6. Concrete cover shall comply with PWD Technical Specification for road and bridge
7. Stone shall comply with PWD Technical Specification for road and bridge



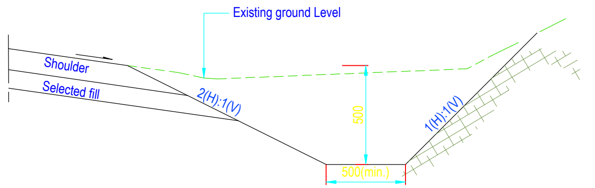
COVER SLAB-REINFORCEMENT



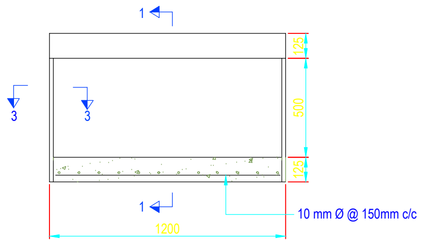
DETAILS SECTION OF STONE MASONRY SIDE DRAIN



PLAN OF COVER SLAB



EARTHEN SIDE DRAIN



LONGITUDINAL SECTION

TOP PLAN OF STONE MASONRY DRAIN

No.	DESCRIPTION	DATE			
			DESIGNED BY:		JH
			CAD BY:		DM
			REVISED BY:		WW
1.	GENERAL REVISION	30/09/10	APPROVED BY:		SN

Public Works Department

Private Mail Bag 004

Tel:22889 Fax:24495

PWD Standard Drawings

DRAWING TITLE :	Typical drawings for drainage (Line drain /unlined drain)
SCALE : 1 : 25	DATE : March 2012
DRAWING NUMBER	SD17

PART E

33 PART E – DOCUMENTATION ON TECHNICAL SPECIFICATIONS

34 Technical specifications

PUBLIC
WORKS
DEPARTMENT

STANDARD TECHNICAL
SPECIFICATION
FOR
ROAD AND BRIDGE WORKS

June 2014

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FORWARD

This specification has been adapted from the Papua New Guinea Department of Works '*Specification for Road and Bridge Works'*, August 1995, and incorporates sections from the draft Vanuatu Transport Sector Support Program (VTSSP) Phase I technical specification. The latest international best practice methods have also been incorporated through the assistance of VTSSP Phase II and the Climate Resilient Road Standards Project (CRRS).

The detail of this Specification is formulated to provide for general requirements relevant to Vanuatu and in a format that may be used for Force Account Works, Locally Bid Contracts or Internationally Bid Contracts. Because of the varied Contract Conditions and requirements of these different types of Contract formats, and the varied types of Projects to which they may refer, this Specification has been formulated with specific reference to where Supplementary Specification may be required, but including a default requirement in lieu of any Supplementary Specification where possible. These default requirements are based on either general conditions applicable in Vanuatu, or minimum requirements for construction.

To assist in reviewing the Specification for Special Provision requirements there follows, as part of this introduction, an index of Clauses in the General Specification that may have a requirement for a Supplementary Specification. This index should be reviewed and each Clause considered when preparing Contract documents.

Standards and Codes adopted for this Specification are those found to be the most commonly used over time in Vanuatu and thus any requirement for Testing Facilities can be met locally. Where Internationally Competitive Bidding is required the General Conditions of Contract should be written to allow for the possible inclusion of equivalent and acceptable Standards and Codes relevant to the source countries of the provider.

Any errors detected in this document, or suggested changes, should be notified to the Deputy Director of the Public Works Department (PWD), Ministry of Infrastructure and Public Utilities (MIPU).

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GROUP 1

GENERAL CLAUSES

1.1 SCOPE OF WORKS

See Supplementary Specification.

1.2 LOCALITY OF THE WORKS

See Supplementary Specification.

1.3 EXISTING SURVEYS AND MARKS

See Supplementary Specification.

1.4 STREAM CROSSINGS

See Supplementary Specification.

1.5 SITE CONDITIONS

See Supplementary Specification.

1.6 SCHEDULE OF DRAWINGS

See Supplementary Specification.

1.7 SITE INFORMATION

See Supplementary Specification.

1.8 TRAFFIC MANAGEMENT

1.8.1 General

The Contractor shall so arrange and plan his operations as to ensure that the least obstruction and inconvenience is caused to vehicular and pedestrian traffic.

The Contractor shall ensure that traffic control measures are in place at all times to ensure that both the safety of pedestrian and vehicular traffic is maintained and that the safety of the Contractor's employees is not compromised.

Where necessary, traffic control measures shall include traffic controllers with “GO” and “STOP” signs at both ends of sections of work in progress.

The details of temporary traffic diversion works and any temporary culverts or bridges which may be found necessary for the proper execution of the works shall be subject to the approval of the Construction Supervisor. Unless provided for elsewhere in the Contract the Contractor shall construct and maintain such diversions and temporary works to a standard as will ensure proper passage for traffic in all reasonable weather conditions.

Upon completion of the works, the Contractor shall remove all diversions and temporary works, restore all drainage and leave the area in a neat and tidy condition, all to the approval of the Construction Supervisor.

Where a new bridge is sited such that during construction the existing bridge cannot be used by normal traffic, the Contractor shall construct a temporary bridge and by-pass designed such that the interruption to the flow of normal traffic is minimised. All temporary bridges shall be designed to T33 loading as given by the AUSTROADS Bridge Design Code 1992a and shall be certified by a Structural Construction Supervisor and approved by the Construction Supervisor. The Contractor shall submit full details of their proposal to the Construction Supervisor. No work regarding temporary by-passes shall be constructed without the Construction Supervisor’s approval.

Closure of the road will not be permitted unless authorised by the Construction Supervisor in respect of particular periods of time and particular sections of road.

The Contractor shall erect and maintain temporary traffic warning signs in advance of any place on the road where his operations interfere with road traffic, and at all intermediate points where the new work crosses or coincides with an existing road. Barricades shall be erected and maintained in front of all obstructions clearly indicating temporary detours. Where traffic is diverted from its original channel and at excavations alongside the travelled way and elsewhere as directed, the edge of the road or detour shall be clearly delineated by guide markers firmly driven into the ground except where the Construction Supervisor permits portable guide markers to be employed. All warning signs, barricades and marker posts shall be constructed, painted and erected in accordance with the details shown on the drawings or as directed by the Construction Supervisor. The signs shall be adequately illuminated during the hours of darkness. The Contractor shall not be relieved of any liability under the Contract by the provisions of this Clause.

All existing road signs, guide posts, guard rails and suchlike road furniture which the Contractor requires to move for the necessary performance of the Works and which would otherwise remain, and all such existing road furniture which is required to be relocated on account of the road reconstruction, shall be dismantled with due care to avoid unnecessary damage and shall be reinstated at the location, and in the manner, directed by the Construction Supervisor. Existing road furniture which is to be removed but is not required to be installed shall remain the property of the Employer and shall be delivered to the nearest Public Works Department office or to such other site as directed by the Construction Supervisor.

The Contractor shall inform the local authorities and the police of all such activities to be carried out which may cause, or have the potential to cause, any significant interruptions or changes to the normal traffic patterns. Such information shall be made in writing and at least five (5) days before the beginning of such activities. Upon request from the

Contractor, the Construction Supervisor shall assist the Contractor in the coordination with the local authorities and the local police.

Any failure on the part of the Contractor to comply with the requirements of this Clause will entitle the Construction Supervisor to carry out such work as he deems to be necessary and to charge the Contractor with full costs thereof which sum will be deducted from any monies due or which may become due to the Contractor under the Contract.

1.8.2 Contractor's Traffic Management Plan

The Contractor shall prepare and submit a Traffic Management Plan for the Site and all other sites related to the Works, unless provided for in any Supplementary Specification, for the Construction Supervisor's approval, **prior to commencement of work at Site (Date for Commencement)**. The Contractor shall implement and maintain traffic control measures and systems in accordance with its conforming traffic management plan, from the Date for Commencement to the date of Practical Completion. If the Contractor does not submit a Traffic Management Plan within the deadline or the Construction Supervisor does not approve the Contractor's Traffic Management Plan, the Construction Supervisor shall:-

a) withhold the amount of **Vt1,000,000** from the next payment certificate and continue to withhold this amount until the next payment after the date on which the overdue Traffic Management Plan has been submitted and approved, or

b) apply a penalty from the next payment certificate of:-

1) **Vt100,000** for each week of late submission, and

2) **Vt100,000** for each submission which is not approved by the Construction Supervisor.

If the Construction Supervisor does not provide written comments within fourteen (14) days following submission, the Traffic Management Plan shall be deemed approved.

The Contractor's Traffic Management Plan shall include but shall not be limited to the following:

(a) The limits of the work site;

(b) Types of signs and devices needed;

(c) A sketch of the location and layout of the signs and devices;

(d) The time, day and date expected for the start and finish of the works;

(e) Contractor's contact details of their site supervisor (primary contact) and secondary contact (e.g. traffic supervisor).

1.8.3 Measurement and Payment

Payment of all necessary work as described in this Clause (1.8) shall be made as a lump sum for the amount stated in the Bill of Quantities for the provision of traffic control, and provision and maintenance of the temporary diversions or for the maintenance of existing roads during construction.

A fixed percentage of the total will be paid each month at the discretion of the Construction Supervisor. If the Contractor is not fully compliant with their approved Plan and/or the requirements of the Contract, the Construction Supervisor shall notify the Contractor in writing setting a time limit for correction. If the Contractor does not fully comply within the time given, a penalty corresponding to the importance of the deficiency will be applied to the monthly payment.

The amount shall be full compensation for furnishing and placing all materials including labour, equipment, tools, maintenance and incidentals necessary to meet all the requirements of the Clause.

1.9 SETTING OUT OF WORKS

Refer to relevant Clauses of the General Conditions of Contract.

Within fourteen (14) days of the Contractor so requesting, the Construction Supervisor shall establish sufficient pegs and level marks to permit the Contractor to prepare for the construction works, and the Contractor will be advised of the exact location of the Works in respect of these pegs.

The Contractor shall maintain all permanent and temporary survey marks and take precautions to prevent them being disturbed.

1.10 CONSTRUCTION PROCEDURES (BRIDGES)

The Contractor shall take into account the construction forces and effects in accordance with AS 5100.2 Clause 21.

The Contractor shall ensure that the erection procedures do not overstress the Permanent Works or are in any way detrimental to the Permanent Works. The Contractor is to pay particular attention to ensuring the stability of the Temporary Works, the Permanent Works and all components thereof at all times.

The Contractor is to submit his detailed erection proposal at least 7 days before commencement of erection of any members, and approval by the Construction Supervisor.

The Contractor shall be fully responsible for the safety and adequacy of the adopted erection procedure.

1.11 LOADING LIMIT ON PUBLIC ROADS

The Contractor’s attention is drawn to the vehicle weight limits laid down in the Road Traffic Control Act, Part 3, Paragraph 21. The Act shall apply to all traffic, including construction traffic, on any existing or completed works within the bounds of the Contact Works and for any construction traffic travelling outside the bounds of the Contract Works. Likewise any specific gross load limits for any structure shall be observed.

1.12 PUBLIC UTILITIES

Where the Works come into conflict with any Public Utilities that are not shown on the Drawings, the Contractor shall notify the Construction Supervisor immediately this is detected. The Contractor shall be required to co-ordinate his operation with the Public Authority, if a relocation is required, or shall protect the facility if it is to be retained in place. No additional cost will be allowed for this work and the relevant allowance should be made in the Billed Rates for Works likely to be affected.

Should the Construction Supervisor direct the Contractor to make the necessary arrangements and payment for relocation of Public Utilities this work shall be paid on presentation of invoices with an allowance for Contractor's on-costs under the relevant Billed Items.

1.13 PRIVATE UTILITY SERVICES

Where Private Utility services require alteration this shall be arranged and co-ordinated by the Contractor. There shall be no additional payment made for this work and any allowance for this work shall be deemed to be included in the relevant Billed Items for construction of the Works.

1.14 HIV/AIDS PREVENTION

1.14.1 General

The Contractor shall prepare and submit a HIV/AIDS Awareness and Information Programme for the Site and all other sites related to the Works, unless provided for in any Supplementary Specification, for the Construction Supervisor's approval, **prior to commencement of work at Site (Date for Commencement)**. The Contractor shall implement and manage the HIV/AIDS Awareness and Information Programme, from the Date for Commencement to the date of Practical Completion. If the Contractor does not submit a HIV/AIDS Awareness and Information Programme within the deadline or the Construction Supervisor does not approve the Contractor's HIV/AIDS Awareness and Information Programme, the Construction Supervisor shall:-

a) withhold the amount of **Vt1,000,000** from the next payment certificate and continue to withhold this amount until the next payment after the date on which the overdue HIV/AIDS Awareness and Information Programme has been submitted and approved, or

b) apply a penalty from the next payment certificate of:-

    1) **Vt100,000** for each week of late submission, and

    2) **Vt100,000** for each submission which is not approved by the Construction Supervisor.

If the Construction Supervisor does not provide written comments within fourteen (14) days following submission, the HIV/AIDS Awareness and Information Programme shall be deemed approved.

A HIV/AIDS Awareness and Information Programme shall use the services of a qualified service provider, who shall be nominated for the Employer's approval, and shall undertake such other measures as to reduce the risk of the transfer of the HIV virus between and among the Contractor's personnel and their families and the local community, to promote voluntary early diagnosis, and to assist affected individuals. If the Contractor does not conduct a HIV/AIDS Awareness and Information Programme as required, the Employer may employ a qualified service provider to provide the required services which the Contractor should have provided and recover the expenses the Employer has incurred from payments otherwise due to the Contractor or, if no payment is due, the payment of the expenses shall be a debt due.

For the purpose of this Clause 1.14:

- "an Approved Service Provider" means a person or entity approved by the Vanuatu National AIDS Committee (VNAC) and the HIV Unit of the Ministry of Health to provide the HIV/AIDS Awareness Programme;
- the "Contractor's Personnel" or "Construction Workers" means, without prejudice to any other definition contained in the Contract, all personnel, who are under the Contractor's control and on the Site in connection with the Contract, including any workers who are under the control of any person or entity to whom the Contractor has subcontracted any of his obligations under the Contract other than those responsibilities set out in this Clause;
- "the HIV/AIDS Awareness Programme" means a HIV awareness programme in compliance with the HIV Awareness Programme curriculum and guidelines published by UNAIDS and/or VNAC and/or the HIV Unit of the Ministry of Health;
- "the Local Community" means the communities local to the Site most likely to have contact with the Contractor's Personnel and, in particular, vulnerable groups and sex workers in those communities;
- "Vanuatu National AIDS Committee" is the authority designated by the Vanuatu national government to have responsibility for preventing and/or combating HIV-AIDS;
- "UNAIDS" shall mean the agency of the United Nations of that name or the United Nations Regional Task Force on mobile population and HIV vulnerability;
- Abbreviations:

  STI – Sexually Transmitted Infection
  HIV – Human Immunodeficiency Virus
  AIDS – Acquired Immune Deficiency Syndrome

1.14.2 Awareness Program

It shall be a requirement of the Contract that the Contractor:

- Subcontracts with an Approved Service Provider to provide a HIV Awareness Programme to the Contractor's Personnel and the Local Community as soon as practical after the Contractor's Personnel arrive at Site but in any case within two (2) weeks, and to repeat the HIV Awareness Programme at intervals not exceeding two (2) months;
- Gives any representative of the Approved Service Provider, the Employer and VNAC and the HIV Unit of the Ministry of Health all reasonable access to the Site in connection with the HIV Awareness Programme;
- If the VNAC or the HIV Unit of the Ministry of Health has not provided the names of available Approved Service Providers within two weeks of being asked the

Contractor may select its own service provider after consultation with the appropriate UNAIDS and/or VNAC office and/or the HIV Unit of the Ministry of Health;

- Instruct the Contractor's personnel to attend the HIV/AIDS Awareness Programme in the course of their employment and during their normal working hours or any period of overtime provided for in the relevant employment contracts and uses all reasonable endeavours to ensure this instruction is followed;
- Provides suitable space for delivery of the HIV/AIDS Awareness Programme and does nothing to dissuade the Contractor's Personnel from attending the HIV/AIDS Awareness Programme;
- As soon as practicable, notifies the VNAC and the HIV Unit of the Ministry of Health of its subcontract with an Approved Service Provider to facilitate the VNAC's or the HIV Unit of the Ministry of Health audit of Approved Service Providers;
- Gives all reasonable cooperation to the VNAC and the HIV Unit of the Ministry of Health if it exercises its right to audit the provision by the Approved Service Provider of the HIV/AIDS Awareness Programme;
- Makes condoms complying with the requirements of ISO 4074 or 23409 available to all Contractor's Personnel at readily accessible points on the site, suitably protected from the elements, for the duration of the Contract;
- Either place and maintain HIV/AIDS awareness posters of size not less than A1 in areas which are highly trafficked by Contractor's Personnel, or provide Contractor's Personnel with a pamphlet, in languages largely understood by the Contractor's Personnel;
- Encourages voluntary HIV/STI testing, provides information on services concerning counselling, support and care of those that are infected.

The outcomes of the HIV/AIDS Awareness Programme shall as a minimum, result in Contractor's personnel exposed to such a programme being able to:

- communicate the existence of problems of HIV and be able to outline the consequences of transmission of HIV to or from the Local Community;
- recall and communicate the mode of HIV transmission and preventative measures including the proper use of the condom;
- be aware of the advantages of abstinence/avoidance.

1.14.3 Measurement and Payment

The Contractor shall complete and submit a HIV/AIDS Compliance Report Form (attached) with each monthly claim. The associated unit rates in Group 1 of the Bill of Quantities shall include full compensation for any temporary or permanent items required to complete the HIV/AIDS Awareness and Information Programme, the on-going availability of condoms, and posters and other materials, to the satisfaction of the Construction Supervisor.

The unit of measurement for the provision of the HIV-AIDS awareness and information programme and activities shall be a Lump Sum item, per item 1.14a. Progressive payments of the tendered lump sum amount in the Bill of Quantities for the preparation and implementation of the Contractor's approved HIV-AIDS Awareness and Information Programme on the following basis:

- 30% of the tendered lump sum amount on acceptance of the Contractor's approved HIV-AIDS Awareness and Information Programme.
- The balance of 70% on a pro-rata basis based on the value of work completed during the period.

If the Contractor is not fully compliant with their approved HIV-AIDS Awareness and Information Programme and/or the requirements of the Contract, the Construction Supervisor shall notify the Contractor in writing setting a time limit for correction. If the Contractor does not fully comply within the time given, a penalty corresponding to the importance of the deficiency will be applied to the monthly payment.

The unit of measurement for the maintenance and restocking of condoms dispensers, and the maintenance of the HIV-AIDS awareness and information posters, shall be a lump sum per item 1.14b, which will only be paid upon approval by the Construction Supervisor.

HIV/AIDS Compliance Report
(SAMPLE FORM)

Contract No. ____________________

Payment Claim No: ____________________

Period covered by Payment Claim: ____________________

1. Distribution of condoms (briefly describe where and how condoms are distributed):

2. Poster/pamphlets (briefly describe where posters were placed/how pamphlets were distributed):

3. Voluntary HIV/STI testing (briefly describe the actions taken/information provided to promote testing):

4. Counselling, support and care (summarize information provided):

5. Schedule of Contractor's Personnel exposed to the HIV/AIDS Awareness Programme:

(Attach list of personnel stating the Names, Trade/Occupation, Name of Employer)

I hereby declare the above to be a true reflection of actions taken to ensure compliance with the Specification.

Name: ____________________

Position: ____________________

Date: ____________________

1.15 SAFETY

1.15.1 General

The Contractor shall be responsible for the safety of all activities on the Site and shall comply with all relevant provisions of the Vanuatu **Health and Safety at Work Act** and the **Public Works Department Work Safety Guidelines** (if available).

The Contractor shall ensure that all Contractors Personnel wear personal protective equipment. This includes, but not limited to, safety vests (hi-viz), hard hat (if required) and appropriate foot wear. Contractors Personnel undertaking concrete works are to be provided with gloves, masks and rubber boots as appropriate. Masks and/or ear protection are to be used as required.

Children are not allowed on the work site, at any time. This applies to <u>all</u> sites, including routine maintenance activities.

For the purpose of this Clause 1.15:

- "Contractor's Personnel" means, without prejudice to any other definition contained in the Contract, all personnel, who are under the Contractor's control and on the Site in connection with the Contract, including any workers who are under the control of any person or entity to whom the Contractor has subcontracted any of his obligations under the Contract other than those responsibilities set out in this Clause.

1.15.2 Contractor's Safety Programme

The Contractor shall prepare and submit a Safety Programme for the Site and all other sites related to the Works, unless provided for in any Supplementary Specification, for the Construction Supervisor's approval, **prior to commencement of work at Site (Date for Commencement)**. The Contractor shall implement and maintain safety control measures and systems in accordance with its conforming safety programme, from the Date for Commencement to the date of Practical Completion. If the Contractor does not submit a Safety Programme within the deadline or the Construction Supervisor does not approve the Contractor's Safety Programme, the Construction Supervisor shall:-

a) withhold the amount of **Vt1,000,000** from the next payment certificate and continue to withhold this amount until the next payment after the date on which the overdue Safety Programme has been submitted and approved, or

b) apply a penalty from the next payment certificate of:-

   a. **Vt100,000** for each week of late submission, and

   b. **Vt100,000** for each submission which is not approved by the Construction Supervisor.

If the Construction Supervisor does not provide written comments within fourteen (14) days following submission, the Safety Programme shall be deemed approved.

The Contractor's Safety Programme shall be in compliance with the Vanuatu **Health and Safety at Work Act** and the **Public Works Department Work Safety Guidelines** (if available) and shall include but shall not be limited to the following:

(a) Contractor's Safety Policy;

(b) Description of Contractor's organization structure, identifying supervisory and safety personnel, job descriptions, responsibilities, authority and functions;

(c) Programme for the dissemination of safety information, material safety data and the conduct of safety awareness, on site from the Date for Commencement to the intended completion date;

(d) Programme for the regular safety inspection of all plant and equipment and for ensuring the Contractor's operators are appropriately licensed;

(e) Identification of all work activities on site with clear descriptions of safety procedures and measures to be implemented during each work activity, including the use of necessary protective equipment for each work activity;

(f) Description of emergency procedures, including responses to accidents and injury, emergency evacuation plans, the supply, use and locations of first aid kits, provisions for rescue and other emergency equipment and personnel, as may be required by the Construction Supervisor;

(g) Description of fire prevention measures and the supply and location of fire fighting equipment;

(h) Description of the safety programme administrative arrangements, including the flow of and filing of communications and correspondences, record keeping, investigating and reporting procedures for incidents resulting in death, injury, loss of work-time, damage to equipment and or property.

Additional to the above minimum requirements, the Contractor shall undertake the following:

(a) Provide an appropriately equipped first-aid 'station' in each construction camp. Arrangements for emergency medical services shall be made to the satisfaction of the Construction Supervisor;

(b) Keep records of all safety and protective equipment and clothing provided by the Contractor to workers and staff;

(c) Safety induction courses for all Contractor's Personnel. All such workers and staff shall attend a safety induction course within their first week on Site. The information and instructions and attendees at each induction course shall be recorded for monitoring purposes;

(d) Periodic safety training courses conducted not less than once every three (3) months. All Contractor's Personnel shall participate in relevant training courses appropriate to the nature, scale and duration of the Project Works. The material provided and attendees at each of the training courses shall be recorded for monitoring purposes;

(e) Abbreviated safety induction course which shall be attended by visiting Employer's Personnel and other authorised visitors on their first visit to the site and at appropriate intervals thereafter;

(f) For new work activities the Contractor shall conduct the equivalent of ‘tool box’ talks at the start of the activity covering the methodology of the proposed work and in particular shall address all safety aspects including the proper use of any associated machinery and safety equipment associated with the proposed work. The material provided and attendees at each of the training courses shall be recorded for monitoring purposes;

(g) For more complex work activities that may or may not be included within the scope of Works – e.g. bridge construction - or components of work – e.g. bridge launching - the Employer through the Construction Supervisor may specifically instruct the Contractor to undertake a formal Job Safety Analysis (JSA) and an associated Work Method Statement (WMS) which shall be submitted and approved by the Construction Supervisor prior to the work activities being undertaken. In such instances an approved format proforma for both JSA and WMS shall be supplied by the Employer.

(h) Safety meetings shall be conducted on a monthly basis. The minutes of all safety meetings will be recorded and forwarded to the Construction Supervisor within seven (7) days of the meeting. The Contractor shall inform the Construction Supervisor seven (7) days in advance of the dates of these meetings and the Construction Supervisor may attend at their discretion.

(i) All vehicles (construction equipment, trucks, 4x4s and cars) should have basic first aid kits and fire extinguishers, and all operators/drivers should have undergone a basic first aid training course. Records of training shall be available for review by the Construction Supervisor if requested.

(j) All stores and offices should have at least one chemical fire extinguisher mounted on the wall in close proximity to the entrance. The extinguisher(s) should be checked regularly. Empty or partially used extinguishers shall be refilled immediately. All store personnel, operators/drivers, and administration staff are required to have been trained in the proper use of a fire extinguisher. Records of training shall be available for review by the Construction Supervisor if requested.

1.15.3 Measurement and Payment

The unit of measurement for the provision and implementation of the Contractor’s approved safety programme shall be a Lump Sum item. A fixed percentage of the total will be paid each month upon the Construction Supervisor’s certification of satisfactory performance.

If the Contractor is not fully compliant with their approved Safety Programme and/or the requirements of the Contract, the Construction Supervisor shall notify the Contractor in writing setting a time limit for correction. If the Contractor does not fully comply within the time given, a penalty corresponding to the importance of the deficiency will be applied to the monthly payment.

1.16 ENVIRONMENTAL PROTECTION

1.16.1 General

The Contractor shall be responsible for protection of the environment at the Site and all other sites related to the Works. The Contractor shall comply with all relevant provisions of the **Environmental Management and Conservation Act** and the **Public Works Department Environmental Guidelines** (if available).

1.16.2 Contractor's Environmental Management Plan (CEMP)

The Contractor shall prepare, implement and maintain a Contractor's Environmental Management Plan (CEMP) for the Site and all other sites related to the Works, unless provided for in any Supplementary Specification, for the Construction Supervisor's approval. The CEMP shall cover the environmental protection practices, resources and sequence of activities required to comply with all the requirements of relevant environmental legislation, conditions of any applicable licence, approval and permit and this Specification.

The CEMP shall be submitted to the Construction Supervisor **within twenty eight (28) days after the Contract Signing and prior to commencement of work at Site (Date for Commencement).** Subject to the approval of the Construction Supervisor, the CEMP may be revised progressively to suit the construction stages. The CEMP should be formally reviewed at least every 12 months. If the Contractor does not submit a CEMP within the deadline or the Construction Supervisor does not approve the CEMP, the Construction Supervisor shall:-

a) withhold the amount of **Vt1,000,000** from the next payment certificate and continue to withhold this amount until the next payment after the date on which the overdue CEMP has been submitted and approved, or

b) apply a penalty from the next payment certificate of:-

   a. **Vt100,000** for each week of late submission, and

   b. **Vt100,000** for each submission which is not approved by the Construction Supervisor.

If the Construction Supervisor does not provide written comments within fourteen (14) days following submission, the CEMP shall be deemed approved.

The Contractor's Environmental Management Plan shall be in compliance with the Vanuatu **Environmental Management and Conservation Act** and the **Public Works Department Environmental Guidelines** (if available) and shall include but shall not be limited to the following:

(a) Contractor's Environment Policy;

(b) Description of Contractor's organization, identifying supervisory and personnel responsible for implementation of its Environmental Management Plan, including organization structure and job descriptions showing functions, responsibilities and authority;

(c) Programme for the dissemination of environmental protection information and the conduct of environmental awareness, on site and in neighbouring communities from the Date for Commencement to the intended completion date;

(d) Programme for the regular environmental compliance inspection of all plant and equipment;

(e) Identification of all work activities and determination of possible environmental impacts of the activities at all work locations, including but not limited to: roadworks, camps, quarries and pits, stockpile and storage sites, fuel dumps, spoil heaps and disposal dumps, etc;

(f) Description of community consultations and local social issues;

(g) Description of procedures and environmental protection measures to be implemented during each work activity, including but not limited to: erosion and sediment control, disposal of stormwater runoff, contaminant spill prevention, water sources protection; protection of wildlife, wildlife habitats, conservation areas, the affects of climate change, archaeological and burial sites, rehabilitation of work sites, including camps, quarries and pits, dump and storage sites, etc., and dust, noise and vibration mitigation measures;

(h) Description of emergency procedures and measures for hazardous material spills, the supply, storage, maintenance, and use of emergency spill kits, as may be required by the Construction Supervisor;

(i) Description of procedures and environmental measures for the disposal of excess and waste materials and the decommissioning of work sites, camps and quarries;

(j) Description of procedures on how corrective and preventive actions will be implemented and closed out;

(k) Plans showing the type and location of environmental protection measures in relation to roadworks, camp sites, quarries, stockpiles, spoil heaps and waste disposal sites, water sources, archeological, burial and any conservation sites, fuel and oils storage, workshops, plant and equipment storage sites, etc.;

(l) Strategy for the provision of relevant environmental site induction for Contractor's Personnel

(m) Description of the Environmental Management Plan administrative arrangements, including the flow of and filing of communications and correspondences, record keeping and reporting procedures.

The CEMP shall be reviewed by the Contractor monthly and revised if necessary to close out any non-conformances and revised copies shall be issued to the Construction Supervisor for approval.

The Contractor shall supply all Subcontractors with copies of the approved CEMP and shall incorporate into all Subcontracts measures to ensure compliance with the approved CEMP at all tiers of the subcontracting.

The Tender documents issued will contain an EMP and the Contractor must prepare the CEMP in response to, and in compliance with, the EMP. The conditions of the EMP are contractually binding. The Contractor shall ensure that all relevant environmental and safety information and requirements as set out in the Contract and the CEMP are adequately communicated to all Contractor's Personnel, and shall ensure that all Contractor's Personnel understand the manner in which they are required to comply with those requirements. Non compliance with the CEMP is non compliance with the contract and may result in penalties.

Before commencing work on Site, all Contractor's Personnel shall have attended the induction which is to include, but not be limited to:

1. purpose, objective and key issues of the Contractor's Environmental Management Plan;
2. due diligence and duty of care;
3. conditions of environmental licenses, permits and approval;
4. environmental emergency plans;
5. reporting process for Environmental harm/ incidents;
6. key issues; and
7. site specific issues such as boundaries for vegetation clearing, locations of refuse bins, washing, sewage removal and refuelling and maintenance of vehicles, plant and equipment.

The Contractor shall maintain a register of those inducted. The register is to contain, but not be limited to, the name of trainees, date trained, elements of training delivered and the name of the trainer.

Should an environmental incident occur during any construction phase, the Contractor shall immediately take the appropriate action to minimise any impact and inform the Construction Supervisor. The Contractor shall carry out any instructions received from the Construction Supervisor.

The Contractor is responsible for the remedy and/or clean up of any contamination caused by the construction Works and no additional payment will be made in this regard.

The Contractor shall record any non–conformances with the procedures of the CEMP. Where a non-conformance is reported the Contractor shall advise the Construction Supervisor and provide a copy of all relevant non-conformance reports.

The Contractor shall provide a monthly summary of any non–conformances to the Construction Supervisor within their monthly Progress Claim.

1.16.3 Measurement and Payment

The unit of measurement for the provision and implementation of the approved Contractor's Environmental Management Plan shall be a Lump Sum item. A fixed percentage of the total will be paid each month upon the Construction Supervisor's certification of the satisfactory performance.

If the Contractor is not fully compliant with their approved CEMP and/or the requirements of the Contract, the Construction Supervisor shall notify the Contractor in writing setting a time limit for correction. If the Contractor does not fully comply within the time given, a penalty corresponding to the importance of the deficiency will be applied to the monthly payment.

1.17 QUALITY ASSURANCE

1.17.1 General

The Contractor shall be responsible for the quality of the Works and compliance with the requirements of the Specifications and the Drawings.

1.17.2 Contractor's Quality Control Plan

The Contractor shall prepare and submit a Quality Control Plan (QCP) for the Works, unless provided for in any Supplementary Specification, for the Superintendent's approval, **prior to commencement of work at Site (Date for Commencement)**. If the Contractor does not submit a QCP within the deadline or the Construction Supervisor does not approve the QCP, the Construction Supervisor shall:-

a) withhold the amount of **Vt1,000,000** from the next payment certificate and continue to withhold this amount until the next payment after the date on which the overdue QCP has been submitted and approved, or

b) apply a penalty from the next payment certificate of:-

   a. **Vt100,000** for each week of late submission, and

   b. **Vt100,000** for each submission which is not approved by the Construction Supervisor.

If the Construction Supervisor does not provide written comments within fourteen (14) days following submission, the QCP shall be deemed approved.

The QCP shall include but is not limited to the following:

(a) Contractor's Quality Policy;

(b) Description of the Contractor's and project organization, identifying personnel responsible for the implementation of its QCP, organization structure and job descriptions detailing quality control personnel qualifications, experience, authority, responsibilities and functions;

(c) Description and details of all setting out for construction control requirements;

(d) Identification of the materials and workmanship to be inspected and tested and arrangements for material storage areas, the management and maintenance of storage areas and procedures for receiving and shipping materials;

(e) Identification of inspections and tests to be conducted, the methods and frequency for tests and inspections, as may be specified in the Specifications or by the Construction Supervisor and any external organizations, laboratories or subcontractors, to be employed in the inspections and or testing;

(f) The acceptance criteria and standards to be applied for inspection and testing of materials and workmanship and the corrective action in the event of non-compliance, as may be specified in the Specifications or by the Construction Supervisor;

(g) Description of the quality control system administrative arrangements, including the flow of and filing of communications and correspondences, record keeping and reporting procedures.

1.17.3 Measurement and Payment

The unit of measurement for the provision and implementation of the Contractor's approved Quality Control Plan shall be a Lump Sum item. A fixed percentage of the total will be paid each month upon the Construction Supervisor's certification of the satisfactory performance.

If the Contractor is not fully compliant with their approved QCP and/or the requirements of the Contract, the Construction Supervisor shall notify the Contractor in writing setting a time limit for correction. If the Contractor does not fully comply within the time given, a penalty corresponding to the importance of the deficiency will be applied to the monthly payment.

1.18 COMMUNITY LIAISON

1.18.1 General

The Contractor has an obligation to respect the rights, expectations, culture and property of local communities, and to work in harmony so as to avoid conflict with the communities at all times.

The Contractor shall at all times take all reasonable precautions to prevent any unlawful, riotous or disorderly conduct by and/or amongst Contractor's Personnel and for the preservation of peace and protection of all persons and property in the neighbourhood of the Works against the same.

The Contractor shall:

1. Visit all affected communities before commencing work on Site to explain construction activities in company with the Provincial Planner, a representative of the Provincial Council of Chiefs and the relevant Community Chief(s) or his/their nominated liaison persons - whose names shall be advised to the Contractor by the Construction Supervisor.
2. Be responsible for the issuing of payments to the Community Chief(s) or their nominated liaison person(s) at a rate specified in the Agreements established between the Contractor and each Community through its respective Community Chief.
3. Treat all chiefs, elders, landowners and villagers with respect and ensure that all Contractor's Personnel do likewise.
4. Within the Gender Awareness Plan establish a Code of Practice towards women and girls to be adhered to by all Contractor Personnel. This Code of Practice shall be included within the Contractor's Induction(s) and a copy shall be issued to the Construction Supervisor.
5. Not discriminate against persons with disabilities either employed or seeking work provided that they would be able to adequately perform the duties of the position.

1.18.2 Contractor's Community Liaison Plan (CLP)

The Contractor shall prepare and submit a Community Liaison Plan (CLP) for the Works, unless provided for in any Supplementary Specification, for the Superintendent's approval, **prior to commencement of work at Site (Date for Commencement)**. If the Contractor does not submit a CLP within the deadline or the Construction Supervisor does not approve the CLP, the Construction Supervisor shall:-

a) withhold the amount of **Vt1,000,000** from the next payment certificate and continue to withhold this amount until the next payment after the date on which the overdue CLP has been submitted and approved, or

b) apply a penalty from the next payment certificate of:-

   a. **Vt100,000** for each week of late submission, and

   b. **Vt100,000** for each submission which is not approved by the Construction Supervisor.

If the Construction Supervisor does not provide written comments within fourteen (14) days following submission, the CLP shall be deemed approved.

The CLP shall include but is not limited to the following:

- Name and contact details of the Community Liaison Officer.
- Details of how the Contractor intends to comply with Sub-Clause 1.18.4 Induction program.
- Details of how the Contractor intends to comply with Sub-Clause 1.18.5 Gender Awareness.
- Details of how the Contractor intends to comply with Sub-Clause 1.18.6 Stakeholder Committees.
- Details of how the Contractor intends to comply with Sub-Clause 1.18.7 Local Labour.
- Details of how the Contractor intends to comply with Sub-Clause 1.18.8 Grievance Resolution.

1.18.3 Community Liaison Officer (CLO)

The Contractor shall appoint a Community Liaison Officer who shall be responsible for liaison with the Provincial Planner, the Island Council of Chiefs and community chiefs or their nominated liaison persons for undertaking community liaison management tasks as required herein.

The CLO shall liaise, meet, discuss, negotiate, discuss and resolve issues and/or potential issues, and undertake any other duties as may be necessary to maintain a professional and cooperative working relationship with each Community group.

The responsibilities of the CLO shall include, but not be limited to, the following:

(a) Coordinate the induction of all Contractor's Personnel concerning social behaviour, relevant cultural practices, gender awareness, relations with local people (especially women and children), and health and safety issues.

(b) Coordinate the formation of a Stakeholder Committee to provide an open forum to discuss the Works and its effect upon the communities.

(c) Coordinate the implementation of the HIV / AIDS Awareness and Information Program as required by the Contract.

(d) Enhance public awareness of the works related to: the benefits to community; start and finish days and working hours; measures taken to minimise traffic and access disruptions, erosion and sedimentation and other environmental impacts.

(e) Assisting to resolve community related issues, with the aim of preventing disputes.

(f) Develop and implement a formal Grievance Redress Procedure.

(g) Assisting the implementation of the Contractor's Environmental Management Plan (EMP).

(h) Assisting in the social and general awareness for the Contractor's personnel, as required by the Contract.

(i) Assisting the implementation of the Gender Awareness requirements of the Contract.

(j) Assisting in the employment of Local Labour as per the Contract.

(k) Assisting to enhance road safety and disability prevention awareness among the Contractor's Personnel and communities affected by the Contract.

1.18.4 Induction

The Contractor shall induct all Contractor's Personnel concerning social behaviour, relevant cultural practices, gender awareness, relations with local people (especially women and children), and health and safety issues. The format and contents of the induction program shall be approved by the Construction Supervisor. The Contractor shall maintain records of the Induction to demonstrate that all Contractor's Personnel on the site have been inducted.

1.18.5 Gender Awareness

The Contractor, through its nominated CLO shall establish and implement a Gender Awareness Program (GAP) to promote opportunities for women as participants in, and beneficiaries, of development.

The GAP shall aim to:

1. Improve women's awareness of health care and economic resources;
2. Promote women's participation and leadership in decision-making at all levels;
3. Promote human rights of women and assist efforts to eliminate discrimination against women.
4. Include an information handout outlining the objectives of gender awareness, social behaviour and summarising the contractor's proposed plan for the works
5. Ensure all Contractor's Personnel are given the information handout and the code of practice and are inducted in social and gender awareness.
6. Actively encourage compliance with the gender awareness plan and the code of practice and by monitoring the success of the procedure through regular feedback.
7. Provide employment opportunities for both genders – as much as is practical - on the basis of equality.

At bi-monthly intervals and also immediately before the issue of a Taking-Over Certificate, the Contractor shall prepare a progress report in relation to gender awareness and submit it to the Construction Supervisor.

1.18.6 Stakeholder Committees

The Contractor through its nominated CLO shall also arrange for a Stakeholder Committee to be formed as to provide an open forum to discuss the Works and its effect upon the communities. Membership of the Stakeholder Committee will consist of members of the Island Council of Chiefs, a women's representative together with representatives from the Provincial Government, the Construction Supervisor and the Contractor. Meetings shall be chaired by the Construction Supervisor. Minutes of the meeting shall be made and distributed by the Contractor.

Meetings of the Stakeholder Committee shall be convened on a monthly basis by the Contractor or at such other intervals as agreed by the Committee. Additional meetings may be convened by any committee representative to address urgent issues.

The Contractor shall provide a suitable venue for the conduct of the meetings of the Stakeholder Committee and shall make reasonable transport and facilitation arrangements for the representatives of the local community to attend. The venue shall be covered against sun and rain. The Contractor shall attend all meetings.

The Contractor shall co-operate with the Stakeholder Committee and shall inform the Stakeholder Committee of future associated work plans, site requirements, labour and materials requirements, and any problems within the Works.

Where implementation of the meeting's decisions affects the conduct of the Contract, the Contractor shall refer the decision, and advise the expected effect on the Contract, to the Construction Supervisor. Actions arising from the Stakeholders Committee decisions which affect the Contract will be dealt with in accordance with the Contract.

1.18.7 Local Labour

The Contractor shall, to the extent reasonable and practical, sub-contract local community and women's groups (from within the boundaries of relevant Nakamal) for suitable aspects of the Works.

Where reasonable and practical, the Contractor should not sub-contract labour for Works outside their Nakamal boundaries. In circumstances where this is unavoidable approval from the associated Community Chiefs shall be first obtained.

All unskilled labour contracted and/or employed for the Works shall be Ni-Vanuatu unless it can be proven by the Contractor that the necessary numbers of unskilled labourers required for the Works cannot be reasonably obtained. In this case, the Contractor shall present to the Construction Supervisor for his approval, a written submission supporting his case for the use on non-indigenous unskilled personnel.

Any foreign personnel included within the Contractor's Personnel shall be specifically nominated. Including sub-contractors, the residency status of all foreign Personnel shall fully comply with the requirements of the Immigration and Labour Act of the Government of Vanuatu.

1.18.8 Grievance Resolution

The Contractor shall immediately verbally inform the Construction Supervisor of any incident and/or complaint and/or situation that may potentially result in conflict or otherwise threaten good relationships with the local population. The Contractor shall also inform the Construction Supervisor in writing of each and every such event within three (3) days of occurrence or awareness of any such incident and/or complaint and/or situation.

The Contractor through its nominated CLO shall develop and implement a formal Grievance Redress Procedure with clear mechanisms for dealing with the resolution of complaints.

The Contractor shall set up and maintain a Register of Complaints, which shall include:

- Time and date of complaint;
- Type of communication (face to face, telephone, written, etc);
- Person(s) to whom the complaint is directed;
- Name, address and contact details of complainant;
- Details of complaint;
- Action planned and taken to settle the matter;
- Confirmation that resolution has been reached to the satisfaction of all parties.

The Register of Complaints shall be available at all times for inspection by the Construction Supervisor during the Works and shall be submitted to the Employer at the conclusion of the Contract.

In the event that a complaint cannot be resolved in discussions with the complainant, the Contractor shall prepare a report for the Construction Supervisor who will direct the Contractor as to the course of action to be followed. The Construction Supervisor and the Contractor shall participate bona fide in any meetings and discussions that take place as part of the said Dispute Resolution Process but shall be bound only by the terms of the Contract.

1.18.9 Measurement and Payment

A monthly summary of the community liaison activities shall be submitted with the Contractor's Monthly Report required by the Contract. Payment for the community liaison services shall be a Lump Sum item. A fixed percentage of the total will be paid each month upon the Construction Supervisor's certification of the satisfactory performance.

If the Contractor is not fully compliant with their approved CLP and/or the requirements of the Contract, the Construction Supervisor shall notify the Contractor in writing setting a time limit for correction. If the Contractor does not fully comply within the time given, a penalty corresponding to the importance of the deficiency will be applied to the monthly payment.

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GROUP 2

ESTABLISHMENT

2.1 CONTRACTOR'S ESTABLISHMENT

2.1.1 General

The Contractor shall provide and maintain all plant and equipment necessary to carry out the Works, all necessary temporary accommodation, sheds and stores, and remove same from the Site on completion of the Works.

All accommodation, sheds and storage areas shall meet with any relevant Health and Safety Regulations, and shall be sufficient in size and comfort to accommodate the Contractor's staff in a manner approved by the Construction Supervisor.

Provision shall be made for the collection and disposal of all wastes generated from the aforementioned facilities in a manner approved by the Construction Supervisor.

2.1.2 Establishment Item in Bill

Unless provided for in any Supplementary Specification to this General Specification, or itemised individually in the Bill of Quantities, the item for the Contractor's Site Establishment shall include for the following:

(i) The provision and transportation to site of all plant, vehicles, equipment, stores and materials not to be incorporated into the Works, and all temporary buildings and accommodation for the Contractor's use necessary for the construction of the Works to commence.

(ii) The erection of all temporary buildings and accommodation for the Contractor's use.

(iii) The provision of all buildings services, including electricity, water and appropriate waste disposal facilities necessary for the Contractor's use.

(iv) Any other expense incurred by the Contractor in establishing themselves on site.

Payment for this item shall be a lump sum and will be certified when the establishment is completed to the satisfaction of the Construction Supervisor.

2.1.3 Establishment Maintenance Item in Bill

Unless provided for in any Supplementary Specification to this General Specification, or itemised individually in the Bill of Quantities, the item for Maintenance of the Contractor's Site Establishment shall include for the following:

(v) All expenses incurred in maintaining and running the site services of the Contractor's Site Establishment.

(vi) All expenses incurred in maintaining and repairing buildings for the Contractor's use.

(vii) All messing for the Contractor's staff and employees (if applicable).

(viii) All other expenses incurred by the Contractor in running his Site Establishment.

Payment for this item shall be a lump sum for the total number of months of the specified Contract period, and will be paid each month on a pro-rata basis upon the Construction Supervisor's certification of the satisfactory performance.

2.1.4 Demobilisation

Unless provided for in any Supplementary Specification to this General Specification, or itemised individually in the Bill of Quantities, the item for Demobilisation of the Contractor's Site Establishment shall include for the following:

(ix) The dismantling of all buildings and accommodations.

(x) Transportation from site of all remaining plant, equipment, stores and materials, buildings and accommodation.

(xi) The disposal on site of any debris approved by the Construction Supervisor for such disposal, in a manner approved by the Construction Supervisor.

(xii) The removal and disposal off site, of all surplus debris and waste not approved for disposal on site. Such disposal to be in a manner approved by the Construction Supervisor.

(xiii) Restoration of the Establishment site to a neat and tidy condition subject to the Construction Supervisor's approval.

(xiv) All other expenses incurred by the Contractor in demobilising from the site.

(xv) Payment for this item shall be a lump sum and is payable upon completion of demobilisation of the Contractor's Site Establishment and site restoration to the Construction Supervisor's satisfaction.

2.2 CONSTRUCTION SUPERVISOR'S ESTABLISHMENT

2.2.1 General

The Establishment requirements for the Construction Supervisor will be included in any Supplementary Specification attached to this General Specification. Minimum requirements, where no Supplementary Specification is included, are detailed in the following Clauses.

2.2.2 Site Office

Within one month of acceptance of tender the Contractor shall erect in a position on the Site, as will be determined by the Construction Supervisor, an approved temporary office. The office shall have a minimum size of 3.7 metres by 3.0 metres by 2.4 metres ceiling height, with gabled roof and fitted with a lockable door, complete with cylinder latch, and window, all to the Construction Supervisor's approval.

The office shall also be fitted with two electric power points and one light fitting suitable to enable work after sunset. The office, and parking for at least two vehicles, shall be provided within a secure area and may be within the Contractor's Establishment area, subject to the Construction Supervisor's approval.

2.2.3 Furniture

The site office specified in clause 2.2.2 shall be provided with the following furniture:

- 1 No. Office desk with three or four lockable draws, minimum size 1.2 metres long by 0.8 metres wide.
- 1 No. 3 metre long wall shelf suitable for project files.
- 1 No. two draw lockable filing cabinet.
- 2 No. Desk Chair.

2.2.4 Services

The following services shall be provided to the Construction Supervisor's Establishment:

- Electrical supply, 220-240 volt service.
- Air conditioner unit, capacity 12,000BTU.
- One toilet and waste disposal as approved by the Construction Supervisor.
- Water supply suitable for drinking.

2.2.5 Vehicles

See Supplementary Specification .

2.2.6 Maintenance of Site Facilities

The Contractor shall maintain the Construction Supervisor's Site Establishment in a clean and tidy condition, providing for disposal of waste in a manner approved by the Construction Supervisor.

2.2.7 Maintenance of Vehicles

See Supplementary Specification .

2.2.8 Demobilisation

The Contractor shall remove from site, all buildings, fences and services, dispose of wastes as approved by the Construction Supervisor, and restore the site to the satisfaction of the Construction Supervisor.

Demobilisation shall be carried out at the Construction Supervisor's direction.

2.2.9 Payment

Payment for the provision of office, furniture, services and equipment shall be a lump sum and will be certified by the Construction Supervisor following completion of the provision of all items to the approval of the Construction Supervisor.

Payment for the maintenance of the Construction Supervisor's Establishment shall be a lump sum for the total number of months of the specified Contract period, and will be paid each month on a pro-rata basis upon the Construction Supervisor's certification of the satisfactory performance.

Payment for Demobilisation shall be paid on certification by the Construction Supervisor at the completion of removal of all facilities, services and wastes and on completion of site restoration to the Construction Supervisor's approval.

2.3 NOTICE BOARDS

Within one month of receiving possession of the Site, the Contractor shall supply and erect Notice Boards at locations directed by the Construction Supervisor.

Additional Notice Board requirements will be noted in the Supplementary Specification to this General Specification.

These Notice Boards shall be as detailed on the Drawings.

These Notice Boards shall be removed, and the site neatly tidied, by the Contractor on completion of the Contract or as directed by the Construction Supervisor.

Payment for provision of the supply and erection of the Notice Boards shall be made at the scheduled rate for the number of signs to the Construction Supervisor's satisfaction.

Payment for provision of the removal of the Notice Boards shall be made at the scheduled rate for the number of signs to the Construction Supervisor's satisfaction.

GROUP 3 - CLEARING, GRUBBING AND STRIPPING OF TOPSOIL

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GROUP 3

CLEARING AND GRUBBING

3.1 CLEARING AND GRUBBING

Except for trees and shrubs to be preserved, as indicated on the Drawings or as designated by the Construction Supervisor, "Clearing" shall mean the felling of all trees and shrubs by cutting, or breaking off, not higher than two hundred and fifty (250) millimetres above ground level. "Grubbing" shall include the removal of fallen trees, stumps, logs, upturned roots, rotten wood and all other vegetable growth and accumulations of rubbish of whatever nature and any other objectionable material from "The Area" as ordered by the Construction Supervisor.

It shall also include the removal of existing cribwork, guard rails, fences, buildings, vehicle chassis and parts within the limits of "The Area" but shall not include the removal of concrete headwalls, wingwalls, or concrete box culverts.

Concrete headwalls, wingwalls and floodways shall be classified as material Type C and shall be paid for as such in accordance with measurements established by the Construction Supervisor, and at the Scheduled Rate for Earthworks Type C in the Bill of Quantities. The stacking and removal of concrete or corrugated metal culverts is covered by Clause 7.8 and reference shall be made to Clause 3.6 for dismantling and removal of existing bridges.

In areas of embankments, stump holes, and other holes from which obstructions are removed shall be backfilled with approved selected material and thoroughly compacted.

The areas to be cleared shall be those described below or as shown on the Drawings or as directed by the Construction Supervisor in writing:

(i) The area between a distance of 5 meters from the outer edge of the road shoulders on each side of the road along the road alignment.

(ii) The area in and around existing drainage paths.

(iii) The area required for turnouts or other drainage ditches and channels for stream diversions.

(iv) The area on bridge approaches shall include all ground lying within 10 metres either side of the construction centreline.

All such areas to be cleared shall be called "The Area".

The contractor shall not be responsible for compensation to land owners for any land or crops or damaged within the limits of clearing for the works. However the contractor shall be responsible for payment of compensation to landowners for any damage to land or caused by the contractor to areas outside the limits for clearing of the works.

3.1.1 <u>Clearing of Vegetation</u>

Clearing shall consist of the removal of all trees, bushes, other vegetation, rubbish, fences and all other superfluous material including the disposal of all material resulting from the clearing and grubbing.

The moving of a certain amount of soil or gravel material may be inherent to or unavoidable during the process of clearing and no extra payment will be made for this. Clearing shall include the removal of all rocks and boulders of up to $0.15m^3$ in size which are exposed or lying on the surface.

Where the line of an existing fence or wall is cut by the Site boundary the severance shall be made good; either by the continuation of the fence or wall in a different direction, or by its termination. In the case of a strained wire or chain link fence a straining post shall be installed, unless otherwise directed, and the fence restrained.

The Contractor shall take the necessary precautions to prevent damage to structures and other private or public property. If necessary trees shall be cut in sections from the top downwards. The branches of trees to be left standing shall be trimmed/pruned so as not to intrude into the space for up to seven (7) metres in height above the carriageway.

3.1.2 Grubbing and Stripping of Topsoil

Grubbing and stripping of topsoil shall be carried out as a joint operation over the whole of the area required for the completed earthworks plus one metre beyond the limit of the earthworks slopes. This operation shall be completed at least 2,300 metres ahead of any earthworks operations.

Grubbing shall consist of the removal and disposal (in accordance with Clause 3.1) of all stumps, roots and embedded logs larger than 30cm in diameter.

In areas of embankments, stump holes, and other holes from which obstructions are removed, shall be backfilled with approved selected material and thoroughly compacted.

Stripping of topsoil shall require the removal of all topsoil to a depth of 150mm and the stockpiling or disposal of same as noted on the Drawings or in the Supplementary Specification to this Specification, or as directed by the Construction Supervisor.

The topsoil shall be the darker coloured, organically rich layer of soil, free of material noted for removal by clearing and grubbing.

If specified or directed, topsoil shall be stripped and stockpiled at a site within the road reserve.

On completion of any grubbing and stripping of topsoil the surface shall be graded to an even finish to facilitate an accurate survey prior to commencement of the earthworks.

3.2 CLEARING OF STREAM CROSSING SITES

Unless directed otherwise by the Construction Supervisor all trees, stumps and roots which would be within five (5) metres of the outer lines of the structure shall be cleared and grubbed to a depth of at least three hundred (300) millimetres below the level of the natural surface or the finished surface, whichever is the lower. In addition, any trees within the right–of-way, which could in the opinion of the Construction Supervisor fall upon the structure, shall be cleared as specified above.

3.3 CLEARING OF DRAINAGE PATHS

Cleaning of existing drainage paths will include removal of all materials that block or cover the drains and/or culverts and shall include all small, localised slips/slumps etc. up to five (5) m^3. Removal of material in slips/slumps larger than five (5) m^3, as determined by the Construction Supervisor, shall be carried out under the provisions of Clause 4 of this Specification. Where no existing drain is apparent the contractor will be required to investigate (through trial holes, local knowledge etc.) the existence of any such feature.

3.4 DISPOSAL OF MATERIAL

All material, slash and debris resulting from clearing operations must be disposed of by burning unless otherwise directed by the Construction Supervisor. Unmerchantable timber, stumps etc shall not be disposed of by pushing outside of the right-of-way. All trees shall be felled within “The Area”, but, in the event of any tree falling outside “The Area” such trees shall be cut up and, together with all debris and slash there from, brought back to “The Area” and there burned. The Construction Supervisor may designate certain trees or shrubbery to be left standing, in which case the Contractor shall take every precaution not to damage or injure such trees or shrubbery in felling adjacent timber, burning or any other clearing operations. Such trees or shrubbery are to be limbed or thinned to such height and extent as may be ordered by the Construction Supervisor.

Except as provided elsewhere, all slash and debris shall be piled and burned at points located centrally in “The Area”. The number of fires to be started at any one time shall be limited to the capacity of the Contractor’s equipment and organisation to provide adequate protection against the spreading of the fires to adjacent timber or property.

Materials and debris which cannot be burned may be buried within the right–of-way, outside of embankment and structural backfill areas, or disposed of outside the right–of-way and limits of view from the project. The Contractor shall make all necessary arrangements with property owners and meet all costs for obtaining and using suitable disposal areas.

Clearing must be carried out and completed at least 300 metres ahead of any earthworks operations.

3.5 MEASUREMENT AND PAYMENT

Clearing, grubbing and stripping of topsoil (including cutting and removal of trees and tree stumps) shall be measured as one item in hectares of “The Area” specified in Clause 3.1. above and shall be paid for at the Scheduled Rate per hectare, and this price shall be accepted as full compensation for the provision of all labour, plant, disposal facilities and any other requirements necessary to carry out all work as described, regardless of the nature or condition of “The Area”. No deductions in measured area shall be made for existing roads and paved areas or other areas within the defined limits for which physical clearing is not required.

Clearing of stream crossing sites as defined in Clause 3.2 shall be made at the scheduled rate for number of steam crossing sites cleared.
Clearing of drainage paths as defined in Clause 3.3 shall be made at the scheduled rate for the length in linear metres of drainage paths cleared.

3.6 REMOVAL OF EXISTING BRIDGE STRUCTURES

Where existing bridges are rendered redundant by the erection of new bridges within this Contract, the existing bridges shall be dismantled by the Contractor unless otherwise directed by the Construction Supervisor or otherwise noted in any Supplementary Specification to this General Specification or indicated on the Drawings.

Unless the Construction Supervisor directs to the contrary, all steel beams and trusses shall be dismantled in such a way as to permit their reuse. Care shall be exercised to avoid damaging the said members during demolition. All reusable materials shall be neatly stacked on supports clear of the ground adjacent to the present site in the location directed by the Construction Supervisor, prior to their transportation to the nearest Public Works Department office, or to such other site as directed by the Construction Supervisor.

The Contractor shall be responsible for the removal and disposal, to the satisfaction of the Construction Supervisor, of all the materials which the Construction Supervisor considers are not reusable.

All piles shall be extracted, or cut off one metre below river bed level or to higher levels as directed by the Construction Supervisor.

Dismantling of Existing Bridges shall be paid for in accordance with the relevant Billed Item(s) and shall be certified by the Construction Supervisor following complete removal and disposal as specified. Such item(s) shall be deemed to include for provision of all labour, plant, materials tools and incidentals necessary to demolish the structures, stack the reusable materials adjacent to the site, transportation to the nearest Public Works Department office or other designated other site and disposal of unusable materials.

The excavation of the existing foundations, where directed by the Construction Supervisor, shall be measured and paid in accordance with Group 4 of this Specification.

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GROUP 4

EARTHWORKS

4.1 DESCRIPTION

Earthworks shall include all excavation, construction of all embankment and the removal of unsuitable materials as required for the formation of the road-bed; excavation for any drainage ditch, take off ditch or channel for stream diversion; removal of surcharge material, organic waste material and unsuitable overburden from any borrow pit and its disposal; excavation of materials below grade; excavation in borrow pits; the earthworks necessary to connect intersecting roads, public or private, within the limits of the Works; the hauling and disposal of all excavated material and the trimming and shaping of all excavations and embankments and the spreading and grassing of topsoil to complete batters, as directed by the Construction Supervisor.

4.2 EXTENT OF WORKS

4.2.1 Dimensions

The dimensions of the excavations and embankments shall be in accordance with the type, cross sections and longitudinal profile shown on the Drawings accompanying this Specification and such additional details as provided by the Schedule of Works. The Construction Supervisor may alter details such as width of the road-bed or the slopes of the batters as conditions and circumstances relating to the pavement thickness, material stability or other reasons, may dictate. The dimensions of other earthworks operations not shown or specified in the Drawings shall be in accordance with the directions and requirements of the Construction Supervisor.

4.2.2 Subgrade Level

The Subgrade level may be adjusted to suit changes in thickness of pavement in those sections where the final surface level cannot be altered because of the requirements for structures, or for any other reason.

4.2.3 Side Slopes

The Slopes of all excavations and embankments shall be trimmed neatly and evenly to the lines and slope shown on the Drawings or as instructed by the Construction Supervisor. Undercutting of slopes in excavation is to be made good as directed by the Construction Supervisor and all costs thereof shall be borne by the Contractor.

4.2.4 Existing Pavement

Existing pavement shall not be excavated where it is to be incorporated in the new construction unless otherwise instructed by the Construction Supervisor. The limit of excavation adjacent to existing pavement which is to remain as sub-base will be determined on site by the Construction Supervisor and this limit will be marked on the cross sections. Where the depth of this excavation exceeds 200 millimetres below the top of sub-base level a step or steps with vertical face of 150 millimetres and horizontal face of 300 millimetres shall be formed and the quantity included in the volume to be excavated.

4.3 TOLERANCE IN LEVEL AND ALIGNMENT

The surface of the finished subgrade shall not be higher than, nor more than 50 millimetres lower than, the required levels and shall contain no depressions which may prevent the free run-off of surface water.

The alignment of the finished earthworks shall be such that the dimension measured at right angles from the designated centreline to the top of the embankment slope, or to the toe of the batter in cuttings, is nowhere less than the dimensions shown or inferred from the Drawings. The Contractor shall not be paid for the earthworks placed outside the limits designated on the Drawings or directed by the Construction Supervisor unless such additional material has been ordered to be placed by the Construction Supervisor in writing.

4.4 SUBGRADE LEVEL

The finished subgrade level specified in the Contract will be subject to adjustment if, in the opinion of the Construction Supervisor, such an adjustment is necessary or desirable

4.5 GENERAL EXCAVATION

4.5.1 General

Excavation shall be carried out to the lines and levels as indicated on the Drawings and to the tolerances as detailed in Clause 4.3.

Materials to be excavated shall be classified under the following material types:

Type A

Type B

Type C

Type D

The material encountered in any road excavation shall be classified as one of the types listed above. In no case will a material be classified using percentages of two or more types.

Where material changes from one type to another in an excavation the Contractor shall immediately notify the Construction Supervisor in order that sufficient field measurements can be taken to establish the boundary between the two types of material for quantity determination. Should the Contractor fail to so notify the Construction Supervisor then the classification of the material type for measurement and evaluation shall be entirely at the discretion of the Construction Supervisor.

4.5.2 Type A - Solid Rock

Type A material shall include all forms of 'solid rock in place' occurring in masses, ledges, seams or layers of sufficient hardness which, in judgement of the Construction Supervisor, it is not practical to excavate without drilling and blasting. It shall not include detached masses of rock or boulders containing a volume of less than 1.0 cubic metre and shall not include material which in the judgement of the Construction Supervisor can be loosened by a single tine hydraulic ripper drawn by a tractor unit with a minimum total weight of 42.5 tonnes and flywheel horsepower rating of 370 HP or metric equivalent.

4.5.3 Type B - Materials Requiring Ripping

Type B materials shall mean those materials of such density or so firmly cemented that they cannot be removed by push blade action of a tractor unit of minimum weight 42.5 tonnes and flywheel horsepower rating of 370 HP or metric equivalent; that is they cannot be removed without first loosening them by means of ripping equipment, or some means other than continuous drilling or blasting.

4.5.4 Type C - Concrete and Masonry

Type C material shall include bridge piers, bridge abutments, culvert headwalls, wingwalls, footings, retaining walls and spillways.

4.5.5 Type D - Common

Type D material shall include all other materials of a nature not included in the foregoing definition of Types A, B, or C materials.

4.5.6 Compaction of In- Situ Subgrade in Excavation

The Contractor shall compact all pavement subgrade, for a depth of 150 mm, to a characteristic value of 95% of the maximum dry density as determined by AS 1289.5.1.1 unless directed otherwise by the Construction Supervisor

No separate payment will be made for complying with this Clause as it will be deemed to be included in the item for general excavation in Group 4 of the Bill of Quantities.

4.6 UNSUITABLE MATERIAL

4.6.1 Unsuitable Material In Excavation

Where material is found in excavation, which, in the opinion of the Construction Supervisor, is not suitable for the construction of embankments, it shall be removed and disposed of in accordance with Clause 4.10 and paid for as excavation. Materials such as organic soils, peat, and material containing large amounts of root or other vegetable matter and compressive soils shall be classed as unsuitable.

Material that cannot be compacted to the required standard merely because it is too wet or too dry is not to be classified as unsuitable unless the results of drying the compaction trials, stipulated in Clause 4.15, demonstrate that it is not practicable to use such materials in the Works

4.6.2 Unsuitable Material in Sub-Grade

Where material is found in the sub-grade or under embankment that in the opinion of the Construction Supervisor will be detrimental to the proper construction of the overlying pavement or embankment, the Construction Supervisor may order the excavation of such materials and shall specify the depth to be excavated. Excavation carried out under the Clause that is not covered by Clause 4.23 shall be paid for as unsuitable material. The refilling of the void created by such excavation shall be measured and paid for in accordance with Clause 4.22

4.7 ROCK CUTS

Excavation in rock shall be undertaken generally according to the Drawings or as directed by the Construction Supervisor on Site.

Rock cuts shall be excavated to at least subgrade level and to a firm and reasonably smooth and uniform surface. No pinnacles of rock shall be left protruding from the surface of the cut and all broken rock of greater than 150mm diameter shall be removed. Payment will be made for the actual quantities taken out as provided in Clause 4.20. All rock cuts shall be brought up to subgrade level by backfilling with material approved by the Construction Supervisor, and the surface made uniform as to line and grade in preparation for the pavement courses.

When ordered by the Construction Supervisor the same procedure for backfill will apply to cuts in material other than solid rock. The work shall be so conducted, whether by blasting or otherwise, so that the sides of the cut shall be left in as regular and as reasonably safe a condition as practicable. Excavated rock of suitable quality required for stone pitching, gabions, etc shall be reserved and deposited in dumps if so ordered by the Construction Supervisor.

A berm of at least 600mm shall be left between the top of slope of rock cuttings and the toe of slope of overlying materials. In solid rock cuts, where pockets which will not drain are formed below the subgrade level by blasting, the Contractor shall, at his own expense, provide drainage by ditching to a free outlet as ordered and shall backfill both.

4.8 DANGEROUS LOOSE AND OVERHANGING ROCK

The Contractor will be required to remove dangerous, loose and overhanging rock within or outside the limits of the road right-of-way when and where ordered by the Construction Supervisor. This work will be measured and paid for as Earthworks.

4.9 OVERBREAK IN SOLID ROCK

Overbreak resulting from fault, negligence, or bad workmanship by the Contractor shall be removed or disposed of as directed by the Construction Supervisor at the Contractor's cost.

If the Construction Supervisor directs that such overbreak requires restoration the Contractor shall carry out the work directed by the Construction Supervisor at the Contractor's cost.

4.10 SURPLUS MATERIAL

All suitable excavated materials shall be used, so far as is practicable, in constructing embankments. Unsuitable materials and required roadway excavation in excess of that needed for construction shall be removed and disposed of at designated areas in such a manner as to provide a stable, well drained and neat appearance and shall not obstruct drainage nor cause injury to road works or private property. Designated areas shall be identified by the Contractor in consultation with, and with the agreement of, the local landowner and community and shall be subject to the approval of the Construction Supervisor.

The cost of spreading and grading of such surplus material shall be included in the rate for excavation of said material.

4.11 ENLARGEMENT OF CUTTINGS

In cases where the quantity of material taken from a regular cutting will not be sufficient to form the requisite embankment, the deficiency may be supplied by taking material from cuttings within or outside the right-of-way at such places as the Construction Supervisor may direct, or from enlargement of the regular cuttings, made uniformly on one or both sides, and the sides of the excavation in all cases shall be dressed to such slopes as the Construction Supervisor may direct. The material excavated in this manner will be considered as Borrow and Clause 4.18 will apply.

4.12 EXCAVATION FOR STRUCTURAL FOUNDATIONS

4.12.1 <u>General</u>

This Clause shall apply to excavations for structural foundations other than those which require cofferdams or caissons. For cofferdams or caissons see Group 10 of this Specification.

4.12.2 Materials Types

Foundation excavation shall be classified as defined in Clause 4.5 of this Specification under one of the following types:

(1) Type A

(2) Type C

(3) Type D

4.12.3 Execution of Works

The Contractor shall be responsible for safely maintaining the excavation and for the observance of all existing and relevant laws and regulations regarding safety on construction sites. The Contractor shall take all necessary precautions and shall make good all settlement or damage to buildings, footpaths, roads and services caused by his excavation or other construction activities. The Contractor shall so plan and execute his works that, as soon as practicable after the Construction Supervisor's approval for the founding surface of the excavation has been given, the blinding concrete shall be poured.

In the event that water or any other cause has in the opinion of the Construction Supervisor caused the deterioration of the surface before the blinding concrete is poured, the Construction Supervisor may order the Contractor, at the Contractor's expense, to excavate until the deteriorated material is removed, and refill in accordance with Clause 4.19.3.

Where the necessity for building up the base of the excavation is due to over excavation by the Contractor the work shall be carried out at the Contractor's expense. Where the Construction Supervisor has instructed additional excavation in unsuitable material the additional excavation and refilling shall be at the relevant Billed rate.

In the case of Bridge Sites the Contractor shall carry out his operations in such a manner as to minimise disturbance to the river banks and to minimise overbreak beyond the extent of excavation required. The sides of all excavations shall be adequately supported and the voids kept free of water at all times.

4.12.4 Measurement and Payment of Excavation for Structural Foundations

The quantities of excavation shall be calculated from the project area of the footings, or parts thereof, onto a horizontal plane (i.e. the plane area of the footings shown on the Drawings) multiplied by the average vertical depth of the excavation, including any additional excavation instructed by the Construction Supervisor, from cleared surface as given in Group 3. Payment shall then be made from such quantity at the Billed Rate for the relevant item in the schedule.

The Contractor will be deemed to have included in his Billed rate for shoring or battering of the excavation, and for any necessary cost of de-watering the excavation to allow inspection and to enable backfilling and compaction to be affected.

In the event of the alterations of the foundation levels, quantities shall be calculated by the same method, but the vertical dimensions shall be measured from the Contract levels. In addition, if the plan dimensions of footings are changed by the Construction Supervisor, quantities shall be calculated by multiplying the variation of the plan by the average vertical depth from the natural surface to the approved foundation level.

4.13 USE OF EXPLOSIVES

Except as specified thereinafter, rock may be carefully excavated with the use of explosives. Care shall be taken to protect the surroundings of any permanent or temporary structure and equipment of every kind.

In the handling, storage and use of explosives, the Contractor shall comply with all applicable legislation, regulations and by-laws, and with AS 2187.1 and AS 2187.2.

When blasting in the vicinity of buildings and structures, ground vibrations shall not exceed the maximum values specified in AS 2187.2. The Contractor shall operate a vibrograph or similar instrument so that the Construction Supervisor can measure ground vibrations at any point. Should the values specified in AS 2187.2 be exceeded, the Contractor shall reduce the amount of charge used. The Contractor may be required to carry out trial blasting so that the maximum charge to be used can be determined.

The Contractor shall give the Construction Supervisor at least ten (10) days notice of any intention to excavate by blasting and shall furnish full details of the location thereof and the methods he proposes to adopt. Blasting shall not be undertaken without the Construction Supervisor's approval and only at times approved by the Construction Supervisor.

The Contractor shall provide screens, barriers, mats and the like as directed by the Construction Supervisor to limit the effects of blasting, but notwithstanding the effects of the provision of such screens, barriers, mats and the like, the Contractor will be held responsible for any loss, damage or injury sustained by the public or by workmen (whether employees of the Contractor, Construction Supervisor, Employer or other authority) and for damage to property of any description whatsoever caused directly or indirectly by such blasting.

Secure storage spaces shall be provided for explosives and all such places shall be clearly marked with warning signs. Only persons trained and experienced in the handling of explosives shall be allowed to use them on the work, and no shot shall be fired until a warning has been sounded and all persons within the radius of danger removed. The warning device shall give an audible warning clearly different from any other sound normally heard on the Site.

In case of the vicinity of the work is accessible by the general public, the Contractor shall, before any shots are fired, post lookouts about the works in various directions to warn all persons of the danger existing and to prevent them approaching closer than safety will permit.

When blasting has the potential to endanger life or property, the Construction Supervisor shall have the power to prohibit the use of explosives or prescribe and enforce such rules and regulations as he may deem necessary; but the prescribing or failure to prescribe such rules and regulations shall not relieve the Contractor from any responsibility under the Contract.

4.14 ROCK EMBANKMENTS

4.14.1 General

This section applies to embankments constructed from material containing more than 15% by volume of rock larger than 150 mm. Embankments shall be constructed in layers equal in thickness to the largest average size of the material but not exceeding 600 mm. Greater lift thickness will be permitted by the Construction Supervisor under special conditions provided the Contractor can spread the larger materials satisfactorily. The materials shall be deposited and spread so that the large rocks are well distributed and the intervening spaces filled with smaller sizes and fines as may be available to form a stable embankment.

4.14.2 Compaction

Each layer shall be compacted by a vibrating roller or grid roller with a static load per 100 mm width of roll of at least 1.75 kN or 7.8 kN respectively. Compaction shall be continued until movement of the surface under the action of the rollers is negligible to the satisfaction of the Construction Supervisor.

Where permitted by the Construction Supervisor, side hill fills where the width is too narrow to accommodate equipment may be placed by end dumping until sufficient width of the embankment has been formed to carry equipment, after which the remainder shall be placed in layers and compacted as specified.

4.14.3 Upper Layer

The 300 mm layer, below the sub base, or such other thickness as may be directed by the Construction Supervisor, shall be formed of material smaller than 75 mm nominal size and shall have a minimum 4 day soaked CBR of 8%, when tested in accordance with AS 1289.5.1.1. Such materials shall be compacted, in layers not exceeding 200 mm loose thickness, to a Characteristic Value of 100% of the Maximum Dry Density obtained in accordance with AS 1289. 5.1.1.

4.14.4 Notice to the Construction Supervisor

At least 7 days prior to the placement of the upper layer, as directed in Clause 4.14.3, of an embankment, the Contractor shall notify the Construction Supervisor and submit for his approval samples of the material to be used in that layer. The Contractor shall obtain the Construction Supervisor's approval of the prepared surface and the upper layer materials prior to the placement of any such materials.

4.15 EARTH EMBANKMENTS

4.15.1 General

This section applies to the embankment constructed from material containing less than 15% by volume of rock larger than 150 mm obtained from cuts along the road or from borrow areas approved by the Construction Supervisor and designated in accordance with Clause 4.11 and 4.18.

The earth embankments shall be constructed in successive horizontal layers not exceeding 300 mm in loose thickness except that the top 600 mm shall be constructed in layers not exceeding 200 mm in loose thickness.

The Contractor shall compact all in-situ subgrade under embankments (after stripping of topsoil) for a depth of 150 mm, to a characteristic value of 95% of the maximum dry density as determined by AS 1289.5.1.1 unless directed otherwise by the Construction Supervisor.

No separate payment will be made for complying with the above requirements of this Clause as it will be deemed to be included in the item for general embankment construction in Group 4 of the Bill of Quantities.

Where the Contractor demonstrates to the satisfaction of the Construction Supervisor that it is impracticable to achieve the degree of compaction specified in Clause 4.5.6, the Construction Supervisor may approve the placement of a bridging layer. A bridging layer shall not be placed within 1.5 m of the finished surface.

The bridging layer shall consist of granular material with strong mechanical interlock and low sensitivity to moisture. The bridging layer material shall have sufficient strength to provide astable platform on which an earthworks layer can be constructed. The material shall be enddumped and spread in a single layer and in sufficient depth to allow the passage of earthmoving equipment with minimal surface heaving. The compaction requirements of Clause 4.5.6 will not apply to the bridging layer.

If specified or directed by the Construction Supervisor, a geotextile complying with the quality requirements of Clause 18.6.1 shall be placed over the bridging layer in accordance with Clause 18.6.2 and paid for in accordance with Clause 18.6.3.

4.15.2 <u>Compaction</u>

Each layer shall be compacted to a Characteristic Value of 100% of the Maximum Dry Density as determined by AS 1289.5.1.1. Soils which cannot be compacted to the required density because of the high moisture content shall not be employed without prior aeration and drying. The Contractor shall allow in his rates for drying out of materials and keeping them at or near optimum moisture content prior to the placing of the next successive layer. When embankments are to be made on hillsides, or where a new fill is to be applied upon an existing embankment, the slopes of the original ground or embankment (except rock embankments) shall be terraced or stepped by ploughing deeply or by other means before filling is commenced.

Where compaction trials show that a soil cannot be sufficiently dried out to a moisture content within such a range as will make possible its compaction to the required density and, in the opinion of the Construction Supervisor, alternative soils are not readily available, such soil shall be compacted to a Characteristic Value of dry density equal to at least the Maximum Dry Density at field moisture content as determined by AS 1289.5.1.1. The field moisture content shall be determined from a representative sample taken at a depth of at least 300 mm from the surface of the material. The Contractor shall so plan his operations that such soils are placed in the lower layers of embankment. The shall not be placed within 600 mm of the underside of sub-base

4.15.3 Upper Layer

The 300 mm layer below the sub-base or such other thickness as may be directed by the Construction Supervisor, shall be formed of material smaller than 75 mm nominal size and shall have a minimum 4 day soaked C.B.R of 8% when tested in accordance with AS 1289.5.1.1. Such materials shall be compacted in layers not exceeding 200 mm loose thickness, to a Characteristic Value of 100% of Maximum Dry Density obtained by AS 1289.5.1.1.

4.15.4 Notice to the Construction Supervisor

At least 7 days prior to the placement of the upper layer, as described in Clause 4.15.3, of an embankment, the Contractor shall notify the Construction Supervisor and submit for his approval samples of the material to be used in that layer. The Contractor shall obtain the Construction Supervisor's approval of the prepared surface and the upper layer material prior to placement of any such materials.

4.15.5 Trimming

Trimming of embankments shall be carried out to provide a neat finish of sub-grade surface and of all batters to the lines shown on the Drawings, and shall include clearing of any waterways of debris arising from the embankment operation, and the removal of any other loose rock, boulders, or excess material resulting from the trimming operations. The Contractor shall trim the embankments to the tolerances required by Clause 4.3 of this Specification prior to the placing of any sub-base material or topsoil as required.

4.15.6 Placement of Topsoil

All topsoil stockpiled for re-use in the Works shall be spread in the areas and to the depths shown on the Drawings, or as otherwise specified, or as directed by the Construction Supervisor. Where no specification or direction is provided the topsoil shall be incorporated into the top 75 mm of the embankment slopes.

Topsoil shall be trimmed and lightly compacted. Stones, roots or other material with a least dimension greater than the depth of spread shall be removed.

This work shall be considered to be part of the embankment construction unless otherwise specified.

4.16 SLOPE FAILURES

Where slope failure occurs on an excavated slope embankment slope or natural hillside, and is considered, by the Construction Supervisor to be a detriment to the Works, the Construction Supervisor shall direct the removal or replacement of such materials.

Materials to replace embankment slope failures shall be obtained from sources approved by the Construction Supervisor.

If a slope failure is caused by the negligence or abnormal work practices of the Contractor, as determined by the Construction Supervisor, or if the Contractor leaves slopes undercut so that a slope failure may subsequently occur, the Contractor shall undertake remedial work to the extent ordered by the Construction Supervisor at the Contractor's expense.

Where a slope failure cannot be attributed to any negligence or work practices on the part of the Contractor, all remedial work directed by the Construction Supervisor shall be measured and paid for at the Billed Rates for the relevant items for General Excavation or General Embankments, and shall be measured as the solid volume of overbreak, in the case of a cut or natural slope, and/or as the solid volume of embankment or natural slope requiring refill.

The classification of material removed from slope failures shall be according to its condition at the time of removal, regardless of any prior classification.

Should the Construction Supervisor direct the use of structural works in the rectification of slope failures, these works shall be paid for at the relevant Contract rates.

4.17 DITCHES

Ditches of whatever nature which may be considered necessary for the proper drainage of the Works shall be constructed at such points and to shown cross sections, alignments and grades as shown on the Drawings or as the Construction Supervisor may direct. This shall include inlets and outlets to culverts and ditching of all kinds. Ditching works shall be considered as part of normal earthworks and the cost of these works shall be included in the items for general earthworks.

4.18 BORROW

Borrow shall consist of suitable and satisfactory material, obtained from Borrow Pits nominated on the Drawings or from sites approved by the Construction Supervisor, actually used for the construction of required embankment.

The Contractor shall give consideration to the requirements of Clauses 4.10 and 4.11 of this Specification and shall plan his earthworks operations to maximise the use of suitable materials obtained from excavations and to minimise the requirements for the use of Borrow. The use of borrow material is subject to the prior approval of the Construction Supervisor.

Borrow Pits nominated on the Drawings or approved by the Construction Supervisor shall be so excavated that they will drain the nearest natural outlet or to such outlets as designated by the Construction Supervisor. Side slopes of Borrow Pits shall be trimmed and dressed to such slopes as the Construction Supervisor may direct. Borrow Pits shall be staked out and cross-sectioned by the Contractor in the presence of a representative of the Construction Supervisor before the Contractor begins work therein and no excavation, other than the excavation of test pits for material testing, will be allowed of any material from the Borrow Pits prior to this being done to the satisfaction of the Construction Supervisor.

The quantity of Borrow used for the calculation of payment for Borrow shall be the net volume required for the construction of embankments to their specified dimensions, resulting from the shortfall, if any, in the net quantity of suitable material obtained from the specified site excavation and the net quantity of material required to construct the embankments to their specified dimensions. No allowances shall be made in the calculation of such quantity for either bulking or wastage. If it is not practicable to use suitable material obtained from site excavation for the construction of embankments, the Construction Supervisor may instruct the Contractor to use Borrow material in its place; in such a case the Contractor will be paid for the use of Borrow at the rate shown in the Bill of Quantities.

The Contractor’s Tender rate for Borrow shall include the removal of overburden and its disposal, the maintenance and tidying up on completion of the Borrow Pits and the construction and maintenance of access roads thereto. The Contractor’s rate for Borrow shall also include the winning, stockpiling, loading and haulage of the material for a distance of up to five kilometres.

Should the Contractor wish to use Borrow in lieu of excavated materials deemed suitable for use in embankments by the Construction Supervisor, he may request the written approval of the Construction Supervisor to do so and such approval shall not be unnecessarily withheld. In such cases Borrow shall be obtained at the Contractor’s own expense and the surplus suitable material resulting from such operation shall be stockpiled neatly to the satisfaction of and at locations proposed by the Contractor and approved by the Construction Supervisor.

4.19 FILL TO STRUCTURAL FOUNDATIONS

4.19.1 General

Fill to structural foundations shall not commence without the approval of the Construction Supervisor. The procedure for construction which the Contractor proposes to employ is to be submitted to the Construction Supervisor for approval. Provisions for cost of any de-watering shall be included in the item for excavation detailed in Clause 4.12.4

4.19.2 Fill Below Structural Foundations

When fill above natural surface is to be of selected material, the nature of and extent of selected materials shall be as indicated on the Drawings or as directed by the Construction Supervisor.

Placing of the fill shall be carried out in even layers not exceeding 200 mm thickness and compacted to at least 95 % Maximum Dry Density (standard compaction) in accordance with AS 1289.5.1.1 or otherwise to the satisfaction of the Construction Supervisor.

4.19.3 Backfill Below Structural Foundations

Where the Drawings require the excavation of unsuitable material from the strata below the permanent foundation, or where ordered by the Construction Supervisor, the excavation shall be backfilled to the underside of the permanent foundation:

(i) with lean mix concrete, if so required by the Drawings, or otherwise

(ii) with sub-base materials as specified in Clause 5.2 of this Specification, spread in layers not exceeding 200 mm and compacted to at least 95% Maximum Dry density (standard compaction) in accordance with AS 1289.5.1.1.

The fill shall extend beyond the base size as shown on the Drawings in all plan directions by a distance equal to the depth of the fill used.

Materials removed during excavation below the permanent foundation shall be disposed of to the satisfaction of the Construction Supervisor.

4.19.4 Backfill to Excavation for Structural Foundations

After installation of permanent foundations and removal of all temporary work, the remainder of the space excavated shall be carefully backfilled and consolidated with selected gravel, gritty loam, or if approved, the excavation material. Material removed during the excavation, if suitable and not required for specific re-use may be used in embankments or disposed of as directed by the Construction Supervisor.

Placing and compaction of the fill shall be carried out in even layers not exceeding 300 mm thick and it shall be compacted to at least 95% Maximum Dry Density (standard compaction) in accordance with AS 1289.5.1.1.

4.19.5 Fill to Bridge Abutments

4.19.5.1 General

Placing of backfill to bridge abutments shall not commence until the Construction Supervisor has satisfied himself concerning pertinent foundation conditions that may affect the future stability of the bridge or embankment. Unless the procedure for construction is stated on the Drawings the Contractor must submit his proposed method to the Construction Supervisor for approval. Work shall not commence until the Construction Supervisor has given his consent in writing, to the Contractor's proposal. Such consent shall not relieve the Contractor of his responsibilities under the Contract.

4.19.5.2 Material

Material used behind bridge abutments shall conform to the requirements for sub-base, as defined in Clause 5.2 of the Specification. In addition, a drainage layer 300 mm wide shall be placed behind wall type abutments and shall extend down to the sub-soil drain. The drainage layer material shall be free of vegetable matter and balls of clay, and shall be free draining gravel, crushed rock or other material all of which will pass a 75 mm sieve, and the percentage passing a 4.75 mm sieve shall not be greater than 25.

Where indicated on the Drawings, drainage pipe, enclosed in a filter fabric approved by the Construction Supervisor, shall be supplied and laid, to a 1% minimum fall, behind the abutment and discharge at locations approved by the Construction Supervisor. Installation is to be concurrent with construction of the drainage layer. The cost of the drainage pipe shall be included in the rate for backfill to bridge abutments**.**

4.19.5.3 Extent of Backfill

Unless otherwise indicated on the Drawings, backfill to bridge abutments shall extend above a surface extending back from the soffit of the headstock, or seat, up to sub-grade level.

4.19.6 Measurement and Payment

The fill to structural foundations is measured by volume in cubic metres. The quantity is calculated from the pay lines shown on the Drawings or as described in the Specification.

Payment shall be made at the Billed rate per cubic metre, such rate providing for all necessary costs incurred in carrying out and completing the work as specified.

4.20 MEASUREMENT AND PAYMENT FOR GENERAL EXCAVATION

4.20.1 Measurement and Calculation

Unless an alternative method is agreed between the Contractor and the Construction Supervisor, all finally accepted excavation shall be measured from cross-sections taken normal to the centreline or the control line at a frequency and at such locations as may be specified by the Construction Supervisor, and after clearing, grubbing and topsoil stripping. The volume shall be determined from original and final cross-sections of the required work by the formula:

> $\frac{1}{2}(A + B)L$
>
> where A and B are the end areas separated by a length L measured horizontally along the road centreline.

Frequency of cross-sections shall be as shown on the Drawings or as stated elsewhere in this Specification or as specified by the Construction Supervisor. The area of the cross-section to be measured as roadway excavation shall be that area bounded by the ground line as it exists after clearing, grubbing and topsoil stripping operations, the required cut slopes and the underside of required sub-base or such lower levels specified or instructed to be excavated. Where excavation in rock is to be paid for separately the area of the cross-section shall be divided along the surface of the rock. Excavation of unsuitable material, and isolated volumes of other required excavation which it is impractical to measure by the cross-section method, shall be measured by taking appropriate measurements on Site.

No account shall be taken of benching cut in existing slopes for the purpose of providing a key under embankments nor for the removal of existing pavement material which may be necessary for preparation of formation of pavement.

4.20.2 Final Payment

The quantities of roadway excavation measured in Clause 4.20.1 shall be paid for at the Billed Rates per cubic metre for the various types of materials excavated. These rates shall include full compensation for loosening, blasting, breaking up, removal, loading, haulage for any distance and satisfactory disposal of all excavated materials; for draining, drying out as necessary and keeping earthworks free from water; for shaping and finishing sub-grade surfaces and for furnishing all labour, materials, tools, equipment and incidentals necessary to complete the work in this Specification and as directed by the Construction Supervisor.

4.20.3 Interim Payments

Subject to the Construction Supervisor's approval, which will not be reasonably withheld, an interim payment may be made on the measured volumes of bulk excavation before final shaping has been carried out and such payment shall be made at a rate of 70% of the Billed Rate.

4.21 MEASUREMENT AND PAYMENT FOR OVERHAUL

The Contractor shall be wholly responsible for locating material for use in the Works and for managing that material to minimise haulage distances. There shall be no payment for overhaul.

4.22 MEASUREMENT AND PAYMENT FOR GENERAL EMBANKMENT CONSTRUCTION

4.22.1 Measurement and Calculation

Embankment shall be measured in cubic metres. The volume to be measured shall be the volume of required embankment completed in accordance with the Specification and the alignments, levels grades and dimensions shown on the Drawings or as directed by the Construction Supervisor. Unless an alternative method is agreed between the Contractor and the Construction Supervisor, the volume shall be determined from cross sections taken normal to the centre line or the control line at a frequency and at such locations as may be specified by the Construction Supervisor and after clearing, grubbing and topsoil stripping. The volume shall be determined by the formula:

$$1/2\ (A + B)\ L$$

where A and B are end areas separated by a length L measured horizontally along the centre line of the road.

The cross sectional area to be used shall be that area bounded by the required finished sub grade, the required side slopes and the original ground level as it exists after clearing, grubbing and topsoil stripping operations have been completed. The finished sub grade is defined as the nominal level shown in the drawings or directed by the Construction Supervisor above which pavement materials as determined by Group 5 of the Specification may be placed. Payment shall not be made for any additional material that may need to be placed because a subsidence below the embankment.

In places where the Contractor is required to replace unsuitable material excavated in accordance with Clause 4.6.2 the volume shall be measured on site by an appropriate method, and added to the volume of the embankment. No account shall be taken of benching, terraces or steps formed in accordance with Clause 4.15.

Where specified as a separate item, top soil replacement shall be measured as square metres of plan area of top soil spread to the depths as specified, and shall be paid for at the relevant Billed rate. If no Billed Item is provided for re-soiling, this work shall be deemed to be included in the measurements and payment for general earthworks.

4.22.2 Final Payment

The quantities of embankment measured in 4.22.1 shall be paid for at the Billed rate per cubic metre regardless of the source of the embankment paid for under another item or not. The rate shall be full compensation for performing all work required including preparation of foundations, benching, spreading, carrying out drying trials, carrying out compaction trials, processing, drying, watering, compacting trimming and furnishing all labour, materials, tools equipment and incidentals necessary to complete the embankments to this specification and as directed by the Construction Supervisor.

4.22.3 Interim Payment

Subject to the Construction Supervisor's approval, which will not be unreasonably withheld, an interim payment may be made on the measured volumes of bulk filling before final shaping has been carried out, and such payment shall be made at a rate of 80% of the Billed rate.

4.23 EXCAVATION AND FILLING OF SOFT SPOTS

Where in the opinion of the Construction Supervisor, unsuitable material occurs in isolated soft spots below ground level under embankments, in quantities of less than 25 m^3, this shall be excavated and filled with suitable material.

Such measurement shall be made separately from the main excavation. The item shall include for excavation and haulage of the unsuitable material to spoil areas nominated by the Contractor and approved by the Construction Supervisor. This quantity shall be paid for at the Billed Rate per cubic metre and shall include work necessary to provide and compact the replacement material to a Characteristic Value of 95% of the Maximum Dry Density as determined by AS 1289.5.1.1 or AS 1289.5.3.1 as appropriate.

4.24 REPLACEMENT MATERIAL IN EXCAVATION

Where the Construction Supervisor directs that adjustment be made to the subgrade level pursuant to Clause 4.4 or where the Construction Supervisor orders excavation in the subgrade pursuant to Clause 4.6.2, the excavated material shall be replaced with materials complying with the requirements of Clause 4.15. Materials replacing any excavated materials in accordance with this Clause shall be measured and paid for in accordance with Clause 4.22.

4.25 CONSTRUCTION COMPLIANCE TESTING

4.25.1 <u>General</u>

Compliance testing of the earthworks shall be undertaken on a lot-by-lot basis.

The number and frequency of tests will be at the direction of the Construction Supervisor and may be adjusted to suit the size of the project requirements and special requirements of the material being tested.

Compliance testing shall not apply to filling adjacent to structures but in such cases the Construction Supervisor shall determine compliance on a test-by-test basis.

4.25.2 <u>Compaction</u>

The in-situ compaction of embankment materials shall be determined as specified in this Group 4, except that the Construction Supervisor may satisfy himself regarding field density and moisture components of these materials using a nuclear hydro densometer or other similar apparatus.

4.26 CALCULATION OF CHARACTERISTIC VALUE

When compliance of the work is to be tested by the assignment of a Characteristic Value determined by the analysis of several individual tests or measurements using a statistical procedure, the following system shall be used:

(a) Compliance testing/measurement will be undertaken as specified in the relevant Clauses

(b) The Characteristic Value for the lot will be determined using individual test results or measurements and one of the following equations, as applicable:

For a minimum limit:

–

Characteristic Value = X – ks

For a maximum limit:

Characteristic Value = $\bar{X}$ + ks

Where

$$\bar{X} = \frac{1}{n} \sum_{i=1}^{n} X_i$$

$$S = \sqrt{\sum_{i=1}^{n} \frac{(X_i - \bar{X})^2}{(n - 1)}}$$

Xi is the individual test result or measurement for i+ 1,2,3….n

k is an acceptance constant dependant upon the number of test or measurements. The relevant value of k shall be selected from the table below:

Number of tests or measurements	Acceptance Constant (k)	Number of tests or measurements	Acceptance Constant (k)
2	0.403	15	0.901
3	0.535	20	0.946
4	0.617	25	0.978
5	0.675	30	1.002
6	0.719	35	1.020
7	0.755	40	1.036
8	0.783	45	1.049
9	0.808	50	1.059
10	0.828	60	1.077
11	0.847	70	1.091
12	0.863	80	1.103
13	0.877	90	1.112
14	0.890	100	1.120

(c) The Rounding of values used in the calculation of the Characteristic Value and the rounding of the Characteristic Value shall be as shown in the table below:

Property / Parameter	Rounding Value

Maximum Dry Density	0.001 t / m^3
In-situ dry density	0.001 t / m^3
Relative dry density	0.10%
X	0.01%
s	0.01%
ks	0.01%
Characteristic Value	0.10%

GROUP 5 - BASE AND SUB-BASE PAVEMENT COURSES

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GROUP 5

BASE AND SUB-BASE PAVEMENT COURSES

5.1 GENERAL

This work shall consist of obtaining, processing hauling, placing and compacting base and sub-base pavement material, plus shaping and preparing the formation, for each pavement course, all in accordance with this Specification, alignments, levels, grades, dimensions and cross sections shown on the Drawings, and as directed by the Construction Supervisor.

5.1.1 Definition of Terms

The terms used in this group of the Specification shall be as defined in the following table:

Term	Definition
Acid Igneous Rock	As defined in AS 1726, including Rhyolite, Rhyodacite, Dacite, Tuffs (of same composition), Granite, Ademellite and Granodiorite.
Base Course	A course or courses principally intended to directly support the traffic load.
Basic Igneous Rock	As defined in AS 1726. Including Basalt, Dolerite and Gabbro.
Coronous material	Poorly consolidated raised coral reef deposits (calcareous materials which contain calcite-calcium carbonate) which now occur above sea level.
Course Component	The fraction of the material which does not pass the AS 0.425mm sieve.
Fines Component	The fraction of the material passing the AS 0.425mm sieve.
Intermediate Igneous Rock	As defined in AS 1726. Including Trachyte, Trachyandesite, Andesite, Tuffs (of same composition), Syenite and Diorite.
Metamorphic Rock	As defined in AS 1726. Including Hornfels, Quartzite, Metagreywacke, Greenstone, Slate and Amphibolite.
Natural Gravel	Granular materials derived from pre-existing rock formations through weathering processes to form residual, colluvial or alluvial deposits.

Sedimentary and Duricrust Rock	As defined in AS 1726. Including Limestone, Mudstone, Arenite, Chert, Silcrete and Dolomite.
Sub-base Course	A course or courses principally intended to distribute, to the subgrade, the loads from overlaying courses.
Wearing Course	A course which has no structural function but protects the underlying course for wear and ingress of water.

5.1.2 Standard Test Methods

Property to be Tested	Standard Test
Sample preparation	AS 1289.1
Moisture Content	AS 1289.2.1.1
Particle Size Distribution	AS 1141.11 / AS 1289.3.6.1
Flakiness Index	AS 1141.15
Ten Percent Fines value & Wet/Dry Strength variation	AS 1141.22
Sodium Sulphate Soundness	AS 1141.24
Maximum Dry Density – Sub-base course	AS 1289.5.1.1
Maximum Dry Density – Base course	AS 1289.5.2.1
Liquid Limit	AS 1289.3.1.1
Plastic Limit	AS 1289.3.2.1
Plasticity Index	AS 1289.3.3.1
Linear Shrinkage	AS 1289.3.4.1
Californian Bearing Ratio	AS 1289.6.1.1
Crushed Particles	Queensland Transport Test Q215
Road Roughness	Queensland Transport Test Q708

5.2 MATERIALS

5.2.1 Material Source Assessment

The Contractor shall provide a material source assessment which shall include an investigation of geological site characteristics and source material properties. The extraction and production operations and plant capacity to process the material shall also be provided.

The Source material shall be classified into one of the material groups nominated in this Specification and the source assessment shall show that material meeting the requirements of this Specification can be produced.

Due to the variable nature of most material sources, the assessment should indicate the presence of materials with properties superior to the standards specified in this Specification to allow such variability and to ensure that the requirements for the product in the stockpile and the pavement are satisfied.

The material source assessment shall be forwarded to the Construction Supervisor at least ten working days before material deliveries commence to the stockpile, or to the pavement if a stockpile is not specified.

5.2.2 Material Types

Subject to Sub-Clause 5.2.3.1, base and sub-base materials shall be graded into four types by Course Component characteristics and up to five sub-types by Fines Component characteristics and strength. The material type nominated on the Drawings, or in any Supplementary Specification to this Specification, for use in the pavement shall meet all requirements tabulated below for that material type. In the event that the material type is not so specified, then the following types shall be adopted as a minimum requirement:

Base Course -	Type 2.1
Sub-Base Course -	Type 3.2

Source material shall not include overburden, seam or infill material. Imported material shall not be added to the source material without the prior approval of the Construction Supervisor.

5.2.2.1 Course Component Characteristics

Material Types 1 to 3 are characterised by their compliance with the requirements of the tables 1a to 1c below. Material Type 4 is specified by the unsoaked Californian Bearing Ratio test as scheduled in Table 5.

Property	Sub-Type	Source Material Group					
		Acid Igneous	**Intermediate Igneous**	**Basic Igneous**	**Metamorphic**	**Sedimentary Duricrust**	**Natural Gravel**
Ten Percent Fines Value (wet) (kN) minimum	1.1 1.2	130 95	140 105	150 110	140 105	130 95	130 95
Wet/Dry Strength Variation (%) maximum	1.1 1.2	40 45	35 40	30 35	35 40	40 45	40 45
Sodium Sulphate Soundness (%) maximum	1.1 & 1.2	12	12	12	12	12	12
Crushed Particles (%) minimum	1.1 & 1.2	70	70	70	70	70	70
Flakiness Index General (%) maximum	1.1 & 1.2	35	35	35	35	35	35

Table 1a – Course Component Standards – Pavement Type 1

Property	Sub-Type	Source Material Group					
		Acid Igneous	**Intermediate Igneous**	**Basic Igneous**	**Metamorphic**	**Sedimentary Duricrust**	**Natural Gravel**
Ten Percent Fines Value (wet) (kN) minimum	2.1 2.2 2.3 2.4 2.5	115 100 85 70 -	125 105 90 80 -	135 115 100 85 -	125 105 90 80 -	115 100 85 70 -	115 100 85 70 -
Wet/Dry Strength variation (%) maximum	2.1 2.2 2.3 2.4 2.5	40 40 45 45 -	35 35 40 40 -	30 30 35 35 -	35 35 40 40 -	40 40 45 45 -	40 40 45 45 -
Sodium Sulphate Soundness (%) maximum	All	15	15	15	15	15	15
Flakiness Index General (%) maximum	2.1,2.2 2.3,2.4 2.5	35 40 -	35 40 -	35 40 -	35 40 -	35 40 -	35 40 -

Table 1b – Course Component Standards – Pavement Type 2

Property	Sub-Type	Source Material Group					
		Acid Igneous	**Intermediate Igneous**	**Basic Igneous**	**Metamorphic**	**Sedimentary Duricrust**	**Natural Gravel**
Ten Percent Fines Value (wet) (kN) minimum	3.1 3.2 3.3 3.4 3.5	100 80 70 60 -	105 90 80 65 -	115 95 85 70 -	105 90 80 65 -	100 80 70 60 -	100 80 70 60 -
Flakiness Index General (%) maximum	3.1 & 3.2 3.3 & 3.4 3.5	35 40 -	35 40 -	35 40 -	35 40 -	35 40 -	35 40 -

Table 1c – Course Component Standards – Pavement Type 3

5.2.2.2 Fines Component Characteristics

The fines component standards for material Types 1 to 3 are given in Tables 2a to 2c below. Material Type 4 has no general fines component requirement unless nominated on the Drawings or in any Supplementary Specification to this Specification.

Linear shrinkage standards are not included in this General Specification but may be included as a substitute for Plasticity Index, in which case this will be shown on the Drawings or noted in any Supplementary Specification to this Specification.

Property	Sub- Type	
	1.1	**1.2**
Liquid Limit	25	28
Plasticity Index Maximum Minimum	 4 3	 6 3

Table 2a Fines Component Standard – Pavement Type 1

Property	Sub – Type				
	2.1	**2.2**	**2.3**	**2.4**	**2.5**
Liquid Limit maximum	25	25	28	35	40
Plasticity Index Maximum Minimum	 6 3	 6 3	 8 3	 12 -	 14 -
Placidity Index x % of whole sample passing the AS 0.425 mm sieve maximum	150	150	200	360	-

Table 2b. Fines Component Standard – Pavement Type 2

Property	Sub- Type				
	3.1	3.2	3.3	3.4	3.5
Liquid Limit maximum	25	28	35	35	40
Plasticity Index Maximum Minimum	 6 3	 8 3	 12 -	 12 -	 14 -
Placidity Index x % of whole sample passing the AS 0.425 mm sieve maximum	150	200	360	-	-

Table 2c Fines Component Standard – Pavement Type 3

5.2.2.3 Particle Size Distribution (Grading)

The particle size distribution requirement for each pavement type is given in Tables 3a and 3b.

For pavement Type 1 the Contractor shall aim at producing materials conforming to the target grading. The maximum and minimum limits define an acceptable zone of departure from this grading for any single sample.

AS sieve Size (mm)	Percentage by mass passing		
	Target	Maximum	Minimum
37.5	100	100	100
26.5	100	85	100
19.0	87	75	100
9.5	69	58	80
4.75	54	45	62
2.36	39	33	45
0.425	18	14	22
0.075	7	5	10

Table 3a. - Particle Size Distribution Standard – Pavement Type 1

AS sieve Size (mm)	Percentage passing by mass			
	Grading B	Grading C	Grading D	Grading E
75.0	100	100	100	100
53.0	100	100	100	-
37.5	85-100	100	100	85-100
19.0	55-90	80-100	100	-
9.5	40-70	55-90	80-100	40-100
4.75	28-55	40-70	55-90	-
2.36	20-45	30-55	40-70	20-100
0.425	10-25	12-30	20-40	10-80
0.075	4-15	5-20	8-25	4-30

Table 3b - Particle Size Distribution Standard –Pavement Type 2 and 3

The following schedule lists the grading types applicable to the various subtypes of pavements:-

Pavement Sub – Type	Applicable Grading
2.1 or 3.1	B or C
2.2, 2.3, 3.2 or 3.3	B, C or D
2.4, 2.5, 3.4 or 3.5	B, C or D if used in base or upper base layer

If in the case where alternatives exist, a particular grading is not noted on the Drawings or any Supplementary Specification to this Specification, then the Contractor shall notify the Construction Supervisor in writing, at least 10 days before the commencement of delivery of the material to the pavement, which one of the alternative grading envelopes will be used for the item.

The envelope chosen shall be the only envelope to be used for the particular item until prior approval is obtained from the Construction Supervisor for the use of one of the other alternatives. Such approval shall be obtained at least 10 working days before the use of the alternative envelope.

The following additional requirements shall apply to the grading envelopes given in tables 3a and 3b:-

(a) The ratio of the material passing through the AS 0.075 mm sieve and the percentage of the material passing the AS 0.425 mm sieve, calculated to the nearest 0.01, shall lie between the limits given in the following table:

Sub- Type	Ratio 0.075 to 0.425 mm	
	Minimum	Maximum
1.1, 1.2 & 2.1	0.30	0.55
2.2 & 2.3	0.30	0.65
3.1	0.35	0.55
3.2 & 3.3	0.35	0.65
2.4, 2.5, 3.4 & 3.5	-	-

Table 4 – Ratio 0.075mm material to 0.425 mm material

(b) For grading envelopes B, C or D the grading curve for the material shall be smooth and shall not vary from one outer third of the total limits range between the minimum and maximum limits for one sieve to the opposing outer third of the total limits range for the next lower sieve.

5.2.2.4 Californian Bearing Ratio

The Californian Bearing ratio standards for all materials are given in Table 5 below:-

Property	Sub – types for all materials				
	***.1**	***.2**	***.3**	***.4**	***.5**
CBR (soaked) minimum	80	60	45	35	15

Table 5 – CBR Standards – All Pavement Types

5.2.3 Coronous Material

5.2.3.1 General

Coronous material that complies with the requirements of this Clause 5.2.3 may be used for base course and sub-base course pavement.

The term Coronous shall only be applied to poorly consolidated raised coral reef deposits (calcareous material which contains calcite – 'calcium carbonate') which now occur above sea level.

5.2.3.2 Material Selection

Materials for base and sub-base courses shall be selected from approved material free from vegetable matter, balls of clay, topsoil, overburden and any other deleterious materials. The method of selection and processing shall be approved by the Construction Supervisor before full scale production commences. The material shall comply with the requirements below. **Figures in brackets show the requirements for roads not to be sealed.**

Californian Bearing Ratio

The four day soaked CBR value for a moisture content range of at least 5% for each material shall be as follows:-

Sub- base course 30% **(30%)**
Base course 80% **(65%)**

Particle Size Distribution

The particle size distribution for base and sub-base courses shall conform to the following requirements:-

5 < Cu (Mod) < 50 **(Same for unsealed roads)**

0.5 < Cc (Mod) < 3 **(Same for unsealed roads)**

Where:

$$Cu\ (Mod) = D80 / D30$$

$$Cc\ (Mod) = D50^2 / \{D30\ x D80\}$$

And: D80 = Particle size for which 80% by mass of the sample is finer

D50 = Particle size for which 50% by mass of the sample is finer

D30 = Particle size for which 30% by mass of the sample is finer

The material shall not contain particles with a size greater than 50% of the compacted layer thickness specified.

The material shall not contain more than 30% by mass passing the AS 0.075mm sieve.

Plasticity

The Plasticity Modulus (Plasticity Index multiplied by percentage of material passing the AS 0.425 mm sieve) shall not exceed the following figures:-

Base Course	500 **(800)**
Sub base course	1,000 **(1,000)**

The shrinkage Modulus (Linear Shrinkage multiplied by percentage of material passing through the AS 0.425 mm sieve) shall not exceed the following figures:-

Base Course	250 **(350)**
Sub base course	500 **(500)**

5.2.4 Cinder or Scoria Material

5.2.4.1 General

Cinder or Scoria material that complies with the requirements of this Clause 5.2.4 may be used for base course and sub-base course pavement if approved by the Construction Supervisor.

Volcanic cinders are pyroclastic materials associated with recent volcanic activity. Cinders vary in color, often within the same pit, and may be red, brown, grey, or black. The cinder particles also vary in size from large irregularly shaped lumps 500 mm in size, to sand and silt sizes. In some pits, however, particles may be more uniform with the largest size not exceeding 30mm in diameter.

5.2.4.2 Material Selection

Materials for base and sub-base courses shall be selected from approved material free from vegetable matter, balls of clay, topsoil, overburden and any other deleterious materials. The method of selection and processing shall be approved by the Construction Supervisor before full scale production commences. The material shall comply with the requirements below.

Maximum size (mm)	37.5	
Oversize index	5 %	*Maximum percentage retained on 37.5 mm sieve*
Grading coefficient	16-34	*(Percent passing 26.5 mm sieve J percent passing 2.36 mm sieve) ò percent passing 4.75 mm sieve/100*
Shrinkage modulus	100-365	*Linear shrinkage ò percent passing 0.425 mm sieve*
Minimum Soaked CBR (%)	30	*At 95 % Modified AS1289.5.2.1 density*
Plasticity index (%)	5-12	

Notes :
Linear shrinkage as determined in accordance with AS 1289.3.4.1.
Plasticity index (%) as determined in accordance with AS 1289.3.3.1.

Mechanical stabilization of cinder gravel may be allowed if approved by the Construction Supervisor. Mechanical stabilization shall be accomplished by mixing or blending soils of two or more gradations to obtain a material meeting the above required specification. As instructed by the Construction Supervisor, cinder gravel shall be stabilized by the addition of volcanic ash or clayey silt soils or clay binder taken from, and within the limits of, an approved source to improve the cinders plasticity characteristics and increase its density. The soil blending may take place at the construction site. The blended material is then spread to the required thickness and compacted to the required density.

5.3 MATERIALS COMPLIANCE TESTING

5.3.1 General

Compliance testing of materials shall be undertaken on a lot-by-lot basis. Samples for compliance testing shall be randomly selected (random sampling) from the stockpile lot. A stockpile lot shall be an essentially homogenous portion of material of the same specification requirements (such as the same sub-type and grading).

5.3.2 Stockpile

The stockpile shall be located on clear, even, firm, well-drained ground and in a location where it can be clearly identified.

There shall be a separate stockpile for each material with the same specification requirements.

All stockpiles shall be separate from other stockpiles by at least 2 metres.

For the purpose of testing, each individual stockpile lot shall be clearly delineated by one of the alternative methods below:-

(a) A separate stockpile lot shall be formed for each stockpile lot; or
(b) Materials of the same specification requirements shall be added to a single stockpile incrementally such that a portion representing a stockpile lot is added, tested and found to be conforming before the next stockpile lot is added. Nonconforming stockpile lots shall be removed from the stockpile prior to the addition of further portions.

5.3.3 Lot Sizes, Testing Frequencies and Number of Tests

Unless detailed in any Supplementary Specification to this Specification, lot sizes, number and frequency of tests will be at the direction of the Construction Supervisor and may be adjusted to suit the size of the project requirements of the material being tested.

5.4 CONSTRUCTION

5.4.1 Maintenance of Sub-Grade and/or Pavement Courses

The Contractor shall be responsible for maintaining in a condition which complies with the relevant specifications, any existing subgrade and pavement course, and the pavement courses constructed under the Contract.

5.4.2 Layer Thickness

Individual compacted layer thickness, which has been chosen to suit the construction process and/or the requirements of the Specification, shall lie between 75 mm and 250 mm.

5.4.3 Overlay of Existing Formation

Where an existing formation is to be retained and no reference is contained in any Supplementary Specification to this Specification or noted in the Drawings, then subject to the Construction Supervisor’s approval, the existing surface shall be lightly scarified, shaped as necessary, and re-compacted with the addition of sub-base material if required. The total depth of scarified and added material shall not exceed the permissible depth of layer as specified.

5.4.4 Moisture Content

The Contractor shall ensure that the moisture content of the pavement materials being placed, and any underlying formation scarified, is maintained evenly throughout the material, so as to be able to be or near the Optimum Moisture Content for that material.

5.4.5 Surface Finish

The final unbound pavement layer shall have a uniform surface free from loose, segregated and contaminated areas and the course particles shall be slightly exposed. If necessary, the surface shall be trimmed, lightly watered, drag-broomed and rolled with an approved roller to achieve the above finish.

5.4.6 Application of Bituminous Prime Coat

The bituminous prime coat, where applicable, shall be applied as soon as practicable after completion of the base course pavement layer, but not before the levels, surface compaction, quality and finish of the base course have been approved by the Construction Supervisor. Should the pavement, due to any reason or cause lose the required quality, stability, density or finish before surfacing is complete, it shall be made good, to the satisfaction of the Construction Supervisor, at the sole expense of the Contractor.

5.4.7 Construction Equipment

Pavements with Type 1 materials shall be constructed using self-propelled spreading machines purpose built for this work.

Such machines shall have the capacity to either:

(a) place and spread the material directly on the prepared surface to the necessary uncompacted layer depth, width and shape in one pass; or
(b) spread previously placed windrows of material to the necessary uncompacted layer depth, width and shape in one pass;

provided always that the Construction Supervisor will approve other methods of construction in areas where the pavement width is such that the use of such purpose built machines is impractical.

Self-propelled spreading machines shall have the capacity to spread the material in one pass to the necessary uncompacted layer depth over at least half of the pavement of at least 3 metres, whichever is the lesser.

Other types of equipment may be used for other pavement types, but shall be approved by the Construction Supervisor prior to commencement of work.

5.5 PRODUCT STANDARDS

5.5.1 Horizontal Alignment

The horizontal location of any point on the pavement shall not differ from the corresponding point shown on the documents by more than + 50 mm except for the following situations:

(a) For pavement edges not adjacent to any other section of pavement and not adjacent to any structure or adjoining road, the transverse tolerance shall be – 50 mm + 50 mm (where the + tolerance is in the direction which increases width of pavement).

(b) Where alignment of the pavement with an existing pavement or structure is necessary, the new work shall be joined neatly to the existing work in a smooth manner as shown on the Drawings or, if this is not shown, in an approved manner.

5.5.2 Surface Finish

The primary tolerance shall apply to the height of any point on the surface of any layer and is included in Table 6.

Pavement Course	**Primary Tolerance (mm)**	**Straight Edge Deviation Limit (mm)**
Base Course	± 15	5
Sub Base Course	± 15	8

Table 6 – Surface Tolerance Standards

Additional tolerances are described as follows and where required are included in Table 6.

(a) The deviation from straight edge

The deviation from a 3 metre long straight–edge placed anywhere on the surface of a layer shall not exceed the standard for the particular pavement course detailed in Table 6, due allowance being made for design shape where relevant.

(b) Crossfall

The crossfall of the final pavement layer shall not depart from the corresponding crossfall shown in the documents by more than 0.5% absolute.

The crossfall shall be measured:

(i) between any two points more than 2 metres apart, except for portions of cross-sections designed with lesser width, for which sections the crossfall shall be measured between the extreme edges of the section;

(ii) transverse to the centre line; and

(iii) within the boundaries of a cross-section element which has a constant fall.

(c) Surface Evenness

The surface evenness of the final pavement layer shall have a maximum Road Roughness Count Rate of 75 counts per kilometre determined in accordance with Queensland Department of Main Roads Test Q708.

Provided however that the Construction Supervisor may, with the agreement of the Contractor, assess the surface evenness on the basis of the surface providing a comfortable ride in a four wheel drive vehicle travelling at the speed limit or in the absence of a speed limit, a speed of 60 km/h. The assessment shall be entirely at the Construction Supervisor's discretion and if the Contractor does not agree with that assessment, the method of assessment shall be as set out in the previous paragraph.

5.5.2 Compaction

Pavements consisting of Type 1 material shall be compacted to a Characteristic Value of 100% of the Maximum Dry Density as determined by AS 1289.5.2.1. All other pavement types, including coronous, cinder or scoria, shall be compacted to a Characteristic Value of 95% of the Maximum Dry Density as determined by AS 1289.5.1.1.

Alternatively, where the pavement is not to have a bituminous seal coat applied, the material may be compacted by a vibrating roller or grid roller with a static load per 100 mm width of roll at least 1.75 kN or 7.8 kN respectively, and compaction shall be continued for 12 passes or until movement of the surface under the action of the rollers is negligible to the satisfaction of the Construction Supervisor, which ever is the later.

5.5.3 Segregation

The particle size distribution of the material in the pavement shall comply with the particle size distribution requirements in Clause 5.2.2.3 of the relevant sub-type.

5.6 CONSTRUCTION COMPLIANCE TESTING

5.6.1 General

Compliance testing of the pavement shall be undertaken on a lot-by-lot basis.

Unless detailed in any Supplementary Specification to this Specification, lot sizes, number and frequency of tests will be at the direction of the Construction Supervisor and may be adjusted to suit the size of the project requirements and special requirements of the material being tested.

5.6.2 Geometrics

The geometric tolerances, except for the surface evenness, shall be checked by a method of random stratified sampling.

For surface evenness the minimum length of lot shall be 100 metres.

5.6.3 Compaction

The compaction standard for each lot shall be represented by the Characteristic Value of the Relative Dry Density.

The in-situ compaction of pavement materials shall be determined by AS 1289.5.3.1 or AS 1289.5.3.3, except when the Construction Supervisor may satisfy himself regarding field density and moisture contents of these materials using a nuclear hydro densometer or other similar apparatus.

The location of each in-situ dry density test shall be chosen by a method of random stratified sampling.

However where compaction has been assessed under Clause 5.5.2 as being acceptable if there is no movement under action of the prescribed roller, this Clause 5.6.3 shall not apply.

5.6.4 Segregation

There shall be no visible signs of segregation in each pavement lot.

Samples shall be taken from each lot to check that segregation of the material in the lot has not occurred.

5.6.5 Vertical Movement of Pavement Layers

The surface of the pavement in every layer shall display no visible vertical movement under the weight of compaction equipment.

5.7 CALCULATION OF THE CHARACTERISTIC VALUE

When the compliance of the product is to be tested by the assignment of a Characteristic Value determined by the analysis of several individual tests or measurements using a statistical procedure, the following system shall be used:

(a) Compliance testing/measurement will be undertaken as specified in the Relevant Clause;

(b) The Characteristic Value for the lot will be determined using the individual test results or measurements and one of the following equations, as applicable;

For a minimum limit:

$$\text{Characteristic Value} = \overline{X} - ks$$

For a minimum limit:

$$\text{Characteristic Value} = \bar{X} + ks$$

Where

$$\bar{X} = \frac{1}{n} \sum_{i=1}^{n} Xi$$

$$s = \sqrt{\sum_{i=1}^{n} \frac{(Xi - \bar{X})^2}{(n - 1)}}$$

Xi is the individual test result or measurement for i+ 1,2,3….n

k is an Acceptance Constant dependant upon the number of test or measurements. The relevant value of k shall be selected from the table below:

Number of tests or measurements	Acceptance Constant (k)	Number of tests or measurements	Acceptance Constant (k)
2	0.403	15	0.901
3	0.535	20	0.946
4	0.617	25	0.978
5	0.675	30	1.002
6	0.719	35	1.020
7	0.755	40	1.036
8	0.783	45	1.049
9	0.808	50	1.059
10	0.828	60	1.077
11	0.847	70	1.091
12	0.863	80	1.103
13	0.877	90	1.112
14	0.890	100	1.120

(c) The rounding of values used in the calculation of the Characteristic Value and the rounding of the Characteristic Value shall be shown in the Table below:

Property / Parameter	Rounding Value
Maximum Dry Density	0.001 t / m ^{3}
In-situ dry density	0.001 t / m ^{3}
Relative dry density	0.10%
X	0.01%
s	0.01%
ks	0.01%
Characteristic Value	0.10%

5.8 MEASUREMENT AND PAYMENT

5.8.1 Preparation of Existing Pavement

Preparation work as described in Clause 5.4.3 shall be measured as the plan area, in square metres, of the actual area of pavement retained, or directed to be retained, whichever the lesser.

5.8.2 Pavement Courses

Each pavement course shall be measured by volume in cubic metres (m^3), the volume being calculated as the product of the nominal end area as shown on the Drawings and the length measured along the centreline of the road over which the area is applicable. The measured volume shall be reduced by the volume of the existing pavement forming part of the new pavement course.

5.8.3 Payment

Payment shall be made for measured work at the relevant Billed Rate and this payment shall be full compensation for the opening up and on-going development of pits, including the removal of overburden, the construction and maintenance of access roads where required to the material source, winning of materials including the payment of royalties, blasting, quarrying and all processing, screening, blending and crushing necessary to obtain the specified materials. This payment shall also be full compensation for handling, hauling maintaining haul roads, scarifying, placing, watering, compacting, finishing and shaping of the pavement course including provision of all labour, plant, equipment, tools and other incidentals necessary to complete the work specified.

Interim payments may be made for approved materials stockpiled, as specified, ready for use in the Works. Any such payment shall be at the discretion of the Construction Supervisor, and shall take into account the security of storage and availability of the material. Payment shall be assessed by the Construction Supervisor at a proportion of the Billed rate giving consideration to the haulage distance and other cost factors for the remaining work, but this proportion shall not exceed 40%. The assessed quantity for such interim payment shall be the stockpiled volume reduced by 30% to obtain a comparative compacted figure.

GROUP 6 – HAND PACKED STONE PAVEMENT

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GROUP 6

HAND PACKED STONE PAVEMENT

6.1 GENERAL

This work shall consist of the supply materials, labour, tools and equipment to construct Hand-Packed Stone Roadbase in accordance with these specifications and to the lines, levels and grades, dimensions and cross-sections shown on the Drawings and as required by Construction Supervisor.

Hand-Packed Stone Roadbase consists of a layer of roughly cubic shaped or selected stones of about 100 - 150mm in size, laid tightly packed together on a bed of loose sand or fine aggregate of 50mm to 60mm in thickness. The larger stones are wedged in place with smaller stone chips rammed by hand into the joints using hammers and steel rods.

Coarse sand or fine crushed aggregate is brushed into the remaining spaces between the stones. When a sufficient area of stones is placed, the layer is watered and compacted with a vibrating or non-vibrating roller. Additional filler is brushed into the surface if necessary. Hand-packed stone can be used as a road base or as a final surfacing. It can be used as part of a staged construction strategy where resources are not immediately available to provide a sealed bitumen surface finish.

6.2 MATERIALS

6.2.1 <u>Stone</u>

The parent material for the broken stone pieces should be a strong, homogenous, isotropic rock, free from significant discontinuities such as cavities, joints, faults and fine bedding planes and shall be approved by the Construction Supervisor. It should be in a fresh condition free from deleterious inclusions, and not susceptible to weathering, degradation or significant strength deterioration on exposure. Experience indicates that igneous rocks such as fresh granite and basalt can be suitable materials. Some other rocks are suitable and approval of these is at the discretion of the Construction Supervisor.

The rock should have the following mechanical properties:

- Uni-axial compressive strength >75MPa
- Los Angeles Abrasion value <25%
- Sodium Sulphate Soundness <10% loss

The stones shall be free from vegetation, soft particles and excess clay or any other substance, which is considered deleterious.

The individual large stones shall be approximately 100 to 150mm in size (or other dimensions approved by the Construction Supervisor) and shall be roughly cubic in shape with uniform texture. Ratios between dimensions of each stone shall be in range of 0.7 to 1. Machine crushed or hand broken stones compliant to the above requirement are suitable for the construction of hand-packed stone road base. However, the stone from hand broken quarry operations is usually more appropriate and performs better than machine crushed because it usually has better characteristics which provide improved interlocking between stones.

6.2.2 Bedding Material (Cushion)

The bedding layer beneath the Hand Packed Stone acts as a cushion and load transfer layer for the overlying construction. Coarse sand or fine crushed aggregate from the stone quarry may be used as bedding layer.

Bedding material shall be clean sharp sand or quarry-crushed-dust free from clay coating, organic debris and other deleterious materials.

6.2.3 Joints Filling and Blinding Material

Material used to fill the voids between the large and small wedging stones shall be non-plastic, angular, well graded, crushed stone or natural sand which shall have:

- Fineness Modulus of sand fraction shall not be less than 1.80 and shall be free from deleterious materials.
- Fraction passing 75 micron sieve shall not exceed 10%

Blinding or joint filling material shall be clean, free from clay coating, organic debris and other deleterious. The following is the recommended target grading envelope:

Sieve Designation	Percentage by weight passing square mesh sieves
25 mm	100
10 mm	60-100
2.00 mm	40-70
0.425 mm	25-45
0.075 mm	0-10

6.3 CONSTRUCTION EQUIPMENT

The minimum compactive effort per constructed layer shall be in the range:

	Minimum Weight	Number of Passes
For primary compaction	1,000 kg vibrating	6-8 per point
For final compaction	3,000 kg vibrating	6-8 per point

The type of the compaction equipment shall be approved by the Construction Supervisor.

6.4 CONSTRUCTION METHOD

6.4.1 Preparation of Foundation

Prior to laying the hand-packed stone roadbase, the Contractor shall correct any deformations, ruts, soft spots or other defects in the formation or sub-base all to the satisfaction of the Construction Supervisor whose approval shall be obtained before roadbase works commence. All drainage works necessary to keep the road formation and pavement layers free of standing water should be completed.

The Contractor shall establish sufficient setting out pins, pegs and string lines to ensure that the final shape of each pavement layer confirms with the Drawings, which shall be checked with a camber board, or straight edge, spirit level and tape. Any depressions in the surface shall be re-scarified and sufficient new material added to attain the correct shape.

6.4.2 Shoulder Construction

Side shoulders shall be constructed in advance to a thickness corresponding to the compacted layer of the hand-packed stone roadbase as indicate in the Drawings. The shoulder material and construction method shall conform to Section 5 of this Specification.

After the shoulders are ready, their inside edges shall be trimmed vertical and the included area shall be cleaned. Arrangement for drainage of the roadbase layer (through the shoulder) should be completed before construction of the bedding layer.

6.4.3 Bedding Layer

Coarse sand or crusher dust shall be spread uniformly upon the prepared sub base in such quantities that the thickness of the compacted layer is 50 – 60mm. The loose layer should be consolidated to about 85% of Maximum Density.

The relationship between the loose thickness and compacted thickness shall be determined from field trials and used in controlling the loose thickness at the time of spreading the materials. Immediately following the spreading of bedding material, it should be rolled dry with the aid of a 0.8 to 1.0 tonne roller. The rolling shall begin from the edges with the roller running forward and backward, parallel to the centre line of the road until the layer has been lightly compacted.

6.4.4 Placing and Packing Stone

Before placing the stones, guiding string lines shall be placed using metal pegs made of reinforcement steel to indicate the finished layer level. The peg interval shall be 5 metres. Lines shall be placed longitudinally and along the cross section of the road, and diagonally, to indicate the desired camber.

Stones shall be placed from the edges of the road towards the centreline. Largest stones shall be used along the edge of the pavement. These larger stones will act as kerbs which will restrain the rest of the stone paving of the carriageway and prevent undesired side movement or damage to the shoulders. Selected large stone shall be laid first, and then followed by the rest of the carriageway to achieve this restraining effect. To aid construction it is advisable to also place a row of stones along the centre line, before placing the rest of the stones. Individual stones shall be laid to have contact to each other but each stone must bed into the sand or fine aggregate cushion without any support from the adjacent stones. Each stone must be tapped firmly into the final position with a hammer. The residual thickness of the bedding layer underneath the stone blocks should not be less than 30mm. After laying of a sufficient area of stones, the large voids between the stones shall be filled with smaller broken stones packed in with a hammer and steel rod. A Camber board should be used to assure an even and regular top surface both longitudinally and across the section during the laying and packing operation.

6.4.5 Joints Filling and Blinding

After laying and packing the stones, the pavement should be checked to ensure that each stone is firmly packed, and then remaining voids shall be infilled with fine graded aggregate. A thin layer of filling materials shall be spread over the surface of the hand-packed stone layer followed by primary compaction. An 800kg to 1 tonne vibrating roller is suitable for this primary compaction with 6-8 passes per point. Water shall only be added to facilitate compaction after 3-4 passes of vibrated compaction. Water is used to assist in the process. However, care is necessary in this operation to ensure that any water sensitive plastic materials in the sub-base or sub-grade do not become saturated. Vibration helps move the fill material into the voids between the larger stones. A heavier compactor of 8 to 10 tonne deadweight (minimum 3 tonnes vibrating) is recommended for final compaction with minimum 5 passes per point. Compaction shall start from the edge into the centreline of the pavement. On superelevated sections the compaction should proceed from the lower side. For sections with longitudinal gradient, compaction shall follow direction of the gradient (from lower toward higher points). Any areas of loose material after compaction shall be re-constructed.

6.4.6 Finishing and Curing

After final compaction of hand-pack stone road-base, the road shall be allowed to dry out for a period of at least 24 hours. After initial laying, handpacked stone road-base may not be totally stable and small areas of losseness may develop. These shall be reworked to the satisfaction of the Construction Supervisor. A minimum curing period of 10 days is required and any identified weak spots shall be corrected within this period before laying any surfacing. Hand packed stone may be opened to traffic after one or two days drying. A temporary layer of about 10 mm thick of suitable granular filling material should be spread on the pavement surface before opening the road to traffic with restricted to moderate speed. The excess material shall be cleaned from the roadbase and disposed of by the Contractor prior to any further rectification works and surfacing. This temporary covering and measures should be included in the Contractor’s rate for the work.

6.5 LABORATORY AND SITE TESTING

The Construction Supervisor shall exercise control over quality of the materials incorporated and works performed through quality control tests carried out to the frequencies indicated here in under. The frequencies are the minimum, and the Construction Supervisor shall have the authority to have these tests undertaken at more frequent intervals, where quality of a material or work is in doubt.

Material tests from each source should be submitted to the Construction Supervisor for approval in advance of the commencement of work. The following table is a recommendation for testing and frequency:

TEST	DESIGNATION	SAMPLING AND TESTING FREQUENCY (1)	COMPLIANT CONDITIONS
Sieve Analysis	AS 1141.11	3 per Source plus 1 per 500 m3	
Los Angeles Abrasion	AS 1141.23	3 per Source plus 1 per 500 m3	< 25%
Uni-axial compressive strength	AS 413.4.2 1993		> 75 Mpa
Fractured faces	Visual	3 per Source plus as required based on visual observation (more frequently if material character changes)	

Visual inspections shall be made to check compliance with the Drawings and Specification, and dimensional regularity of stones. Maximum clearance to a 2 metre straight edge laid at any orientation across the finished pavement to be 10mm.

Shallow inspection pits shall be excavated through the completed roadbase on centre line and 0.5 metres from each edge of the road base every 1.0 km and to be properly reinstated all as directed by the Construction Supervisor. Layer thickness tolerances should be -5 mm to +15 mm.

A pavement layer quality and specification compliance inspection will be undertaken on all completed sections of the stone paving layer by the Construction Supervisor prior to acceptance of the Works.

6.6 MEASUREMENT AND PAYMENT

The unit of measurement shall be square metres (m^2) of placed and compacted material, including the bedding layer, kerbs / edge stones and hand packed stone with blinding material. The quantity for which payment shall be made shall be the product of the instructed average width and the measured length along the centre line of the road.

The rates shall include the supply, placing, spreading, shaping, watering and compaction as specified and shown on the Drawings. The work as measured shall be paid for at the Contract unit price shown in the Bill of Quantities. Payment shall be full compensation for performing the work including supplying the materials, and providing all labour, tools, equipment, incidentals necessary, overheads and profit.

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GROUP 7

REINFORCED CONCRETE PAVEMENTS

7.1 GENERAL

The work comprises providing materials for and constructing reinforced concrete slabs, laid to lines, levels and dimensions, as shown on the Drawings and as directed by the Construction Supervisor.

7.2 MATERIALS

7.2.1 <u>Reinforcement</u>

Reinforcement shall conform to the requirements of Section 15 of this Specification for concrete reinforcement.

Typically, reinforcing grids shall be a minimum of 6 mm commercially fabricated mesh and/or 10 mm diameter rods at 200mm centres each way and located in the top half of the slab depth. Details of steel mesh stipulated in Section 15 and on the Drawings shall govern.

7.2.2 <u>Concrete</u>

Concrete shall conform to the requirements of Section 16 of this Specification. In general, concrete shall have a minimum compressive strength of 25Mpa (28 days cylinder strength) and comply with Durability strength requirements as per Section 16and cover to reinforcing steel as per Section 15.

7.2.3 <u>Load Transfer Dowels</u>

Load transfer dowels shall be provided at each construction joint. Construction joint transfer dowels shall typically be 16 mm diameter hot dipped galvanised round bar at 300 centres at mid slab height and of commercially available lengths but in no case less than 400 mm long.

Load transfer dowels shall be provided at contraction joint locations where the reinforcing mesh is not continuous across the joint. Contraction joint transfer dowels shall typically be 16 mm diameter deformed bars at 300 centres at mid slab height and not less than 500 mm long.

7.3 CONSTRUCTION EQUIPMENT

Equipment shall comply with Section 16 of this Specification.

All tools and equipment shall be approved by the Construction Supervisor prior to start of works.

7.4 CONSTRUCTION METHOD

Reinforced Concrete Pavements shall be constructed on a previously prepared sand bedding layer that has been examined and accepted by the Construction Supervisor. The sand bedding layer shall be constructed in accordance with the details on the Drawings and shall normally consist of a layer of selected sand with a suitable grading to provide effective drainage and to prevent the infiltration of fill or roadbed material into the sand filter blanket. The surface on which the sand filter blanket is to be constructed, shall be smooth and even and the sand shall be spread evenly to the required thickness and be given a light compaction with suitable rollers. The final surface of the sand filter blanket shall be finished off true to line and level. Sand bedding layer must in soaked, compacted and in an undisturbed state immediately prior to concrete pavement placement.

Concrete slabs should normally be constructed at full carriageway width. In some circumstances (e.g. to allow traffic flow in difficult terrain) construction of half-width concrete slabs may be permitted, but only with the agreement of the Construction Supervisor and in such cases construction joints as per Sub-Clause 7.4.2 shall be provided. The width of the concrete pavement to be constructed shall be specified in the Drawings.

In some instances concrete strips will be required to be constructed and where this is the case the same construction method shall apply. Width of strips and width of the central reserve between strips are specified in the Drawings of the Contract.

7.4.1 <u>Reinforcement</u>

The reinforcing steel mesh should be placed in the top half of the concrete slab depth with minimum concrete cover on the steel reinforcement as per the requirements of Section 16 of this Specification with respect to durability. The mesh grid is to have dimensions of 200mm x 200mm, as detailed on the Drawings. If the mesh is formed of reinforcing rods, they are to be secured with steel binding wire. The reinforcing grid is to be positioned on, and secured to, solid concrete spacers or bar chairs to ensure the correct height. Reinforcing is to be continuous under contraction joints with every second mesh/bar cut.

7.4.2 <u>Pavement Joints</u>

7.4.2.1 <u>Pavement Contraction Joints</u>

Contraction joints shall be formed in green concrete no later than 4 hours after the concrete has been poured using a grove trowel or similar approved tool.

Contraction joints are to be in straight lines each 10mm in depth and provided at intervals in the pavement not exceeding 2.5 times the pavement width (to relieve shrinkage cracking and tensile stresses). Reinforcing is to be continuous under contraction joints with every second mesh/bar cut or where reinforcing is not continuous then deformed reinforcing bars shall be provided as per Section 15 of this Specification and the Drawings.

7.4.2.2 Pavement Construction Joints

Construction joints are created between concrete pours.

All construction joints are to be formed within the concrete formwork and shall typically be 25mm deep and 10 mm wide. All construction joints are to be provided with load transfer steel dowels as per Sub-Clause 7.2.3.

Following the full 28 day concrete cure period, construction joints shall be cleaned, washed, filled and sealed with a mixture of 50% sand and 50% bitumen, with a proud reservoir of bitumen provided at the top of each joint.

Longitudinal construction joints should have load transferring dowels and sealing arrangement similar to that of transverse construction joints.

7.4.3 Concrete

Concrete shall be batched, placed compacted and cured in conformity with the stipulations of Section 16 of this Specification.

Aggregates shall be stored separately in a clean area. Proportions of aggregates shall be measured using weighing apparatus or batching boxes. Water should be fresh, not brackish (total salt content <3,000mg/litre), and not contaminated by industrial or other waste. Water proportions shall be determined using containers of known volume.

All formwork shall be as per Section 16 of this Specification and shall be well secured, free from defects or gaps, and able to resist the tamping forces. The top edge of the formwork shall be within ± 3 mm of the required finished road levels.

Prior to placing the concrete, all formwork and reinforcement shall be thoroughly inspected and passed by the Construction Supervisor. All wood chips, dust, sand, construction debris and any other deleterious material shall be removed from the formwork and reinforcement prior to placing the concrete. All formwork shall be oiled or have an approved releasing agent or be otherwise able to release cleanly upon stripping from the insitu cured concrete. Temporary planking walkways shall be provided to allow the concrete to be barrowed to the location of placement without disturbing the reinforcement mesh.

Once the concrete had been placed uniformly within the forms, compaction shall be carried out using a mechanical poker vibrator or similar vibration method approved by the Construction Supervisor. Over-vibration of concrete must be avoided at all times. Care should be taken to ensure a good bond between layers of fresh concrete placed separately by vibrating the two layers together until a satisfactorily homogenous cross section is obtained. No concrete shall be compacted after initial setting has commenced.

After placement and compaction, the camber shall be shaped in the fresh concrete to lines and levels detailed in the Drawings. In order to improve the skid resistance of the surface and to mimimise the vehicles' breaking distance, transverse grooves shall be etched in the fresh concrete surface utilising an appropriate rake or applying a coarse synthetic bristle broom finish.

Concrete shall be properly cured by ensuring that exposed concrete surfaces remain wet over the initial period of the curing process of 7 days. The surface of the slab shall be kept wet by any approved method including but not limited to: providing a sand dam for contained water or spreading sand or sacking over the surface of the pavement and repeatedly wetting the materials for a period. The Contractor shall assure that the wetting is continuous over night. No traffic shall be allowed on the pavement until a period of 14 days has elapsed. Suitable temporary diversions should be made for continued flow of normal traffic.

Concrete shall not be mixed or poured when ambient shade temperatures are more than 35 degrees Celsius.

7.5 LABORATORY AND SITE TESTING

7.5.1 General

The Contractor has control over quality of the materials incorporated and works performed through quality control tests carried out to the frequencies indicated here in under. The frequencies are the minimum. The Construction Supervisor shall have the authority to have these tests conducted at more frequent intervals where quality of a material or work is in doubt.

7.5.2 Laboratory Testing

Concrete and materials for concrete are subject to the testing requirements as per Section 16 of this Specification.

Steel reinforcement may be tested in accordance with the stipulations of Section 15 of this Specification If so instructed by the Construction Supervisor.

7.5.2 Site Testing

Visual inspections will be made to check compliance with this Specification, the Drawings and Section 16 of this Specification:

- bedding sand
- steel mesh/reinforcement
- dowels
- formwork
- aggregate
- water
- concrete placing and finish

A Slump Test will be carried out on every new concrete batching shift, or as directed by the Construction Supervisor. The slump shall comply with Section 16 of this Specification.

A pavement layer quality and specification compliance inspection will be undertaken on all completed sections of the reinforced concrete pavement by the Construction Supervisor prior to acceptance of the Works.

7.6 MEASUREMENT AND PAYMENT

The unit of measurement shall be square metres (m^2) of constructed reinforced concrete pavement (full width or strips). The quantity for which payment shall be made shall be the product of the instructed average width and the measured length along the centre line of the road.

The rates shall include the supply, placing, spreading, shaping, watering and compaction as specified and shown on the Drawings.

The rates shall include the supply, placing, fixing, shoring, stripping and removal of all formwork.

The work as measured shall be paid for at the Contract unit price shown in the Bill of Quantities. Payment shall be full compensation for performing the work including supplying the materials, and providing all labour, tools, equipment, formwork, incidentals necessary, overheads and profit.

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GROUP 8

BITUMINOUS SURFACING

8.1 GENERAL

This Section covers the provision of a single or double bituminous surface treatment, otherwise known as SBST and DBST or a single and double chip seal.

This Section is supported by Overseas Road Notes (ORNs) 3 and 31, which should be referred to for design and construction guidance.

SBST consists of a layer of bitumen which is spread onto the underlying layer followed by a layer of single sized chippings which are spread onto the bitumen and compacted into the surface. If the underlying layer is non-bituminous, a thin bituminous prime coat should be applied to seal pores in the underlying layer (which would reduce the effectiveness of the layer of bitumen) and provide a bond between the underlying layer and the surface treatment.

SBST comprises a single surface treatment. DBST comprises a first surface treatment followed by a second surface treatment using smaller chippings. The required chipping size depends upon the traffic which will use the road and the strength of the underlying layer.

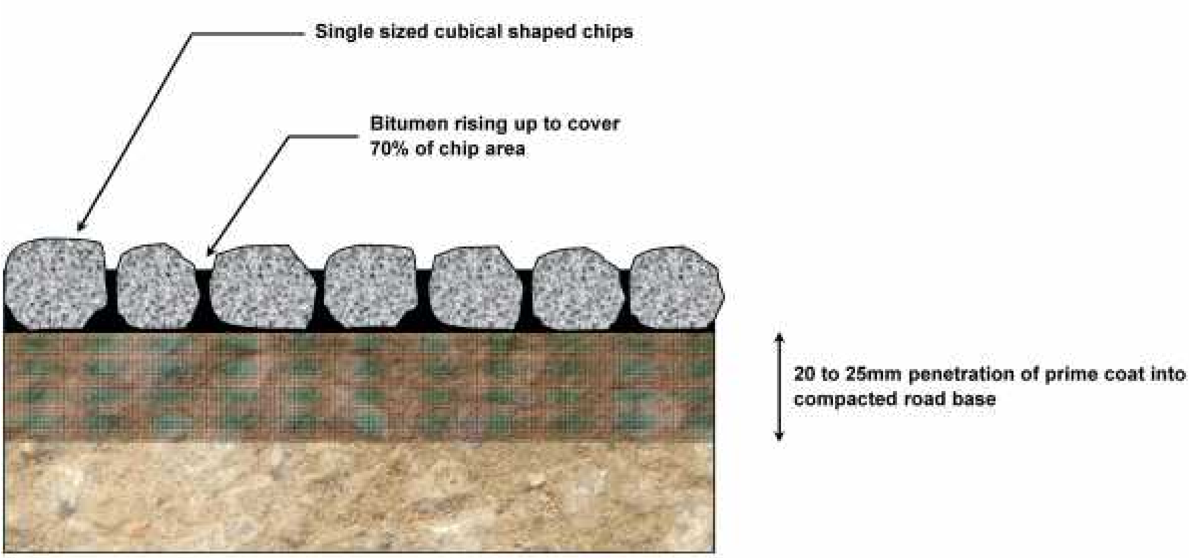

Figure 1: Components of a Single Bituminous Surface Treatment (SBST)

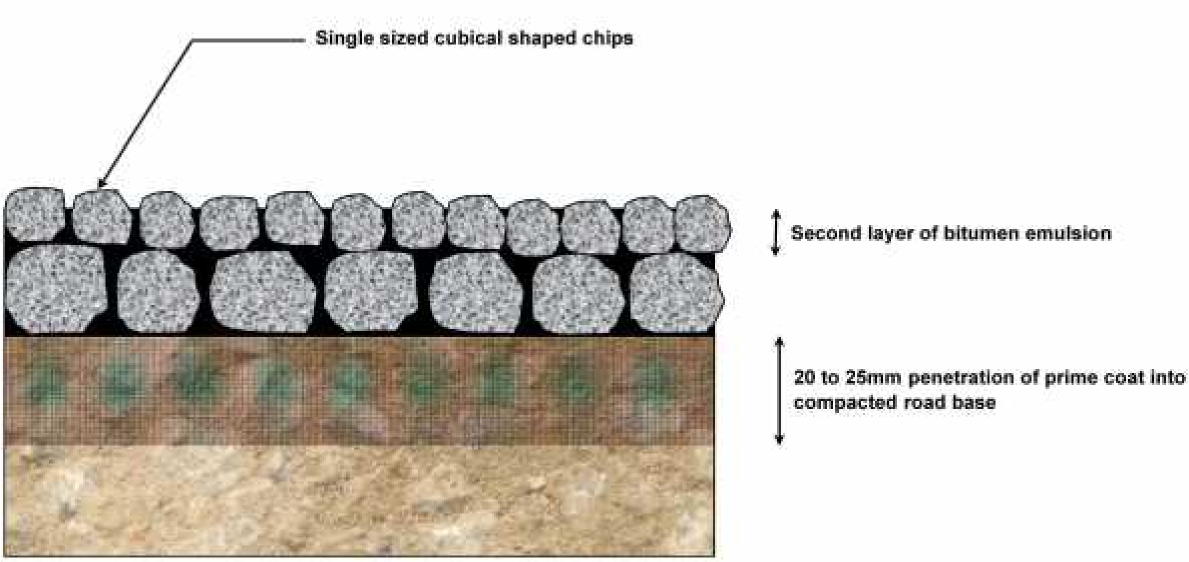

Figure 2: Components of a Double Bituminous Surface Treatment (DBST)

8.2 BITUMINOUS PRIME COAT

8.2.1 General

This work shall consist of the furnishing and application of a cutback bitumen, and blotter material where necessary, to an area of the prepared surface of the base course in accordance with this Specification and as directed by the Construction Supervisor.

8.2.2 Cutback Bitumen

The prime material shall be AMC1 cutback bitumen complying with AS 2157 or similar approved by the Construction Supervisor.

The prime material may be prepared in the field by mixing aviation kerosene or power kerosene with Class 170 bitumen to AS 2008. The Contractor shall propose the appropriate ratio to obtain characteristics consistent with AMC1 cutback bitumen for the Construction Supervisor's approval. The kerosene, without being previously heated, shall be pumped into the distributor through the bitumen which has been heated to a temperature within the range 165^0C – 175^0C and the mixture shall then be thoroughly circulated for at least 20 minutes before application.

The bitumen and cutter used to manufacture the cutback bitumen in the field shall comply with AS 2008 and AS 3568 respectively.

8.2.3 Blotter Material

Blotter material shall be approved by the Construction Supervisor and shall be clean, dry sand or stone screening free from any adhesive material. It shall contain no organic matter.

8.2.4 Measuring Road Temperatures

Unless the Construction Supervisor gives directions to the contrary, the Contractor shall measure and record road temperature at regular intervals during the course of the work. For this purpose a road surface thermometer shall be placed in direct contact with the pavement and allowed to remain in position until the reading becomes steady. If the pavement is partially in sun and partially in shade, the temperature of both conditions shall be taken and recorded.

8.2.5 Base Course Surface

Immediately before spraying, the surface of the base course shall be swept free of loose stones, dust, dirt and foreign matter so as to uncover but not dislodge the course aggregate. Sweeping shall extend 300 mm beyond the area to be primed. A mechanically operated rotary broom may be used for the sweeping provided it does not disturb the surface stones but if a satisfactory clean surface is not obtained thereby, additional sweeping shall be done by hand using stiff bristle or similar approved brooms. Adhering patches of foreign material shall be removed from the surface of the road by use of a steel scraper or other approved method. No spraying shall be undertaken until the pavement has been prepared to the satisfaction of the Construction Supervisor. The application of a prime coat shall not commence until the PWD Basecourse Approval Form has been signed off by the Construction Supervisor.

8.2.6 Mechanical Distributor

The application of prime coat shall be made by means of a mechanical distributor approved by the Construction Supervisor which shall have pneumatic tyres of such width and number that the load produced on the road surface shall not exceed 120 kilograms per centimetre of type width and shall be so designed, equipped, maintained and operated so that the prime coat may be applied at even heat uniformly over variable widths of surface up to 5 metres at readily determined and controlled rates of from 0.2 to 3.0 litres per square metre with uniform pressure and with an allowable variation from any specified rate not exceeding 0.1 litres per square metre. The distributor shall be fitted with instruments for measuring the speed of travel accurately at low speeds, the rate of flow of bituminous material through the nozzles, the temperature of the contents of the tank and the pressure of the material in the spray bars.

These instruments shall be so located that the operator can easily read them whilst operating the distributor. A spare maximum recording mercury thermometer and strainer shall also be available. The tank of the distributor shall be fitted with accurately calibrated dipsticks or content gauges. The distributor shall be equipped with a separate power unit for the pump and full circulation spray bars.

8.2.7 Calibration of Distributor

The Spray bar and all measuring equipment on the distributor shall have been recently calibrated (within the previous 12 months) and an accurate and satisfactory record of such calibration shall be supplied to the Construction Supervisor. If at any time the distribution of bituminous material is found to be in error, the distributor shall be withdrawn from the work and recalibrated in a manner satisfactory to the Construction Supervisor before continuing with the work.

8.2.8 Performance of Distributor

The Construction Supervisor may require such tests as he considers necessary to check the performance of the distributor. As and when directed by the Construction Supervisor, the Contractor, at his own expense, shall make the distributor and its equipment available for field testing and shall supply any assistance required for this purpose. Any distributor which does not operate satisfactorily or conform to the requirements of the Specification in all respects may be rejected by the Construction Supervisor for further use in the Works.

8.2.9 Hand Spray Equipment

Where the use of the mechanical distributor is not practical for application to small areas and areas not satisfactorily sprayed during a run of the distributor, the spraying of such areas as the Construction Supervisor may approve shall be done by means of the hand spray equipment of the distributor.

8.2.10 Length to be Sprayed

The length of the surface to be sprayed by each run of the distributor shall be measured and marked on the ground. The application shall commence and finish on a protective strip of paper laid across the surface beforehand, unless the Construction Supervisor approves the omission of the protective strip at the finish. The protective strip shall be of paper of quality not less than 50 Kraft, or such other material as the Construction Supervisor may approve. The width of the protective strip shall be not less than that endorsed on the distributor or such additional width as the Construction Supervisor may direct. At the time of spraying, the road surface shall be clean and slightly damp. Spraying shall not proceed if rain threatens.

8.2.11 Prime Coat Rate

The prime application rate shall be determined by the Contractor and submitted to the Construction Supervisor for approval at least seven (7) days prior to any priming works commencing.

8.2.12 Width of Primed Surface

The width of primed surface shall be one hundred and fifty (150) millimetres wider on each side than the sealed surface specified on the drawings or as directed by the Construction Supervisor. The edges of the area primed shall not vary by more than $\pm$ 75 millimetres from the lines specified or directed by the Construction Supervisor.

8.2.13 Optimum Temperature

The optimum temperature of the cutback at the time of the application will depend upon climatic conditions and the equipment used but shall be in the range 35^{o}C – 55^{o}C. Heating quantities in excess of requirements or prolonged heating at high temperature are to be avoided. Any material which, in the opinion of the Construction Supervisor has been damaged by overheating shall be rejected and shall be replaced at the Contractor's expense.

8.2.14 Application of Prime Coat

Prime coat shall be applied only when the weather is dry and when the road temperature is at above 18^{o}C. Road temperature shall be measured as set out in Clause 8.2.4.

Any prescribed application shall be divided into two applications when necessary to prevent bitumen flowing off the surface, and additional material shall be applied where surface conditions indicate it to be necessary, if the Construction Supervisor so directs. No further courses shall be applied until the prime coast has set and the solvent evaporated.

When so directed, the prime coat shall be applied in lanes of approximately one half of the width of the completed surface. A lane of prime coat shall be applied, allowed to penetrate not less than 4 hours, unless otherwise permitted by the Construction Supervisor, then covered with blotter material if required, and opened to traffic before prime coat is applied to the adjacent lane. When applying blotter material to the first treated lane, a strip at least 200 millimetres wide shall be left uncovered where the two lanes shall join to permit a slight overlap of the prime material.

8.2.15 Adjacent Trees and Structures

The surfaces of structures and trees adjacent to the area being treated shall be protected in such a manner as to prevent their being spattered or marred. No bituminous material shall be discharged into a unlined, stone pitched or concrete lined side drain.

8.2.16 Traffic Restrictions

Traffic shall not be permitted on the primed surface until the bituminous material has penetrated and dried and, in the opinion of the Construction Supervisor, will not be picked up by the traffic. Where the Construction Supervisor deems it impractical to re-route traffic, the Contractor shall spread the minimum quantity, as approved by the Construction Supervisor of blotter material necessary to avoid picking up, and traffic shall be allowed to use areas so treated. Any areas containing an excess or deficiency of priming material shall be corrected by the addition of sand or prime as directed by the Construction Supervisor. Should any break occur in the surface, the area affected shall be cut out and made good as directed by the Construction Supervisor. All repairs and corrections of faulty work shall be carried out at the expense of the Contractor.

8.2.17 Measurement of Prime Coat

Measurement of bituminous prime coat shall be in square metres of the actual area covered. The rate in the Bill of Quantities shall be deemed to allow for a suitable spray rate to meet the Specification requirements as no cost variation will be considered in relation to varied spray rates.

8.2.18 Measurement of Blotter Material

Where a separate item is included in the Bill of Quantities for blotter material, the quantity of blotter material measured for payment shall be the area in square metres (m^2) of material spread as required by the Consruction Supervisor. Where there is no such item, provision for supply and spreading blotter material shall be included in the rate for supply and spray prime coat.

8.2.19 Payment

The work measured as provided above shall be paid for at the tendered unit rates for each of the items listed above. The rates and payment shall be full compensation for preparation of the surface and for furnishing and placing the materials including all labour, equipment, tools and incidentals necessary to complete the work prescribed in Clause 8.2.

8.3 BITUMINOUS SURFACE TREATMENT

8.3.1 General

This work shall consist of the furnishing of one or more applications of bituminous material and cover aggregate to a previously constructed and prepared surface in accordance with this Specification and as directed by the Construction Supervisor.

8.3.2 Bituminous Material

This work shall consist of residual bitumen Class 170 conforming to the requirements of AS 2008, and the Contractor shall be responsible for the testing of bitumen in accordance with AS 2008. He shall submit to the Construction Supervisor a copy of all test results obtained. Bitumen which does not comply with the requirements of AS 2008 shall not be used for sealing works without the written approval of the Construction Supervisor.

8.3.3 Adhesion Agents

To improve the adhesion of cover aggregates to the binder, an approved adhesion agent shall be added to the binder in accordance with the manufacturer's recommendations. The Contractor shall submit his proposals, together with written evidence of the successful use of such additives to the Construction Supervisor for his approval prior to purchasing.

8.3.4 Aggregates

Aggregates shall consist of clean, hard, dry, tough, sound, crushed stone or crushed gravel of uniform quality, free from dust, clay, dirt or other deleterious matter and from excess of flat or laminated pieces and shall be of such a nature that when thoroughly coated with the bituminous material proposed for the work, the coating will not peel off upon contact with water.

They shall comply with AS 2758.2 as modified by the following requirements:

a) Weak particles shall not exceed 2.0% when tested in accordance with AS 1141.32.
b) When crushed gravel is used, not less than 60% by weight of the particles retained on a 4.75 mm sieve shall have at least two fractured faces.

8.3.5 Aggregate Size

Unless otherwise shown on the drawings:

(a) For a single application of bituminous material and cover aggregate the aggregate size and grading shall be 14 mm nominal size.
(b) For a double application of bituminous material and cover aggregate, the aggregate for the first application shall be 14 mm nominal size, and for the second 7 mm nominal size unless otherwise directed by the Construction Supervisor.

The gradings shall comply with AS 2758.2 Clause 8.1.

8.3.6 Aggregate Stockpile

Aggregates shall be stockpiled clear of traffic, drains and services and other property on well-drained ground approved by the Construction Supervisor. A separate stockpile shall be made for each nominal size of aggregate at each location and each shall be at least 15 metres from the adjoining stockpile. The site of the stockpile shall be cleared of all vegetation and debris, graded and drained for an area extending 5 metres outside the limits of the stockpile and, where the Construction Supervisor deems it necessary, the area shall be surfaced with a 100 millimetre layer of approved stone or rock. Unless otherwise approved by the Construction Supervisor each stockpile shall be built 1 metre high over the whole area of the stockpile and with slopes of 1 vertical to 1 horizontal. The Contractor shall supply any planking or other material required in connection with movement of vehicles over and about the stockpiles. The bottom 50 millimetres layer of aggregate or any contaminated aggregate shall not be used in the work.

8.3.7 Pre-coating of Aggregates

All particles of aggregate must be completely but thinly coated by means of a fine pressure spray on a moving stream of aggregate or by other means approved by the Construction Supervisor. The quantity of pre-coating material needed will vary with the nature of the stone but will be within the range 6 to 12 litres per cubic metre. Pre-coating material shall be a distillate with 10% bitumen and 1% megamine BA or equivalent, unless otherwise approved by the Construction Supervisor.

8.3.8 Plant and Equipment

The Contractor shall supply details of the make, model, capacity, weight and such other details of the plant and equipment as may be required by the Construction Supervisor. Such equipment shall include a powered broom or power blower or both, a drag broom, a self-propelled pneumatic tyred roller, aggregate spreading equipment, an adequate number of trucks and when necessary, equipment for heating bituminous material. A steel wheeled roller may be used only when so authorised by the Construction Supervisor.

The plant and equipment shall comply with the following requirements:

(a) The bituminous material distributor shall conform to the requirements for the mechanical distributor described in Clause 8.2.6.

(b) The power broom shall be a rotary broom, towed or self propelled, specifically designed for sweeping road surfaces.

(c) The drag broom shall be capable of distributing unevenly spread aggregate without disturbing the particles freshly bedded in the binder.

(d) The pneumatic tyred roller shall be of an approved type having not less than seven wheels mounting smooth tread compactor tyres of equal size and construction capable of operating at inflation pressures up to 800kPa. Wheels shall be equally spaced along both axle lines and arranged so that tyres on one axle line track mid way between those on the other with an overlap. Each type shall be kept inflated to the specified pressure such that the pressure difference between any two types shall not exceed 35kPa. Means shall be provided for checking and adjusting the tyre pressure on the job at all times. For each size and type of tyre used, the Contractor shall supply to the Construction Supervisor charts or tabulations showing the relationship between wheel load, inflation pressure and tyre contact pressure, width and area.

Pneumatic tyred rollers shall be ballasted until there is a mass of approximately one tonne per wheel. Tyre pressure shall be approximately 550kPa. Speed of operation of the roller shall be approximately 15km/h. The roller shall not be allowed to stand on finished work. Care should be taken when reversing, so as not to damage the surface.

(e) The steel roller, where its use is permitted, shall have a load of between 25 to 45 kilograms per centimetre width of roll.

(f) The aggregate spreader shall be approved mechanical equipment capable of spreading the uniform layer of cover aggregate of the specified sizes.

(g) Heating equipment shall be capable of producing uniform heating to the repaired temperature without damage to the bituminous material. An approved instrument for temperature measurement with an accuracy of plus or minus 3% shall be provided. Means shall be provided to drain completely the heating tank or tanks. Three or more approved fully charged chemical fire extinguishers and a stockpile of approved loose sandy material, and a shovel shall be provided and shall be placed adjacent to the heaters while heating is in progress

8.3.9 Surface Preparation

Prior to the application of binder, loose stones and dirt and other objectionable material shall be removed from the surface by means of the power broom or blower or both but without dislodging the stones embedded in the pavement. If this does not produce a uniformly clean surface, additional sweeping shall be done by hand, using stiff bristle or similar brooms. Sweeping shall extend at least 200 millimetres beyond each edge of the area to be sprayed. Adhering patches of objectionable material shall be removed from the surface by steel scraper or other approved method and where the Construction Supervisor so directs the scraped area shall be washed down with water and hand brooms. No application of bituminous material shall be undertaken until the pavement has been cleaned and patching of the surface of the road has been completed to the approval of the Construction Supervisor. Any area in which the prime coat has been insufficiently applied or is defective in any way shall be reprimed as directed by the Construction Supervisor.

A period of at least 24 hours or such longer period as may be necessary for the prime coat to become completely dry shall elapse before any further bituminous material is applied.

8.3.10 Application Rate

The application rate of bituminous binder material and cover aggregate shall be determined by the Contractor and submitted to the Construction Supervisor for approval at least seven (7) days prior to any sealing works commencing. Sealing works shall not commence until the application rates have been approved by the Construction Supervisor.

The application rate of bituminous binder material and cover aggregate shall be determined by the Contractor by the methods set in Road Note 3 – A "Guide to Surface Dressing in Tropical and Sub-Tropical Countries", published by Transport and Road Research laboratory United Kingdom.

OR

The application rate of bituminous binder material and cover aggregate shall be determined by the Contractor using the Update of the Austroads Sprayed Seal Design Method (AP-T68-06) and Update of Double / Double Design for Austroads Sprayed Seal Method (AP-T236-13) and Towards Incorporating Heavy Vehicles into the Austroads Sprayed Seal Design Method (AP-T260-14). The Contractor shall provide full design calculations including details of any assumptions to the Construction Supervisor.

The Construction Supervisor reserves the right to alter the application rates during the course of the work if necessary.

The authorised rate of application of bituminous binder material shall be based on residual bitumen at a temperature of 15^{o}C and corresponding allowance shall be made for expansion of the binder when heated to spraying temperature, and where adhesion agent is included, the application rate shall be adjusted to allow for the quantity of adhesion agents.

The application of bituminous binder material shall be made by means of a mechanical distributor except that where the use of the distributor is not practicable for application to small areas, the application to such areas, as the Construction Supervisor may approve, may be done by means of hand held spray equipment attached to the distributor.

8.3.11 Spraying Temperature

The temperature at the time of spraying the bituminous material shall be within the range of 165^{o}C to 185^{o}C.

At no time during the heating shall the upper limit be exceeded. Quantities of bituminous materials in excess of requirements shall not be heated, nor shall such materials be held at temperatures within the spraying range for periods in excess of ten hours. Any bituminous material which has been heated for an excessive period of time or which has been overheated shall be rejected.

8.3.12 Area to be Sprayed

The area to be sprayed with bituminous material at any time shall be limited to that which can be covered with aggregate at the specified rate within 15 minutes of the time of spraying or such smaller period of time as the Construction Supervisor shall direct. When so directed the bituminous material shall be applied in lanes of approximately one half of the width of the completed surface and when so applied there shall be an overlap of 75 millimetres of bituminous material along the adjoining edges. The width of the area sprayed shall not vary by more than + 50 millimetres from the width specified in the Contract or directed by the Construction Supervisor. The area to be sprayed shall be marked prior to spraying operations commencing for that area.

8.3.13 Spraying

No spraying shall be carried out on a wet pavement nor when rain appears imminent nor during high winds nor when the ambient temperature is below 18^{0}C. The Construction Supervisor shall order work to cease temporarily on account of adverse weather, unsatisfactory condition of materials, equipment, pavement or any condition which he considers may affect the work adversely.

Spraying shall commence and finish on a protective strip of paper or other approved surface for at least the full width to be sprayed. Paper or other material so used shall be immediately removed and disposed of in a manner satisfactory to the Construction Supervisor. The distributor shall commence moving at a sufficient distance in advance of the start of the application to ensure that the correct road speed for the required application is attained before the spray nozzles are opened and shall maintain this speed until past the finishing point of the application. Spraying shall cease immediately if any defect develops in the spraying equipment and it shall not recommence until the fault has been rectified.

Provision shall be made for 10 per cent, or such other percentage as may be determined by the Construction Supervisor, of the rated capacity of the distributor tank to be retained in the tank at the completion of each run, so as to avoid air entrainment within the delivery system and provide for any minor excess in the rate of application.

After each application the quantity of material sprayed shall be checked against the area covered, and any necessary adjustment shall be made to ensure that the specified rate of application is maintained in subsequent runs.

8.3.14 Cover Aggregate Supply

Before the bituminous material is applied, sufficient cover aggregate shall be in trucks at the site of the work to provide the full cover for the area to be sprayed.

The application of the aggregate shall proceed immediately after application of bituminous material commences and shall be completed within 15 minutes of the completion of spraying or such shorter period of time as the Construction Supervisor may direct. The aggregate shall be spread uniformly over the bituminous material by means of the approved aggregate spreader at the rate approved by the Construction Supervisor. Any bare or insufficiently covered areas shall be re-run by the mechanical spreader or covered by hand as necessary to give uniform and complete coverage. Any aggregate spread in excess of the rate specified or ordered shall be scattered and evenly distributed on the road or otherwise removed and stockpiled as directed by the Construction Supervisor.

8.3.15 Rolling

Immediately after spreading to the satisfaction of the Construction Supervisor, the aggregate shall be rolled with one or more pneumatic tyred rollers or, if permitted by the Construction Supervisor, by approved steel rollers, for a minimum of 1 hour for each 1200 litres of bituminous material sprayed or until the aggregate has predominantly been turned over until the ALD is positioned vertically, whichever is the longer.

Where required by the Construction Supervisor, the surface shall be drag broomed after the initial rolling except that if the drag broom has any tendency to dislodge aggregate particles bedded in the binder the Construction Supervisor may direct that drag brooming be deferred or eliminated and that light hand brooming be substituted.

Any remaining loose particles shall be removed from the pavement and shoulders.

8.3.16 Traffic Restrictions

No traffic shall be permitted to pass the working area during the application of bituminous material nor shall traffic be permitted to encroach upon the edge of bituminous material until such time as it is covered with aggregate. The Contractor shall take all reasonable precautions to protect traffic against damage or disfigurement by construction equipment, tools and materials, splashes of bitumen or other construction materials and shall be responsible for any claims arising from such damage or disfigurement.

Traffic shall not be allowed on the new work until sufficient rolling has taken place to minimise the risk of disturbing the aggregate. Traffic shall then be allowed to run on the work at a controlled speed. Approved signs bearing the words “wet bitumen” and “20km/h” shall be erected at appropriate locations not more than 300 metres apart and shall remain in position during and for 24 hours after each days work.

Other signs, signals, barriers, and lamps for warning and guidance of traffic shall be provided at all times during the course of the work in accordance with Group 1, General.

8.3.17 Monitoring of Completed Works

After completion of this work and until the end of the Defects Liability Period the treated surface shall be consistently checked for any tendency to softening or bleeding and these should be attended to by addition of small quantities of aggregate evenly spread.

Seven (7) days after the completion of rolling, all loose aggregate shall be removed from the surface by light sweeping to the satisfaction of the Construction Supervisor. All excess aggregate shall be removed from the work site to the satisfaction of the Construction Supervisor. Should any break occur in the surface the area affected shall be thoroughly cleaned and treated with binder and aggregate as directed by the Construction Supervisor.

8.3.18 Measurement

Measurement shall be in square metres of the actual area covered. The rate in the Bill of Quantities shall be deemed to allow for suitable rates to meet the Specification requirements as to binder, adhesion agents, precoating material and cover aggregates as no cost variation will be considered in relation to varied rates of application.

8.3.19 Conformance and Non-Conformance

The actual binder application rate at 15°C on a spray run shall be deemed to be conforming to the approved binder application rate if it falls within the tolerances given in the table below.

Where the actual binder application rate at 15°C on a spray run differs from the approved rate, the Quality Level shall be deemed to be either a non-conformance or one of a range of conditional conformance levels depending on the difference between the actual binder application rate and the approved binder application rate as per the table below.

A Pay Factor shall be applied for work at the appropriate conformance levels in accordance with the table below. The Pay Factor shall reflect the lower level of serviceability of conditionally conforming sprayed bituminous work.

Where sprayed work is deemed non-conforming, corrective action shall be determined by the Contractor for approval by the Construction Supervisor. Non-conforming work shall be rectified.

ACTUAL BINDER APPLICATION RATE (BAR) FOR SEALS & RESEAL (BAR) L/m^2 at 15^{o}C	**QUALITY LEVEL**	**PAY FACTOR**
(ABAR - 0.16) or less	Non-Conformance	N/A
(ABAR - 0.15) to (ABAR - 0.11)	Conditional Conformance Level 2	0.90
(ABAR - 0.10) to (ABAR + 0.10)	Conformance	1.00
(ABAR + 0.11) to (ABAR + 0.15)	Conditional Conformance Level 1	0.90
(ABAR + 0.16) to (ABAR + 0.20)	Conditional Conformance Level 3	0.70
(ABAR + 0.20) or more	Non-Conformance	N/A
(ABAR = Superintendent Approved Binder Application Rate at 15^{o}C)		

Volume Conversion

The following table gives factors to be used when converting binder volumes or spray rates at temperatures other than 15°C to volumes or spray rates at 15°C or vice versa.

Observed Temp TîC	**Factor For TîC**	**Observed Temp TîC**	**Factor For TîC**	**Observed Temp TîC**	**Factor For TîC**
15	1.0000	80	0.9543	145	0.9105
20	0.9964	85	0.9509	150	0.9072
25	0.9929	90	0.9475	155	0.9039
30	0.9893	95	0.9441	160	0.9007
35	0.9857	100	0.9407	165	0.8974
40	0.9822	105	0.9373	170	0.8942
45	0.9787	110	0.9339	175	0.8909
50	0.9752	115	0.9305	180	0.8877
55	0.9717	120	0.9272	185	0.8845
60	0.9682	125	0.9238	190	0.8813
65	0.9647	130	0.9205	195	0.8781
70	0.9612	135	0.9171	200	0.8749
75	0.9578	140	0.9138		

Adjustment shall be made using the following formulae:-

(i) Volume at 15°C = Volume at T°C x Factor for T°C

Spray Rate at 15°C = Spray Rate at T°C x Factor for T°C

(ii) Volume at T°C= Volume at 15°C / Factor for T°C

Spray Rate at T°C = Spray Rate at 15°C / Factor for T°C

Factors for other intermediate temperatures may be obtained by direct interpolation.

8.3.20 Payment

Works specified in Clause 8.3 shall be paid for at the tendered unit rate, respectively, for each of the items listed above. The rates shall be full compensation for furnishing, mixing and placing all materials, including all labour, equipment, tools and incidentals necessary to complete the work including the rectification of any defective work.

Payment shall be subject to the Pay Factors outlined above for Conditional Conformance.

8.4 HOT–MIXED ASPHALT SURFACING

When hot-mixed asphalt is required in the Contract the detailed specification for these works are included in the Supplementary Specification to this Specification.

8.5 OTTA SEAL

When Otta seal is required in the Contract the detailed specification for these works are included in the Supplementary Specification to this Specification.

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GROUP 9

DRAINAGE

9.1 GENERAL

The work covered in this Specification shall include both the construction of new and the extension of existing reinforced concrete culverts and corrugated steel pipe culverts and associated activities. The details of the locations, sizes, lengths, skew angle, invert levels and classes of pipe culvert required are provided on the Drawings or as directed by the Construction Supervisor.

Corrugated steel pipes and helical lock-seam pipes shall only be permitted if shown on the Drawings or approved by the Construction Supervisor.

The length of a culvert shown on the Drawings or instructed by the Construction Supervisor shall refer in the case of a vertical ended culvert (square or skew) to the length along the invert of one barrel and in the case of a bevel ended culvert (square or skew) to the mean of the invert and obvert lengths.

9.2 MATERIALS

9.2.1 Reinforced Concrete Pipes

Reinforced concrete pipes shall conform to AS 4058 and shall be of the class shown on the Drawings or, if not so shown, shall be Class 3 unless otherwise ordered by the Construction Supervisor. The type of jointing shall be flexible rubber ring, spigot and socket joints. Flush or butt joints shall only be used for the first pipe when extending existing pipes. The class of pipe, date of manufacture and the name or trademark of the manufacturer shall be clearly marked on each pipe. Pipes shall be tested as provided by AS 4058 in the presence of a representative of the Construction Supervisor prior to leaving the place of manufacture. All pipe sections shall be free from defects or damage to ends and upon request the Contractor shall furnish at his own expense such tests as may be required by the Construction Supervisor on any pipes on Site appearing to be defective or to have been damaged.

Alternatively, the Contractor may manufacture the pipes on site. In that case the Contractor shall provide details of the wall thickness, concrete class, reinforcement (if any) and manufacturing methodology for the approval of the Construction Supervisor at least two (2) weeks before the intended commencement of manufacture. The Construction Supervisor may require additional information to be provided and / or a prototype to be manufactured on site and then tested in accordance with AS 4058 or in such other manner as may be agreed with the Contractor.

9.2.2 Mortar for Joints

Jointing mortar shall be of smooth consistency consisting of one part Portland cement and two parts fine sand by dry volume. The amount of water added to the mix shall be just so much that the consistency is satisfactory to the Construction Supervisor. All mortar shall be used within 30 minutes of adding water.

9.2.3 Corrugated Steel Pipes

9.2.3.1 Nestable and Bolted

Where permitted, nestable and bolted corrugated steel pipe sections shall comply with the requirements of AS 2041. Unless otherwise shown or permitted by the Construction Supervisor, all bolted pipes to be incorporated in the Works shall have had their load carrying capacity increased by shop rolling of the plates at the place of manufacture so that there is a 5 percent increase in the dimension of their vertical axis.

No variation greater than plus or minus 25 percent from the specified elongation (5%) will be accepted. All pipes shall be hot dip galvanised unless otherwise directed.

The gauge and length of the pipe shall be as shown on the Drawings or as directed by the Construction Supervisor after analysis of the soil type to be used as backfill.

9.2.3.2 Helical Lock-Seam

Where permitted, helical lock-seam corrugated steel pipe shall be supplied in accordance with AS 1761and shall be of the class and size as shown on the Drawings. The galvanised steel sheet used in manufacture shall comply with AS 1397 for steel based grade G250 and a minimum coating Class of Z600.

Unless otherwise approved by the Construction Supervisor, no part of the pipe shall incorporate steel strips which have been joined by welding.

Field cut ends shall be carefully wire brushed to remove any scale followed immediately by two coats of zinc-rich organic primer complying with AS 3750.9 or two coats of inorganic zinc silicate paint complying with AS 3750.15. Pipes and coupling bands shall be given a protective hot-dip coating of bitumen on both sides to AASHTO standard M190-04 or equivalent as part of the process of manufacturing.

9.2.4 Precast Reinforced Concrete Box Culverts

Precast reinforced concrete box culverts shall conform to AS 1597 and shall be of a type and manufacture approved by the Construction Supervisor. The date of manufacture and the name of trademark of the manufacturer shall be clearly marked on each culvert section. Culvert sections shall be tested as provided by AS 1597 in the presence of a representative of the Construction Supervisor prior to leaving the place of manufacture. All culvert sections shall be free from defects or damage to the edges and upon request the Contractor shall furnish at his own expense such tests as may be required by the Construction Supervisor on any culvert sections on Site appearing to be defective or to have been damaged. The Contractor shall arrange for all defects and damage incurred to be repaired at his cost.

Lifting hooks or holes shall be provided in the decks of culvert sections. Other lifting arrangement shall be subject to the approval of the Construction Supervisor.

The base slabs shall either be precast or cast in-situ. Where a cast in-situ base slab is used, a suitable rebate shall be cast into the slab to provide the same rebate for mortar and the legs of the crown unit as for the precast base slabs. Cast in-situ base slabs shall conform to the requirements of Group 16 of this Specification. The Contractor is required to submit a base slab design for approval of the Construction Supervisor if no such design is shown on the Drawings. Where the Contractor is required to provide a design the loading requirements shall be as specified by the Construction Supervisor.

Alternatively the Contractor may manufacture the box culverts on site. In that case the Contractor shall provide details of the thicknesses of the walls, base and invert slabs, concrete class, reinforcement and manufacturing methodology for the approval of the Construction Supervisor at least two weeks before the intended commencement of manufacture. The Construction Supervisor may require additional information to be provided substantiating that the design is adequate for the intended purpose and / or a prototype to be manufactured on site and then tested in accordance with AS 1597. or in such other manner as may be agreed with the Contractor.

9.3 EXCAVATION AND BEDDING

The Contractor shall carry out all necessary excavation associated with the laying of the culvert including excavation for the specified foundation or bedding material and shall dispose of surplus material as directed by the Construction Supervisor. Culvert bedding shall be carried out in accordance with this Specification and in accordance with the Drawings. Where selected material is not ordered below the bedding layer, the top 150 mm of the foundation area shall be thoroughly compacted to the relative dry density of the equivalent adjacent embankment material as specified in Clause 4.15 of this Specification. The Contractor shall trim the foundation to the correct line and level specified on the Drawings or directed by the Construction Supervisor.

The Construction Supervisor may require the culverts to be laid in a trench excavated in the embankment after this has been constructed to the level of the top of the culvert. The width of the trench shall be just sufficient to permit satisfactory jointing of the pipe and thorough compaction of bedding and backfill material under and round the pipe, provided that the width of trench to be excavated for pipes shall be not less than the external pipe diameter plus 600 mm or the outside dimensions of the box culvert plus 600 mm each side.

Where rock is encountered at or above the proposed invert level of the culvert it shall be excavated to a depth at least 150 mm below the invert level over the full width of the foundation and the area backfilled with selected material and compacted to the density specified in Clause 9.5.

Where the foundation material is soft and spongy or otherwise consists of unsuitable material, this material shall be removed to a sufficient depth as directed by the Construction Supervisor and for a width equal to one and a half times the diameter or span of the culvert from the centreline of the barrel, before backfilling with material as defined in Clause 9.5.

All culverts shall be bedded on sand or other approved fine granular material of a least 75 mm thick. Bedding for all pipe culverts shall be shaped to fit the underside of the culvert for a depth of one tenth the pipe diameter and graded to provide uniform bearing throughout the length.

9.4 PLACING

9.4.1 Reinforced Concrete Pipe

Laying shall begin at the outlet end of the barrel with the socket ends upstream and spigot ends downstream. The ends of each length of pipe shall be carefully butted together to provide a continuously straight barrel. Where pipes are so designed that there is a "top" side for the pipe, this "top" must be so placed. When jointing, the trench shall be dry and the joints shall be cleaned and wetted before sealing with mortar. The mortar shall be kept damp until the Construction Supervisor approves backfilling to proceed. Internal joints of pipes more than 1 metre in diameter shall not be mortared until after backfilling is complete. All excess mortar shall be removed from inside the pipe. Where more than one barrel forms the culvert, the barrels shall be spaced as indicated on the Drawings.

7.4.2 Corrugated Steel Pipe –Nestable

Unless otherwise permitted by the Construction Supervisor, assembly of nestable culverts shall commence at the inlet and progress to the outlet end. The full circle shall be assembled and fastened with the bottom plates one sheet ahead at all times and circumferential joints staggered. As additional sections are added to the pipe, they shall always be placed outside the section already placed and fastened. The pipe shall be assembled and placed with the longitudinal joints in the same horizontal plane. A pipe may be wholly or partially assembled adjacent to its final location and lifted into position. Proper facilities shall be provided for careful handling without excessive deflection.

All joints or lap joints in pipes (excluding rubber ring joint coupling bands) shall be covered with strips of non-woven geotextile material, of minimum 250 mm width and of minimum mass 270 g/m^2 in accordance with the requirements for geotextile in Clause 20.6 of this Specification.

Any pipe which shows any undue settlement after laying or is in any way damaged shall be taken up and re-laid or replaced at the Contractor's expense. Where more than one barrel forms the culvert, adjacent sides shall be spaced as shown on the Drawings.

7.4.3 Corrugated Steel Pipe - Bolted

Unless otherwise permitted by the Construction Supervisor, the assembly of bolted culverts shall commence by laying all the bottom plates first from the outlet end. Side and top plates shall then be added generally completing the circle in sections but commencing at the inlet end. Side plats shall be added only so far ahead as is necessary to support the plates above. Only sufficient bolts shall be inserted during this stage to hold the plates in position with the nuts screwed up but not tightened. When all the plates are in place all bolts shall be inserted and the nuts thoroughly tightened. When all the bolts in the complete assembly have been inserted and tightened they are to be checked again and retightened where any slackness has occurred. Where more than one barrel forms the culvert, adjacent sides shall be spaced as shown on the Drawings.

9.4.3.1 Corrugated Steel Pipe - Helical Lock-Seam

Installation of helical lock-seam corrugated steel pipes shall be in accordance with AS 1762.

Field cut ends shall be carefully wire brushed to remove any scale followed immediately by two coats of zinc-rich organic primer complying with AS 3750.9 or two coats of inorganic zinc silicate paint complying with AS 3750.15. Pipes and coupling bands shall be given
a protective hot-dip coating of bitumen on both sides to AASHTO standard M190 or equivalent as part of the process of manufacturing.

Where helical-lock seam corrugated steel pipes are to be joined, both ends of the join shall be rerolled with four annular corrugations of pitch 68 mm. Coupling of the rerolled ends shall be made in accordance with AS 1761 by using semi-corrugated bands. Rubber ring joint seals shall be used in conjunction with the coupling bands except where specifically indicated otherwise in the Drawings.

All joints or lap joints in pipes (excluding rubber ring joint coupling bands) shall be covered with strips of non-woven geotextile material, of minimum 250 mm width and of minimum mass 270 g/m^2 in accordance with the requirements for geotextile in Clause 20.6 of this Specification.

Any pipe which shows any undue settlement after laying or is in any way damaged shall be taken up and re-laid or replaced at the Contractor’s expense. Where more than one barrel forms the culvert, adjacent sides shall be spaced as shown on the Drawings.

9.4.3.2 Corrosion Protection of Corrugated Steel Pipes

After assembly, all corrugated steel pipes shall be given a protective coating on the outside and inside of the steel plate, of a coal tar epoxy protective coating applied in accordance with the manufacturer’s recommendations or equivalent paint approved by the Construction Supervisor. Invert plates shall be coated on the outside before they are placed on the pipe bed. The plate surface shall be cleaned and degreased with a cleaning solution recommended by the protective coating manufacturer. The protective coating shall be applied to give a uniform minimum dry thickness of 400 microns. Any coating damaged shall be recoated by first cleaning any grease, mud or other foreign matter from the affected area. The area shall then be recoated so that the minimum dry thickness of the coating is 400 microns.

9.4.4 Extension of Culverts

Where an extension to an existing culvert is shown on the Drawings or is required by the Construction Supervisor, the removal of the end sections and end treatments as required shall be carried out so as to prevent damage to the remaining culvert sections. The Contractor may use any undamaged sections subject to approval by the Construction Supervisor. Damaged sections are to be removed from the Site by the Contractor.

9.4.5 Precast Reinforced Concrete Box Culvert

Precast box culverts shall be laid strictly in accordance with the manufacturer's recommendation or as directed by the Construction Supervisor, using one of the three methods described as follows:

(a) For small size culverts and where access is required the crown units shall be laid with "legs up" and the cover slabs set in place on mortar pads on top of the legs.

(b) Using precast base slabs with the crown units "legs down" on mortar pads in the base slab rebates.

(c) Using cast in-situ base slabs with the crown units "legs down" on mortar pads in the base slab rebates. The Contractor is required to submit a base slab design for approval of the Construction Supervisor if no such design is shown on the Drawings.

This form of installation may also be used for multiple units where a link deck slab is laid between the crown units with mortar pads under the rebates in the link slab.

Culvert units shall be placed carefully on the prepared bedding with ends butted to form a continuous base. Mortar pads shall be placed along the edges of each culvert unit and the next section shall be carefully lowered into place and then bedded on to the wet mortar. Any excess mortar extruding from the joints shall be trowelled off and the key checked in final position. Any gaps between the side walls and the checked grooves in the invert slab shall be packed with cement mortar. Butt joints and lifting holes along the barrel of each cell shall be packed or sealed with cement mortar.

In the case of multi-cell culverts, a minimum of 15 mm gap shall be provided between adjacent cells, and this gap shall be filled with cement mortar or an approved bitumen filler.

All mortar joints shall be protected from sun, and, if necessary, covered with earth, sheet plastic or wet bags for not less than 48 hours to allow proper curing of the mortar.

9.5 BACKFILLING

Backfill shall not be placed until the culvert has been inspected and approved for backfill. The backfill material shall be selected granular material free from lumps and vegetable matter and boulders or stone of greater size than 75 mm and having at least 50% retained on 2.36 mm sieve. The Plasticity Index of this material shall not exceed 12% when tested in accordance with AS 1289.3.3.1.

Backfill material shall be placed in uniform horizontal layers not exceeding 150 mm thickness and shall be thoroughly compacted to 95% of the Maximum Dry Density determined by AS 1289.5.1.1 except that any backfill within 300 mm of the underside of the sub-base level shall be compacted to 100% of the laboratory maximum dry density. The density of the material shall be determined by AS 1289.5.3.1. Material under the haunches of the pipes and those near the sides of the culverts shall be compacted with hand held equipment. The backfill on both sides of the culvert shall be placed concurrently, the levels of each side differing by no more than 150 mm at any stage.

For corrugated steel pipe culverts special care shall be exercised during backfilling to prevent distortion of the corrugated metal pipe and for reinforced concrete box culverts to prevent wedge action against the vertical surface of the box culvert during the backfilling.

Backfilling material shall be placed around the culverts to a depth of 300 mm above the top of the culverts unless in a trench, and for a minimum distance of one diameter from the centreline of the pipe or one half the height of the wall from the vertical face of the box culvert. Where the culvert is laid in a trench the backfill shall be placed for the full length, width and depth of the trench.

During construction of the Works, care shall be taken to avoid damage to culverts by the passage of heavy construction equipment, and the Contactor shall be wholly responsible for any damage resulting from such operations.

9.6 INLETS AND OUTLETS TO CULVERTS

Inlet and outlet ditches to culverts shall be constructed for such length, width, depth and fall as will ensure correct functioning of the culvert as directed by the Construction Supervisor.

Unless specifically provided for by means of a particular Billed Item, the cost of these works shall be included in the relevant item for drainage installation or end structure construction.

9.7 TAKING UP AND STACKING CULVERTS

Where shown on the Drawings or ordered in writing by the Construction Supervisor, culverts shall be carefully taken up and stacked neatly in lines in an accessible position as approved by the Construction Supervisor at least 1 metre clear of all earthworks, watercourses, drains, fences or timber.

Unless otherwise instructed, any culvert pipe or section not re-laid shall be taken to the Construction Supervisor’s office compound and stacked as directed.

The trench or excavation resulting from the removal of an existing culvert including headwalls shall be further excavated to expose sound material and backfilled and compacted in layers
as specified in Clause 9.5.

9.8 MEASUREMENT AND PAYMENT

Culverts shall be measured as the length of each separate nominal diameter, type, class, and for corrugated steel pipes the plate thickness, complete in place and accepted, as shown on the Drawings or as directed by the Construction Supervisor. The length of bevel ended corrugated pipes shall be measured as the mean of the invert and obvert lengths. Payment will be made at the rates entered in the Bill of Quantities per metre for each culvert depending on size, type, class or plate thickness. These prices shall include full compensation for supply, transport, laying, assembling or jointing, compaction of foundation and bedding, and for all labour, materials, plant and tools and incidentals necessary to complete the work herein specified.

Such incidentals shall include the necessary work for excavation and backfilling required for all culverts.

End treatment works including end wall, reinforced concrete or stone pitched, aprons, riprap shall be measured and paid for at the respective rates entered in the Bill of Quantities.

Excavation for inlets and outlets shall be measured and paid for as provided in Clause 4.17.

9.9 REMOVAL OF EXISTING CULVERTS

The Works required are as defined in Clause 9.7 and include taking up of existing culverts, disassembly or disjointing, neatly stacking and/or disposing and/or transporting to locations as nominated by the Construction Supervisor, and backfilling of the excavation.

Culverts shall be measured and paid for as the length of each type and diameter at the appropriate rate in the Bill of Quantities.

Payment for excavation and backfilling is deemed to be included in Clause 9.8.

Payment for excavation and replacement of unsuitable material below exciting culverts shall be made at the appropriate rate in the Bill of Quantities.

Removal of existing end structures shall be measured by number and payment shall include for all associated work including disposal to the Construction Supervisor's satisfaction.

9.10 SUB-SOIL DRAINAGE

9.10.1 General

Sub-soil drainage shall consist of slotted crown unplasticised polyvinyl chloride (UPVC) pipes, conforming to AS 2439.1 Class SN8, of nominal internal diameter 100 mm, installed in a trench, of minimum width 300 mm, minimum depth 650 mm, and maximum depth 1500 mm.

One of the following three forms of backfill shall be used, as indicated on the Drawings, and if there is no such indication, Type A shall be used:

Type A No filter fabric required and full depth backfill graded as per table below.

Type B Filter fabric lining to trench and cover to backfill, with full depth backfill graded such that 100% of material (by mass) passes the 19 mm sieve, and a minimum of 98% of material (by mass) shall be retained on the sieve of size equal to 1.5 times the pipe slot width or hole diameter.

Type C Filter fabric sleeve to pipe, with full depth backfill graded as per table below.

AS Sieve Size	Percentage (by mass) Passing Sieve
9.5 mm	100

4.75 mm	90-100
1.18 mm	45-80
0.300 mm	10-30
0.150 mm	0-10
0.075 mm	0-1

Grading Table for Types A & C Backfill

9.10.2 Bedding and Laying Slotted Crown UPVC pipes

A bed of filter material 50 mm thick shall be spread and compacted to a uniform grade. The pipe shall be embedded firmly in the bedding material and all line jointing completed. After acceptance by the Construction Supervisor of the laying and bedding of the pipe, filter material shall be placed around the pipe to a minimum thickness of 300mm above the slotted crown of the pipe. Care shall be taken that no pipe is displaced. The filter surround shall then be compacted by vibrating plates or tampers. Additional lifts of filter material not exceeding 200 mm loose thickness shall be similarly spread and compacted for the design depth of the trench.

Filter material in sub-soil drainage shall be compacted to a density of at least 90% of the Maximum Dry Density as determined by AS 1289.5.1.1. The density of the material shall be determined by AS 1289.5.3.1.

9.10.3 Measurement and Payment

Subsoil drains shall be measured as the length completed in place inclusive of filter fabric, filter material and pipe as shown on the Drawings or as directed by the Construction Supervisor. Payment shall be made at the applicable unit rate per metre entered in the priced Bill of Quantities which rate shall include the cost of excavation, preparation of bed, provision and installation of UPVC pipes, fittings and filter fabric, providing backfilling and compacting filter material for the depths as shown on the Drawings to a maximum of 1,500 mm.

9.11 LINED DRAINS

9.11.1 General

Lined drains shall be constructed to lines, grades, cross-sections and of materials as shown on the Drawings or as approved by the Construction Supervisor.

Varied cross-sections for prefabricated products detailed on the Drawings may be used, subject to the Construction Supervisor's approval.

9.11.2 Stone Pitched Lined Drains

Stone pitched lined drains shall be constructed as shown on the Drawings and in accordance with Group 11 of this Specification. Where the Type specified has a reinforced concrete base, this part of the work shall accord with the provisions of Groups 15 and 16 of this Specification.

Stone pitched lined drains shall consist of sound durable stones, of not less than 0.001 m^3 with a least dimension of 75 mm.

Geotextile fabric, where specified, shall be in accordance with Clause 20.6 of this Specification.

9.11.3 Cast In-situ Concrete Lined Drains

Cast in-situ concrete lined drains shall be constructed as shown on the drawings. Concrete shall be Grade 25 and shall meet all relevant requirements of Group 16 of this Specification. Reinforcement as detailed shall be in accordance with the provisions of Group 15 of this Specification.

Formwork shall be used, unless otherwise approved by the Construction Supervisor, to maintain the line and level of the concrete surface to a tolerance of $\pm$ 25 mm to the design surface, with a maximum deviation of 5 mm against a three metre straight edge. Any such formwork shall be provided in accordance with Group 14 of this Specification.

Care shall be taken to ensure that no earth, rock or other matter is permitted to fall into the mix as the concrete is poured into place.

9.11.4 Precast Concrete Lined Drains

Precast concrete units for drain lining shall be constructed as detailed in the Drawings. The units shall be Grade 30 concrete and shall be cast in steel forms and manufactured in accordance with the requirements of Group 16 of this Specification. All formwork and casting processes shall be submitted for approval by the Construction Supervisor who may request a sample be produced prior to this approval being granted. The dimensions of the precast units shall not exceed those shown on the Drawings by more than $\pm$ 3 mm.

9.11.5 Lined Drains Using Other Prefabricated Products

Various types of prefabricated products not detailed in these Clauses may be specified for use in the Contract. In each case the manufacture of the product shall be subject to the approval of the Construction Supervisor and installation shall be strictly in accordance with the manufacturer's recommendations.

9.11.6 Measurement and Payment

These works shall be measured and paid on a linear metre basis at the relevant Billed Item for the type of lined drain constructed. Payment shall include full compensation for all labour, plant, equipment, formwork and materials; for excavation, trimming, transportation, installation, backfilling and removal of spoil all as necessary for complete construction of the work.

9.12 DRAINAGE STRUCTURES

9.12.1 General

This section includes for the construction of all drainage structures including such items as end walls and aprons, dispersal flumes, catch pits, junction chambers, and anchor blocks. Each item shall be constructed as indicated, and to the dimensions shown on the Drawings or Drainage Schedule or as directed by the Construction Supervisor, and the nature of each type shall accord with the requirements of this Specification as follows:

(a) Masonry work shall be carried out in accordance with the provisions of Group 11.

(b) Concrete work shall be carried out in accordance with the provisions of Groups 14, 15 and 16 as applicable. Unless otherwise noted, concrete shall be Grade 25.

Precast items shall be of a type and manufacture approved by the Construction Supervisor with the concrete in this case being Grade 30.

(c) Steelwork for gratings, covers, step irons and ladders shall be heavy duty galvanised and meet with the relevant provisions of Group 17.

(d) Repairs to existing structures shall be as required under the provision of (a), (b), or (c) above.

9.12.2 Measurement and Payment

The Contract rates for drainage structures (excluding box culverts which are covered by Clause 9.8) shall include for all labour, plant, equipment, formwork, materials, transportation, miscellaneous fittings, and any incidentals required to excavate, remove spill, construct and install the complete item as detailed.

Measurement for the various types of structures shall be as follows:

(i) Masonry structures shall be measured in cubic metres of actual structure as per the dimensions shown on the Drawings.

(ii) Concrete structures shall be measured as a complete item including all covers and fittings unless scheduled separately.

(iii) Repairs to existing structures shall be measured on a unit basis for each structure and shall include for the complete works to the satisfaction of the Construction Supervisor including supply of all any new covers and fittings unless scheduled separately.

9.13 CONSTRUCTION OF CONCRETE KERBS, CHANNELS AND EDGE STRIPS

9.13.1 General

Concrete kerbs, channels and edge strips shall be constructed, to the cross-sections detailed, and in the locations as shown on the Drawings.

Adjustment to cross-sections shall be made, in accordance with the Drawings, where required for vehicle and pedestrian crossings as directed by the Construction Supervisor.

9.13.2 Cast In-situ by Formwork

Where the works are to be constructed using fixed formwork all works shall conform to the relevant provisions of Groups 14, 15 and 16 of this Specification.

Unless indicated otherwise on the Drawings the concrete used shall be Grade 25.

9.13.3 Cast In-situ by Extrusion Mould

Where an extrusion process is used, the concrete shall be batched to Grade 30 design but due to the low moisture content needed for machine operation, the test standards shall only be required to meet Grade 25. All other concrete is required to meet Grade 25. All other requirements shall conform to the relevant requirements of Group 16 of this Specification.

The extrusion machine shall be fitted with a tamper suitable to producing a well compacted mix and sufficient control mechanisms to produce a product meeting the tolerances specified in this Clause 9.13.

The extruded surface shall be free of voids and any honeycombing, and shall have a steel trowel finish.

Where the Contractor intends to use this method of construction he shall provide a test section to the approval of the Construction Supervisor, and this test section shall subsequently be the guide for product finish on the Contract Works. If the Contractor is unable to achieve a standard approved by the Construction Supervisor he shall be required to carry out the work by fixed forms at no additional cost to the Contract.

9.13.4 Precast Concrete Sections

Where indicated on the Drawings a precast concrete section of a type and manufacture approved by the Construction Supervisor shall be used.

These sections shall be constructed using Grade 30 concrete and in addition to the tolerances for line and grade each unit shall have an individual tolerance of $\pm$ 3 mm to the specified dimensions.

9.13.5 Jointing

All cast in-situ work shall have the following joint types:

(a) Expansion Joints shall be constructed at even intervals not exceeding 20 metres. The joints shall be made by installing 6 mm thickness of bitumen impregnated fibreboard, or other approved type of compressible material, in the full cross-section of the product. Where relevant, joints shall line up with expansion joints in adjacent structures.

(b) Construction Joints shall be made at regular intervals not exceeding 5 metres. The joints shall be made by forming grooves 40 mm deep and not more than 6 mm wide in all exposed surfaces of the product. All grooves shall be normal to the top surfaces and square to the alignment of the product.

9.13.6 Curing

Cast in-situ concrete works shall be cured in an approved manner for a period of not less than seven days before any other roadwork operations are carried out adjacent to the product.

9.13.7 Tolerances

The horizontal and vertical alignments of the product shall not vary from those specified by more than $\pm$ 10 mm.

Notwithstanding the above tolerances, the alignments of the product shall be smooth. The alignments of the product shall be smooth. The overall dimensions of the product shall nowhere be less than those shown on the Drawings.

9.13.8 Preparation and Bedding

Following completion of the earthworks, in situations where the product is not based on a pavement layer, the sub grade shall be compacted as required by the relevant provisions of Group 4 of this Specification and a bedding layer of sub-base materials (Type 3 unless otherwise specified) shall be placed to a compacted thickness of 75 mm with the compaction to be at least 95% of the Maximum Dry Density of the sub-base material as indicated by AS 1289.5.1.2.

9.13.9 Measurement and Payment

Concrete kerbs, channels and edge strips shall be measured in linear metres and paid at the relevant Billed Rate which shall include for all labour, plant, equipment, materials and any other requirements needed to complete the construction as specified including the provision of bedding where applicable. Any earthworks requirements in preparation for these works shall be included in the general earthworks item if such an item is provided. If no such item is provided then the cost of any earthworks shall be included in the rate for the relevant kerb, channel or edge strip.

9.14 CLEANING EXISTING CULVERTS

Where any existing culvert is indicated to remain, the culvert including the headwalls and apron slabs, inlets and outlets, and approach drains within 5 m of the culvert, shall be cleared over its full length, of any vegetation, rubbish or dirt, and inspected for soundness. Any resulting material will be disposed of clear of the Works.

Payment for cleaning out existing culverts including the headwalls and apron slabs, inlets and outlets, and approach drains within 5 m of the culvert shall be made at the rate per culvert in the Bill of Quantities irrespective of the size and type of the culvert and shall include for disposal of the cleared material which shall not be paid for under any other item of the Bill of Quantities.

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GROUP 10

ROAD FURNITURE AND MARKINGS

10.1 ROAD SIGNS

10.1.1 General

Permanent road signs shall be supplied and installed at specific locations in accordance with this Specification and as indicated on the Drawings and/or the Schedule of Works.

10.1.2 Standard

All signs shown on the Drawings and/or in the Schedule of Works shall be manufactured in accordance with AS 1743 and erected as shown on the Drawings.

The retroreflective materials used in the background or legend of the signs shall conform in colour and grade to Appendix C of AS 1743 for Class 2A materials and comply with AS 1906.1.

10.1.3 Measurement and Payment

This work shall be measured as the actual number of signs complete with plates and posts erected and accepted, and shall be paid for at the unit rate entered for the item in the Bill of Quantities. This rate shall include full compensation for furnishing all materials, treating, labour, tools and incidentals necessary to complete the work as directed by the Construction Supervisor.

10.2 GUARD RAILS

10.2.1 General

Steel beam guardrails and posts shall be constructed and erected in accordance with the Drawings or as directed by the Construction Supervisor. Unless specifically noted on the Drawings, posts may be either Armco Flex-Beam Guardrail posts (or similar approved) or treated timber posts as specified below.

10.2.2 Timber Posts for Guardrail

Where shown on the Drawings and/or the Schedule of Works or approved by the Construction Supervisor, posts to support the guard rail shall be made from sound, fully seasoned approved Vanuatu hardwood of straight grain and free from shakes, knots and other defects and have a strength not less than Forestry Division designation Strength Group 3. Posts shall be sawn square and straight on all sides and shaped to the required dimensions.

Posts shall be chamfered on the top as shown on the Drawings. The timber shall be pressure treated with copper chrome arsenic solution to a retention of not less than 0.032 gram per cubic centimetre or as recommended by the Forestry Division for the type of timber used.

10.2.3 Steel Beam Guard Rail

The steel beam guardrail, posts and terminal sections shall be Armco Flex-Beam Guardrail or similar as approved by the Construction Supervisor. No punching, cutting, or welding shall be done in the field except that holes for special details may in exceptional circumstances be drilled in the field when approved by the Construction Supervisor.

The surfaces of all ferrous metal components including posts, blockout pieces, rail elements, anchor plates, connectors and terminal pieces shall, after fabrication, be treated in accordance with AS 1627.4 or AS 1627.5, and finished by hot dip galvanising in accordance with AS 4680.

Field cut ends shall be carefully wire brushed to remove any scale followed immediately by two coats of zinc-rich organic primer complying with AS 3750.9 or two coats of inorganic zinc silicate paint complying with AS 3750.15.

Bolts, nuts, and washers shall comply with AS 1111.1, AS 1112.3 and AS 1237 and shall be galvanised to comply with AS 1214. Bolts shall be sufficiently long to extend at least 6 mm beyond the nuts but, except where required for adjustment, shall not extend more than 12 mm beyond the nuts.

Steel rail shall be factory curved where a radius of less than 45 m is specified. Curving shall be carried out in such a manner that the galvanising is not damaged. The curve radius shall be clearly marked in a permanent manner on the rear face of factory curved steel rail.

10.2.4 Erection of Steel Beam Guard Rail

The posts shall be set to line, level and spacing consistent with erection of the rail in a manner that will result in a smooth continuous taut guard rail closely conforming to the line and grade of the roadway. After setting the posts, the holes shall be backfilled with approved material and thoroughly tamped. When the end of a section of guardrail is to be splayed out as shown on the Drawings the posts shall be set to accommodate the splaying.

All steel posts and blockout pieces shall be erected with the open or concave face away from the ultimate direction of approach of traffic in the closest adjacent carriageway, unless shown otherwise on the Drawings.

The laps in the rail shall be such that the ends of the rails do not face oncoming traffic in the adjacent lane.

The rail shall be erected so that the bolts at expansion joints shall be located at the centres of the slotted holes. All bolts except where otherwise required at expansion joints shall be drawn tight. Bolts through expansion joints shall be drawn up as tight as possible without being so tight as to prevent rail elements from sliding past one another longitudinally.

Painting and treatment of the rail and posts is to conform with the requirements of the Drawings or as directed by the Construction Supervisor.

10.2.5 Measurement and Payment

The quantity of steel beam guard rail of the type and design specified shall be measured by the length in metres measured from centre to centre of end posts actually ordered by the Construction Supervisor and completed. Payment of this measured quantity shall be made at the rate entered in the Bill of Quantities and shall be inclusive of guardrail posts, either steel or timber, required to support the guardrails.

10.3 ROAD EDGE MARKER POSTS

Road edge guide markers shall be of the type shown on the Drawings and shall be positioned and spaced as directed by the Construction Supervisor or shown on the Drawings.

Painting of the markers is to conform with the requirements of the Drawings or as directed by the Construction Supervisor. Reflectors shall be affixed to the markers after painting in accordance with the Drawings.

Road edge guide markers actually installed, completed and accepted by the Construction Supervisor shall be measured for payment on a numbers basis.

This price shall include full compensation for furnishing all materials, labour, tools and equipment and for all expenses necessary for the placement, erection and installation.

10.4 PAVEMENT MARKING

10.4.1 General

This Clause 10.4 applies to paints suitable for application by spray to road surfaces consisting of asphaltic concrete and bitumen seal coats.

10.4.2 Pavement Marking Type

All pavement markings shall be in accordance with the Drawings and the following Clauses of this section of the Specification. All barrier markings are to be established in accordance with AS 1742.2.

10.4.3 Paint for Road Marking

Paint shall be in accordance with AS 4049.3. It shall be suitable for applying by brush or mechanical means to bituminous surfaces to give a mechanically stable film of uniform thickness. The colour shall be white, except for the Bridge Hazard Bar Markings which shall be yellow, Type 2 and of the class appropriate to the method of application. The paint shall be supplied fresh and ready for use in sealed containers which shall be stored in accordance with the manufacturer's instructions.

The dry paint thickness (excluding surface applied beads) for water borne paint shall be:
- Longitudinal lines ≥ 0.300 mm
- Transverse lines ≥ 0.200 mm

10.4.4 Pavement Condition

All pavement markings shall be applied only on a surface which is clean and dry and in the option of the Construction Supervisor in suitable condition for application of paint.

10.4.5 Reflective Glass Beads

Glass beads shall be applied to all pavement markings as per AS 2009.

The application rate for surface applied reflective glass beads shall be:-
- Longitudinal lines
  - Type D standard glass
  - Rate retained in the painted surface ≥ 400 g/m^2
- Transverse lines
  - Type B
  - Rate retained in the painted surface ≥ 300 g/m^2

10.4.6 Measurement and Payment

The work shall be measured as the actual length measured in metres of pavement marking applied and accepted by the Construction Supervisor. The rate shall include the preparation of the surface to be painted, the supply and application of paint and glass beads, all labour, tools and incidentals necessary to complete the work as directed by the Construction Supervisor.

10.4.7 Warning Bar Marking for Single Lane Bridges

Where shown on the Drawings or directed by the Construction Supervisor, the road surface on the approaches to single lane bridges on sealed roads shall be marked with a yellow coloured, painted bar marking system set out as follows:-

The pattern comprises 90 yellow transverse lines (referred to as bars), 600 mm wide, laid at right angles from the centreline of the carriageway to the edge of the seal and spaced in accordance with the table below.

A standard "Give Way" holding line shall be marked as shown on the Drawings, or at a location at least 5 metres clear of the commencement of the road narrowing as directed by the Construction Supervisor.

The first bar shall be laid at a distance of 35 metres measured back along the centre line of the carriageway from the “Give Way” holding line. Successive lines shall then be marked in accordance with the measurement table as follows where the distance is measured from the leading edge of the first bar to the leading edge of the nominated bar number.

Bar No.	Distance	Bar No	Distance	Bar No	Distance
D1	0.00	D31	94.95	D61	224.70
D2	2.75	D32	9/8.65	D62	229.80
D3	5.50	D33	102.40	D63	234.90
D4	8.25	D34	106.15	D64	240.10
D5	11.05	D35	110.00	D65	245.40
D6	13.90	D36	113.85	D66	250.70
D7	16.80	D37	117.75	D67	256.10
D8	19.70	D38	121.70	D68	261.50
D9	22.60	D39	125.65	D69	267.00
D10	25.55	D40	129.70	D70	272.60
D11	28.55	D41	133.75	D71	278.25
D12	31.60	D42	137.85	D72	283.90
D13	34.65	D43	142.00	D73	289.60
D14	37.70	D44	146.15	D74	295.45
D15	40.80	D45	150.40	D75	301.30
D16	43.95	D46	154.65	D76	307.25
D17	47.15	D47	158.95	D77	313.30
D18	50.35	D48	163.35	D78	319.35
D19	53.55	D49	167.75	D79	325.55
D20	56.80	D50	172.25	D80	331.75
D21	60.10	D51	176.75	D81	338.15
D22	63.45	D52	181.30	D82	344.65
D23	66.80	D53	185.95	D83	351.35
D24	70.15	D54	190.60	D84	358.30
D25	73.60	D55	195.35	D85	365.50
D26	77.05	D56	200.10	D86	373.50
D27	80.55	D57	204.90	D87	380.90
D28	84.10	D58	209.80	D88	388.60
D29	87.65	D59	214.70	D89	396.25
D30	91.30	D60	219.70	D90	403.95

Warning Bar Set Out Table

Payment for this item shall be at the scheduled rate of number of bridge approaches marked (90 lines per approach) as measured on site and agreed with the Construction Supervisor.

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GROUP 11

MASONARY FOR STRUCTURES

11.1 STONE PITCHING

11.1.1 General

Stone pitching shall be laid where specified on the Drawings or ordered by the Construction Supervisor as slope protection, aprons, etc. at the inlets and outlets to culverts, and other erodable areas where protection is required. The stone shall be roughly dressed naturally occurring sound rock with a general minimum dimension of 150 mm and maximum dimension of 450 mm and of such shape as can allow close laying.

11.1.2 Mortar for Grouting

Mortar for the cement grouting of stone pitching shall consist of one part of Portland Cement to two parts of clean well graded fine sand mixed with just sufficient water to be of workable consistency. Mortar shall be used within 30 minutes of adding water.

11.1.3 Laying

The stones shall be well bedded in mortar, trowelled to a depth of 60 percent of the maximum thickness of the stones onto the underlying formation. They shall fit closely and present an even top surface. The large stones shall be used as toe stones at edges or in aprons. Stone pitching shall be placed on a freshly excavated and stable surface and when on any embankment or backfill, this shall be compacted well in advance of the pitching to avoid settlement.

Where a foundation for stone pitching is not rock or other hard non-erodable strata, it shall be founded and sealed on the bottom with a cut-off wall at least 450 mm thick or as shown on the Drawings. The trench for the cut-off wall after dewatering shall be filled with mortar to a depth of 60 percent of the maximum dimension of the stones and immediately thereafter stones shall be placed in the unset mortar to make a solid dense wall. The process shall be repeated until the trench is filled. Only such length of trench is to be worked upon at a time as will permit all stones to be inserted in fresh mortar.

Stone pitching shall be placed in tight contact with the cut-off wall or other foundation and laid from the bottom towards the top. Weep holes shall be constructed as shown on the Drawings or as directed by the Construction Supervisor.

11.1.4 Cement Grouting of Stone Pitching

The mortar shall be applied by means of a trowel and shall be well rodded between the stones so that the interstices are completely filled as far down as practicable but to a depth of at least 75 mm. The grouted stone shall be kept damp for at least 48 hours after the mortar is set.

11.1.5 Measurement and Payment

Payment will be made at the rate per cubic metre for stone pitching to culvert structure and cut-off walls, or at the rate per linear metre for stone pitching to table drains as itemised in the Bill of Quantities for Cement Grouted Stone Pitching. The volume shall be measured by multiplying the surface area by the average depth perpendicular to the surface. The length in linear metres shall be measured along the longitudinal centre lie of the drain.

11.2 ROCKWALLING

11.2.1 General

Rockwalling shall be constructed in accordance with the Drawings or as otherwise directed by the Construction Supervisor. It shall consist of sound durable stones, of not less than 0.016 cubic metres in volume, at least 150 millimetres in vertical dimension and 300 millimetres in both horizontal dimensions. Stones shall be roughly dressed and coursed and all vertical joints shall be broken. The base of the wall shall be bedded in a trench at least 300 millimetres deep unless it is founded on rock, in which case the wall shall be securely bedded on the rock by keying or interlocking.

The wall shall be built up simultaneously with the filling of the bank. When it is found necessary to use stones smaller than those specified above for wedging, such stones shall be adequately bonded to the adjacent courses with cement mortar. However under no circumstances shall more than two edging stones be bonded to any stone of volume 0.016 cubic metres or more. The cost of any cement motor bonding required, excavation and backfilling shall be deemed to be included in the Billed Rate.

11.2.2 Cement Grouted Rockwalling

Cement Grouted Rockwalling shall be constructed to the details given in Clause 11.2.1 above except that:

(i) Stones used shall be minimum volume 0.016 cubic metre and least dimension 200 millimetres. However for each stone of this minimum size placed up to two stones of some lesser dimension may be used for wedging.

(ii) Each stone shall be firmly bedded in cement mortar prepared as specified elsewhere for cement grouting of stone.

(iii) Weep holes shall be provided as shown on the Drawings or otherwise directed.

11.2.3 Masonry Rockwalling

Masonry Rockwalling shall be constructed to the details given in Clause 11.2.1 above except that:

(i) Stones used shall be a minimum of 0.016 cubic metre with a least dimension of 200 millimetres.

(ii) Each stone shall be properly bedded with a gap of not more than 25 millimetres between stone faces.

(iii) Each stone shall be firmly bonded in cement mortar prepared as specified elsewhere.

(iv) Weep holes shall be provided as shown on the Drawings or otherwise directed.

11.2.4 Weathering

Grouted and masonry rockwalling shall be weathered on the top with a twenty five millimetres thick layer of cement mortar splayed 1 in 3 and neatly trowelled to an even surface with clean sharp ridges and angles.

11.2.5 Measurement and Payment

The Billed Rate for rockwalling in each of the three categories stated above shall include for all work specified for the complete construction of the rockwall. Measurement of the volume in cubic metres for which payment will be made shall be based on the dimensions shown on the Drawings for the extent of rockwalling constructed in accordance with the Contract.

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GROUP 12

PILING FOR STRUCTURES

12.1 DESCRIPTION

Piles used in the Works shall be in accordance with the Drawings unless otherwise directed by the Construction Supervisor.

Steel H piles shall be rolled universal sections conforming to AS 3678 and AS 3679.2 (Grade 250).

Tubular steel pipe shall be fabricated from steel plate which, after rolling, shall be welded longitudinally to form segments which are shop spliced into lengths suitable for delivery to site. The longitudinal welds and shop splices shall be made with full penetration butt welds. Segments shall be rotated 90^0 to each other so that the longitudinal welds on the fabricated casings are staggered. Alternatively, spirally welded tubes shall be fabricated in accordance with AS 1579. Welding shall be by the submerged arc process from both sides of the plate. Unless otherwise specified in the Drawings, the steel plate shall conform to AS 3678 – Grade 250 or 350, AS 1548 - all grades or AS/NZS 1594 - Grade HU24.

Steel piles shall have reinforced pile toes as detailed on the Drawings or if not detailed on the Drawings, as required to suit the Contractor’s pile driving methods. All welding shall be carried out as specified in the Drawings and in Clause 17.3.4. Where tubular steel piles are to be driven with a closed end, driving shoes shall be provided as detailed on the Drawings. Where details are not provided on the Drawings, the pile shoe shall be approved by the Construction Supervisor.

Where indicated on the Drawings, piles shall be given protective coatings for which the steel shall be prepared, and the coating supplied, in accordance with Group 18 of this Specification.

Reinforced concrete piles shall conform to the Drawings. The materials used shall conform with the relevant parts of Groups 15 and 16 of this Specification.

The work shall comprise the supply, delivery, storing, handling, pitching, driving, splicing, testing, withdrawing, trimming, and preparing of the piles, welding of toe reinforcement of shoes and shear rings, protective coating and all other ancillary operations necessary for the satisfactory completion of the work as shown on the Drawings or as further specified herein.

12.2 ACCURACY

Unless otherwise specified in the Drawings, piles shall be driven or bored with a variation of not more than 1 in 100 from the vertical or from the specified batter within vertical or from the specified batter with a maximum tolerance of $\pm$ 75 mm at the pile head.

Where a pile has not been positioned and driven within the above limits, such piles shall not be forcibly corrected for line or position.

12.3 DRIVEN PILES

12.3.1 Programming

The work shall be programmed to allow ample time for the procurement of additional lengths of piling, should the piles act, under actual driving, in a manner outside the range of that allowed for in the design. Any delay in the delivery of piling materials to the Site shall be at the Contractor's expense and shall not be a legitimate charge for an extra to the Contract.

12.3.2 Handling of Piles

Handling, transporting and pitching of piles shall be carried out in such a manner as will ensure that the piles are not damaged in any way.

Reinforced concrete piles must be lifted and stacked at two points 1/5th of their length from each end. Pitching may be effected by lifting at a point 3/10ths of the length from the head unless otherwise specified. Holes for lifting and for toggle bolts will not be permitted; suitable clamps and straps must be provided. Reinforced concrete piles shall not be driven until at least twenty-eight (28) days after casting, unless otherwise approved by the Construction Supervisor.

12.3.3 Preparation for Driving

Unless otherwise shown on the Drawings or directed by the Construction Supervisor, pile toes on steel piles shall be cut square to the axis and finished off without any excessive protrusion.

Precast concrete piles shall be provided with a pile shoe as shown on the Drawings.

Should any special treatment be found necessary, it shall be carried out by the Contractor as directed by the Construction Supervisor, and payment for such treatment will be made as a variation.

The Contractor shall pitch the pile and position and set the rake of the pile as required. Any surface boulders or other obstructions affecting the position or rake shall be removed and such removal is deemed to be included in the Billed Rates for positioning, pitching and driving.

In general, piles shall not be driven until after the excavation is complete. Any material forced up between the piles shall be removed to correct elevation at the Contractor's expense. The heads of all steel piling shall be cut squarely and a driving helmet shall be provided to hold the axis of the pile in line with the axis of the hammer.

Pile helmets for concrete piles shall be of substantial steel construction, loose fitting on the pile head, with a steel diaphragm at approximately mid-height. Between the steel diaphragm and the pile head there shall be placed an approved cushion of pine, rope, bags or neoprene rubber. On tope of the diaphragm and fitting tightly into the helmet there shall be a hardwood block approximately 400 mm long. The helmet shall slide in, and be fully guided by, the leaders of the pile frame.

Unless otherwise approved or directed by the Construction Supervisor when additional lengths of pile are required to be pitched and spliced, twelve (12) metre lengths shall be used.

Steel H pile sections shall be spliced by double bevel full strength butt welds at web and flanges with two (2) millimetres reinforcing on both sides of the weld. All welding shall be carried out as specified in Group 17 of this Specification.

Tubular steel pile sections shall be spliced by single bevel full penetration butt welds with two (2) millimetre reinforcing on the external weld surface. Splices shall be made against close fitting internal split welding bands tack welded into the upper pile section prior to jointing. The piles shall be set, aligned and clamped prior to splicing with a five (5) millimetre root gap. The bevel shall extend the full thickness of the metal and will be 45° on the upper pile section and 15° on the lower pile section.

The axis of a completed pile shall not deviate by more than twelve (12) millimetres from the line jointing the centres of the two ends.

The concrete at the top of reinforced concrete piles shall be stripped back for sufficient length to permit either a lapped or welded connection splice, as shown on the Drawings. Should a welded splice connection be used, the welding shall be carried out as provided for in this Specification. No welding shall approach closer than one hundred and fifty (150) millimetres to a concrete surface. The in-situ concrete section shall be at least of the same Grade of concrete as the remainder of the pile. The in-situ section shall be cured for at least twenty-eight (28) days at a temperature of at least ten (10) degrees Celsius before any further driving is commended. Alternatively, epoxy concrete of a Grade and manufacture acceptable to the Construction Supervisor may be used and the curing period will then be at the discretion of the Construction Supervisor.

12.3.4 Method of Driving

12.3.4.1 General

Piles shall only be driven in the presence of the Construction Supervisor, or his representative, and the Contractor shall give the Construction Supervisor at least forty-eight (48) hours notice of his intention to commence driving.

The Contractor shall provide adequate pile driving equipment, acceptable to the Construction Supervisor, to complete the whole of the work and shall submit to the Construction Supervisor details of the equipment he proposes to use prior to commencing work.

Piles may be driven with a gravity hammer, a steam (or air) hammer, a diesel hammer or by a combination of any of these with water jets except that water jetting will not be permitted with steel H-piles. A steam or diesel hammer is to be preferred. Where driving is so hard that the pile may be damaged by driving, pre-boring and shooting shall be used in combination with the hammer.

12.3.4.2 Hammers for Steel Piles

The mass of any gravity hammer used for driving steel piles shall be not less than 1.5 tonnes, and in no case less than the combined mass of driving head and pile. The fall shall be so regulated as to avoid injury to the piles and in no case shall exceed 3 metres. When a steam or diesel hammer is used, the total energy developed by the hammer at test shall be not less than 30 kilojoules per blow. When a gravity hammer is used the energy developed by the hammer at test shall be not less than 40 kJ per blow.

Where diesel hammers are to be used, and the ultimate bearing capacity is to be checked by pile driving formulae, the Contractor shall provide a calibration for the hammer, acceptable to the Construction Supervisor, under homogenous soil conditions for the same type and size of pile. The cost of calibration shall be deemed to be included in the rates for piling.

12.3.4.3 Hammers for Concrete Piles

Steam, air or diesel hammers shall be single acting and shall develop an energy per blow at full stroke of the piston of not less than 18 kJ for each cubic metre of concrete in the pile driven with a minimum energy per blow of 20 kJ.

If a gravity hammer is used it shall have a mass of not less than 80% of the mass of the pile, but in no case less than 2 tonnes and the drop of the hammer shall not exceed 2 metres. The energy per blow at test shall be not less than 18 kJ for each cubic metre of concrete in the pile driven.

12.3.4.4 Driving Concrete Piles

(a) Soft Strata The pile shall be gently eased through the soft strata by resting the hammer on the driving head, or lightly tapping until the pile ceases to move further into the strata. Care shall be taken to prevent a tensile stress being developed in concrete piles.

(b) Medium Strata Where the pile cannot be eased into the strata under the dead weight of the hammer or light tapping, the maximum movement downwards (set per blow) shall not exceed the following:

Length of Pile	Maximum Set (with head cushion in place)
Up to 15 m	60 mm
15 m to 18 m	50 mm
longer than 18 m	40 mm

12.3.4.5 Additional Equipment

In case the required penetration is not obtained by the use of a hammer complying with the minimum requirements, the Contractor shall provide a heavier hammer or resort to jetting or preforming or preboring the shooting at his own expense. Preforming and jetting will not be permitted with steel H-piles.

12.3.4.6 Leads

Pile driver leads shall be constructed in such a manner as to afford freedom of movement of the hammer, and they shall be held in position by guys or stiff braces to ensure support to the pile during driving. Except where piles are driven through water, the leads preferably shall be of a sufficient length so that the use of a follower will not be necessary. Inclined leads shall be used in driving battered piles.

12.3.4.7 Followers

The driving of piling with followers shall be avoided if practicable and shall be done only with the approval of the Construction Supervisor. When followers are used, one pile from each group of 10 shall be a long pile driven without a follower, and shall be used as a test pile to determine the average bearing power of the group.

12.3.4.8 Water Jets

When water jets are used, the number of jets and the volume and pressure of water at the jet nozzle shall be sufficient to freely erode the material adjacent to the pile. The plant shall have sufficient capacity to delivery at all times at least 700 kPa pressure at two 20 mm nozzles. One metre before the desired penetration is reached, the jets shall be withdrawn and the piles shall be driven with a hammer to obtain the final penetration.

Side jets shall only be used in free running sand which will run back around the pile when jetting is stopped.

In clayey material a single jet may be used to pre-jet a hole having an area not exceeding 50% of the pile cross section before the pile is pitched. If a pre-formed or jetted hole is used, care shall be taken to prevent tensile cracking in concrete piles and the penetration per blow for the latter piles shall be restricted to that specified above as maximum set in medium strata. Water jetting shall not be used with steel H-piles.

12.3.4.9 Pre-formed Holes

Pre-formed holes shall only be used if written approval is granted by the Construction Supervisor who shall approve the diameter and method of drilling. Pre-formed holes shall not be used with steel H-piles.

12.3.4.10 Pre-boring and Shooting

Holes shall be blown singly.

The cost of pre-boring and shooting shall be deemed to be included in the schedule unit rate for driving piles.

12.3.4.11 Ultimate Geotechnical Strength (Ultimate Pile Capacity)

The Contractor shall determine the ultimate geotechnical strength (R_{ug}) (also known as the ultimate pile capacity) which the piles must attain to ensure that the design geotechnical strength (R_g*) (or working load) specified on the Drawings is assured.

R_{ug} is a function of R_g^* and is dependent on the method used by the Contractor to determine the capacity of the piles during installation. It shall be calculated using the formula:

$$R_{ug} = R_g^* \times LF / \boldsymbol{\Phi}_g$$

Where: LF is the load factor and taken as 1.25
$\boldsymbol{\Phi}_g$ is a geotechnical strength reduction factor ascertained from the following table:

Method of assessment of pile ultimate geotechnical strength	$\boldsymbol{\Phi}_g$
Static load testing to failure	0.8
Static proof (not to failure) load testing	0.8
Dynamic load testing to failure supported by signal matching	0.7
Dynamic load testing to failure not supported by signal matching	0.6
Dynamic proof (not to failure) load testing to failure supported by signal matching	0.7
Dynamic proof (not to failure) load testing to failure not supported by signal matching	0.6
Static analysis using CPT data	0.5
Static analysis using SPT data in cohesionless soil	0.4
Static analysis using laboratory data for cohesive soil	0.5
Dynamic analysis using wave equation method	0.5
Dynamic analysis using driving formula for piles in rock	0.5
Dynamic analysis using driving formula for piles in sand	0.5
Dynamic analysis using driving formula for piles in clay	0.3

Note: This Table is based on AS 2159 Table 4.1.

The above approach shall be adopted in the assessment of piles in compression and intension. Where the method of assessment provides a value for the skin friction component of the pile capacity, the tension capacity shall be taken as 80% of the skin friction component. Where the method of assessment does not provide a breakup of the pile capacity into skin friction and end bearing components, the tension capacity shall be taken as 30% of the pile capacity.

The Contractor shall supply to the Construction Supervisor full details of his proposed method/s of assessment of pile ultimate geotechnical strength together with supporting details and calculations at least two week before piling is to commence.

12.3.5 Penetration

The Contract Toe Level (CTL) shown on the Drawings is for use only for determining a quantity for inclusion in the Bill of Quantities. The Contractor's equipment shall be capable of driving the piles to the CTL plus an additional 5 m minimum.

The Maximum Toe Level (MTL) is the highest level at which the pile may be founded as determined by the designer. Subject to this Clause 12.3.5, the piles shall be driven at least to the MTL specified on the Drawings notwithstanding that the ultimate geotechnical strength (R_{ug}) (Clause 12.3.4.11) can be shown to have been achieved at a higher level.

The Contractor shall drive the piles until they are shown to be able to sustain the ultimate geotechnical strength (Rug) and the toes are at or below the MTL.

If achievement of the ultimate geotechnical strength is found to have been caused by strata which the Construction Supervisor determines to be of insufficient thickness, the Construction Supervisor may order driving to continue with the assistance of boring and shooting, jetting and/or a heavier hammer until a satisfactory stratum is reached, except that jetting shall not be used with steel H-piles.

Where driving conditions above the MTL are encountered such that, in the opinion of the Construction Supervisor, driving could not satisfactorily continue to the MTL, driving operations and all other operations on the works for which the foundations are being piled, shall be suspended, and the Contractor shall request instructions from the Construction Supervisor as to any alterations required to the Drawings. Immediately the work is suspended, the Contractor may remove the pile driving frame and equipment from the head of the pile but not from the Site and may continue driving piles in other abutments. The Construction Supervisor will ascertain the reason at the Employer's cost, or if the Construction Supervisor so elects, the Contractor shall ascertain the reason at a cost to the Employer to be agreed by the Construction Supervisor before commencement of the investigation.

Provided that details sufficient to permit the Contractor to recommence and thereafter complete the pile are supplied by the Construction Supervisor within 14 days of the Contractor so requesting, no claim shall be considered for additional costs occasioned by the suspension, other than the cost of moving the plant back to the pile. However, all alterations ordered shall be paid for as a Variation.

12.3.6 Pile Driving Records

Each pile, after being prepared for driving and prior to being driven, shall have its identifying number and overall length marked on it near the head by stamping into the metal or other means directed by the Construction Supervisor. Each pile shall also be marked legibly by painting at intervals of five hundred (500) millimetres with marks to indicate the distance from the pile toe. Such marks shall not be injured, defaced or removed by any person.

Complete driving records giving details of the driving and penetration from commencement until completion shall be taken under the supervision of the Construction Supervisor for all piles driven, unless otherwise directed by the Construction Supervisor. The records shall be written on the Employer's standard form for this purpose, and shall be submitted in duplicate to the Construction Supervisor for each pile cap together with an as built location plan which shall give:

(a) cutoff level for each pile,

(b) toe level for each pile,

(c) internal soil surface level in each pile,

(d) exact plan location for each pile at cut off level, and

(e) vertical inclination and direction for each pile.

Pile records shall indicate but shall not be limited to:

(a) type and dimension;

(b) date of driving;

(c) driving equipment and hammer efficiency;

(d) depth driven and tip elevation;

(e) pile sets;

(f) driving details (height of drop, frequency of blows, etc);

(g) details of any interruptions in piling;

(h) pre-bore and shooting details;

(i) level of pile immediately after driving and level when all piles in a group have been driven; and,

(j) details of re-driving.

12.3.7 Pile Heads

After the driving has been satisfactorily completed and approved by the Construction Supervisor, the piles shall be cut off at the levels indicated on the Drawings. Flame cutting tools may be used on steel piles but the cut shall be free of all significant protrusions. When required by the Drawings, a pile cap of the type shown shall be provided and preparation of the surface and welding shall be carried out as specified elsewhere. The cost of cutting off the head of the pile is deemed to be included in the amount tendered for positioning and pitching.

After cutting off the pile heads the Contractor shall supply, fit and weld shear rings or other steelwork details at the top of the piles as shown on the Drawings. Any pile protective coating at the required location of a shear ring or other detail shall be removed by grinding, or other method acceptable to the Construction Supervisor, over a minimum width of 100 mm centred on the location indicated on the Drawings.

For concrete piles a length of reinforcement shall remain above the cut-off level equal to 40 times the main bar diameter or such other lengths as indicated on the Drawings.

12.4 BORED PILES

12.4.1 General

Where indicated on the Drawings piles shall be bored, and cased if so specified.

Boring shall only be carried out in the presence of the Construction Supervisor, or his representative. The Contractor shall give the Construction Supervisor at least forty-eight (48) hours notice of his intention to commence boring.

The Contractor shall provide boring equipment, acceptable to the Construction Supervisor, to complete the whole of the work and shall submit to the Construction Supervisor details of the equipment he proposes to use prior to commencing work.

12.4.2 Equipment

Boring equipment shall be of suitable size and stability to carry out the boring requirements as shown on the Drawings and indicated in any geotechnical information provided in the Contract.

The boring equipment shall be fitted with suitable controls to ensure that bore alignment can be monitored prior to and during boring operations.

Augers and cutting edges shall be maintained in a good condition such that the borehole is not subject to deviation during normal boring operations.

Where bore casing is not specified the Contractor shall keep available on site sufficient suitable casing to place in and protect a bore should an unstable stratum be encountered.

12.4.3 Boring Logs

Logs of the boring operations shall be taken and submitted to the Construction Supervisor, in report form, within three (3) days of completion of each bore. Standard penetrometer tests and undisturbed samples shall be taken every three (3) metres, or as otherwise directed by the Construction Supervisor. The samples shall be provided to the Construction Supervisor in a secure form for transport to a laboratory. The Construction Supervisor will be responsible for the testing of the samples.

12.4.4 Prevention of Ingress of Foreign Matter

Following completion of boring, the bore holes shall not be exposed to the atmosphere longer than is necessary and shall be adequately covered at all times when work is not in progress. The Contractor shall take all precautions necessary to prevent the ingress of surface water or foreign matter into the boreholes. Lining tubes shall be provided for sufficient depth to ensure the stability of the pile excavation during boring and concreting operations.

12.5 DEFECTIVE PILES

The procedures incident to the driving of piles shall not subject them to excessive and undue abuse producing damage to the pile. Manipulation of piles (to force them into the planned position) will not be permitted. Any pile damage as a result of internal defects, or improper driving, or any pile driven outside the tolerances specified above or below the level authorised by the Construction Supervisor shall be corrected at the Contractor's expense by one of the following methods as determined by the Construction Supervisor for the pile in question:

(a) The pile shall be withdrawn and replaced by the new pile.

(b) A second pile shall be driven adjacent to the defective or low pile.

(c) The pile shall be spliced or built up as otherwise provided herein, or the headstock shall be extended to embed the pile.

All piles pushed up by the driving of adjacent piles or by any other causes shall be driven down again by the Contractor at his own expense.

12.6 LOAD TESTING

12.6.1 Determination of Actual Ultimate Strength of Piles

The Contractor shall propose for the approval of the Construction Supervisor his intended means of assessment of the pile ultimate geotechnical strength (Rug) as driven. This shall include, but not be limited to:

(i) The type of assessment as per Clause 12.3.4.11.

(ii) How individual piles are to be assessed.

(iii) Method of application of the results of the assessment to piles during driving to ensure that the required capacities are achieved.

The cost of the assessment (including static load testing if so selected by the Contractor) shall not be paid for separately and shall be deemed to be included in the rates for piling.

12.6.2 Static Load Testing

The Construction Supervisor may instruct the Contractor to carry out static load testing additional to the Contractor's means of assessment and notwithstanding that the Contractor is using a different method of pile capacity assessment. If the static load tests do not confirm the Contractor's assessment, the Contractor shall submit revised proposals for pile capacity assessment for the Construction Supervisor's consideration. Note that the static load tests take precedence over any other method of assessment.

Payment for static load tests ordered by the Construction Supervisor shall be made under the applicable item in the Bill of Quantities unless the tests show that the Contractor's assessment method does not result in the required ultimate pile capacity being achieved.

Where static load testing is required by the Contractor's proposed method of assessing Rug or is instructed by the Construction Supervisor, the Contractor shall be deemed to have allowed in his tender for the cost of the provision of all equipment for, and the carrying out of, full scale load tests under the supervision of the Construction Supervisor, of any pile on any bridge as selected by the Construction Supervisor.

The loading and measuring equipment shall be designed for a maximum load application equal to the ultimate geotechnical strength (Rug) (ie in this case - the design geotechnical strength multiplied by 1.25 and divided by 0.8) and details of the proposed equipment and method of application of the load shall be submitted to the Construction Supervisor. The Contractor shall ensure the accuracy of the test load within 2%.

The Contractor shall be responsible for carrying out the load test including the measuring of load and settlement and the recording of the information, under the supervision of the

Construction Supervisor. The load test on a selected pile shall be carried out within 14 days of notification by the Construction Supervisor of the pile to be tested.

The amount, rate and sequence of loading for each test shall be as follows, or as determined by the Construction Supervisor on site:

(a) Load the pile to 50% of the maximum ultimate load indicated on the Drawings by increments of 10% of the maximum ultimate load applied at 15 minute intervals. Hold the load so achieved for a period of 24 hours and then unload by 10% decrements at 15 minute intervals.

(b) Load the pile as in (a) above and hold the load for 15 minutes; then load the pile to 100% of the maximum ultimate load indicated on the Drawings by increments of 5% at 15 minute intervals. Hold the load so achieved for 15 minutes, and then fully unload by 10% decrements at 15 minute intervals.

(c) Repeat load sequence (b) above.

The settlement of the pile during the load test shall be measured by three dial gauges reading to 0.25 mm and capable of a minimum travel of 25 mm. Settlement measurements shall be made at the beginning and end of each load cycle and at the beginning and end of each waiting period between load increments or decrements. The dial gauges shall be set up under cover on a rigidly supported frame so that the dial gauges remain unaffected by ground movements immediately adjacent to the pile or reactive structure against which the pile is being jacked.

The ultimate capacity of the pile shall be determined as the load producing a settlement equal to 10% of the effective pile diameter or width. The results of the load test together with the driving record of the tested pile shall be submitted to the Construction Supervisor in duplicate within 7 days of carrying out the test. If as a result of the load test, or for any other reason, re-driving of piles is considered necessary by the Construction Supervisor, it shall be carried out by the Contractor as specified elsewhere in the Specification.

The Construction Supervisor may order that no load testing or additional load testing to that specified above shall be carried out and such variations shall be adjusted at the Billed Rate for load testing. The Contractor will be advised of the Construction Supervisor’s interpretation of the results of the test within 7 days of the receipt, by the Construction Supervisor, of the results of the test and the driving record. The Contractor will be deemed to have allowed for any resultant delays, including idle time of plant, in his rates and programme.

12.7 FILLING OF PILES

12.7.1 General

Sections of steel tubular piles shall be filled as shown on the Drawings or as directed by the Construction Supervisor.

Payment for filling to piles shall be by volume, in cubic metres. The volume shall be calculated as the internal volume of the pile between the levels shown on the Drawings or as directed by the Construction Supervisor. The Billed Rate per cubic metre shall be full compensation for all necessary costs in labour, plant, materials, and transport, for placement and compaction of the filling to the Construction Supervisor’s satisfaction.

12.7.2 Concrete Filling

Concreting shall be carried out in accordance with the relevant requirements of Group 14 of this specification.

Concrete filling shall be of a type as shown on the Drawings or as directed by the Construction Supervisor, and shall be supplied at a slump approved by the Construction Supervisor.

The concrete shall be placed in a manner approved by the Construction Supervisor and compacted, rodded or vibrated as necessary to obtain a density approved by the Construction Supervisor.

Immediately after the excavation or sand filling (as applicable) has been completed, the Construction Supervisor's approval to the commencement of concreting shall be sought and, when this has been obtained, concreting shall start forthwith and continue without interruption. Unless otherwise agreed by the Construction Supervisor, no concrete shall be placed in a pile excavation which contains water.

The top of the concrete filling to the pile shall be brought above the required finished level and any defective concrete removed to ensure satisfactory bonding of the pile head to the substructure.

12.7.3 Reinforcement

Reinforcement shall be supplied and installed in accordance with the relevant requirements of Group 13 of this Specification.

When in place the reinforcement shall be maintained in its correct position during concreting of the pile. Where it is made up into cages they shall be sufficiently rigid to enable them to be handled without damage.

12.7.4 Withdrawal of Casings and Linings

When casings and linings are to be withdrawn as concreting proceeds a sufficient head of concrete shall be maintained above the toe of the casing to prevent the entry of ground water or reduction of cross section of the pile excavation.

12.7.5 Sand filling to piles

Tubular steel piles shall be filled with sand to the extent shown on the Drawings or as directed by the Construction Supervisor.

A sample of the sand proposed for use shall be provided for the Construction Supervisor's approval prior to commencement of the filling of the piles. During placement the sand shall be maintained at moisture content approved by the Construction Supervisor and shall be compacted, in layers not exceeding 300 mm, to the Construction Supervisor's satisfaction.

12.8 MUCKING OUT PILES

The Contractor shall muck out piles as directed by the Construction Supervisor where the as-driven soil surface level within the pile is above the lower level given on the Drawings for the extent of concrete or sand filling, or where the contained soil is unsuitable to support the concrete or sand filling, as determined by the Construction Supervisor.

Payment for mucking out piles shall be by volume in cubic metres, calculated as the internal volume of the pile from the measured soil surface level to the mucking out level authorised by the Construction Supervisor and shall include disposal of mucked out material in areas approved by the Construction Supervisor.

12.9 COFFERDAMS AND CAISSONS

10.9.1 General

Foundation excavation shall include the removal of all material of whatever nature necessary for the construction of foundations and substructures requiring cofferdams in accordance with the Drawings or as directed by the Construction Supervisor. It shall include the furnishing of all necessary equipment and the construction of all cofferdams, caissons, dewatering etc. which may be necessary for the execution of the work.

It shall be also include the subsequent removal of cofferdams and the placement of all necessary backfill as hereinafter specified.

It shall also include the disposal of excavated material which is not required for backfill. All excavated material not required for backfill shall be disposed of in a manner and in locations such as not to affect the carrying capacity of the channel or be unsightly. If directed by the Construction Supervisor, the material may be used as filling for approach embankments.

12.9.2 Design of Cofferdams

All cofferdams shall be carried to adequate depths and heights, be safely designed and constructed and be made as watertight as is necessary for the proper performance of the work done inside them. They shall be of sufficient height to protect green concrete from sudden rising of the stream and to prevent erosion of the foundation.

At least four weeks before he proposes to work on a cofferdam the Contractor shall furnish the Construction Supervisor with drawings of the cofferdam and supporting calculations for the Construction Supervisor’s review. Work shall not commence until the Construction Supervisor’s consent in writing has been obtained.

All shoring, timbering and tomming must be carried out in an effective and substantial manner and to the approval of the Construction Supervisor. No timber bracing shall be left inside any excavation so as to extend into the substructure concrete.

12.9.3 Removal of Cofferdams

Upon completion of the footings, all sheeting, bracing, timber construction piles and sheet piling shall be withdrawn and removed from the Site. In waterways, all sand islands and obstructions to the waterway shall be removed and disposed of as directed by the Construction Supervisor.

12.9.4 Caissons

Where caissons form part of the permanent works they shall be positioned accurately and sunk true to level, position and plumb as shown on the Drawings and to the Construction Supervisor's satisfaction.

12.10 MEASUREMENT AND PAYMENT FOR PILING

12.10.1 Supply of Piles

Piles shall be measured in linear metres, along the axis of the pile from the cut-off level to the Contract Toe Level as shown on the Drawings or as amended by the Construction Supervisor including for pile toe enforcement and other strengthening of the casing if shown on the Drawings.

12.10.2 Driving Piles

Measurement for the driving of piles shall be in linear metres and shall be based on the distance from the toe of the pile, after the pile has been given the equivalent of one blow of a two tonne hammer free falling 1.2 metres, to the Contract Toe Level, or the amended toe level ordered by the Construction Supervisor, except where piles are driven through overburden when the payment shall be based on the distance from the original ground level to the Contract Toe Level or the amended toe level ordered by the Construction Supervisor.

12.10.3 Bored Piles

Measurement of bored piles shall be in linear metres and shall be based on the distance from original ground level, or base of excavation, whichever is the lower, to the Contract Toe Level or amended toe level as ordered by the Construction Supervisor. Where a bund is used to facilitate the boring operations no payment will be made for boring through the bund.

Measurement for the supply and placing of concrete and steel reinforcement shall be in accordance with the relevant provisions and items as described in Group 13 and 14 of this Specification, and shall be calculated by using the distance from the cut-off level to the Contract Toe Level, or amended toe level as ordered by the Construction Supervisor.

Where the casing is required to be retained in the bore, or sections of casing are retained in the bore at the direction of the Construction Supervisor and measurement of such casing shall be in linear metres and shall be the length of actual casing retained in the bore. The Billed item for bore casing shall include for the complete operation including supply and placement.

Provision of temporary casing is included as part of the boring requirements and no separate allowance will be made for this work.

12.10.4 Static Testing of Piles

Subject to Clause 12.6, the static testing of piles ordered by the Construction Supervisor shall be measured by number.

12.10.5 Splicing of Piles

Where separate provision is made in the Bill of Quantities for splicing of piles, the measurement shall be by number calculated by the formula:

N = L x 0.300 / 12, rounded down to the nearest whole number

Where:

N is the number of splices for measurement and
L is the length of pile between cut off level and approved Contract Toe Level

Payment will not be made for splicing to lengths less than the lengths to the Contract Toe Level plus three hundred (300) millimetres, or twelve (12) metres, which ever is the lesser, unless otherwise approved by the Construction Supervisor.

However where splices are required due to the design CTL being lowered by the Construction Supervisor, the additional splices shall be paid for as a variation to the Contract Price provided that there shall be no more than one splice for each 12 m or part thereof of extra length of pile required.

12.10.6 Establishment of Piling Rig

Establishment of the piling rig on Site shall be included as a lump sum item in the Bill of Quantities.

This item is deemed to include, but shall not be limited to, all costs associated with the establishment and setting up of the piling rig at the works site, and transportation within the Works area as may be necessary. No separate payment shall be made for dismantling the piling rig and its removal from the Site.

Where noted in the Bill of Quantities an item may be included for positioning and pitching of piles. This item shall include for all costs incurred in moving the rig and accessories from pile to pile and shall be measured by number. Where no such item is included in the Bill of Quantities all costs associated with positioning and pitching shall be included in the relevant Billed Item for establishment.

12.10.7 Re-purchase of Steel Piling

Provided that the quantity of piling material approved by the Construction Supervisor is delivered to the Site, the Employer will purchase from the Contractor any surplus piling which may remain at the end of the Contract, at the rate stated in Item 1, Group 10 of the Bill of Quantities.

Such pile lengths shall be full lengths supplied by the manufacturer and lengths made up to at least ten (10) metres from sections of pile no shorter than 1.2 metres, the butt welds to be in accordance with Sub-clause 10.3.3 of this Specification., The surplus piling material shall be safely stacked in a location directed by the Construction Supervisor.

OR

The Employer will not repurchase any surplus piling material and the Contractor shall remove from the site and dispose of properly any such surplus piling material.

12.10.8 Pile Heads

Cutting off of pile heads shall be measured by number.

Supply, fit and weld shear rings or other steel work detail shall also be measured by number.

The items shall include for all plant, labour and materials required, including the removal of any pile precoating.

12.10.9 Filling to Piles

Measurement of pile filling shall be by volume in cubic metres.

A Concrete - The volume shall be calculated as the internal volume of the pile from levels indicated on the Drawings to the pile cut-off level shown on the Drawings to such levels as directed by the Construction Supervisor.

B Sand The volume shall be the actual volume placed. The Contractor shall propose for the approval of the Construction Supervisor a means for measuring the volume.

Payment shall be full compensation for all necessary costs in supply, transport, placement and compaction of the filling to the Construction Supervisor's satisfaction.

12.11 MEASUREMENT AND PAYMENT FOR COFFERDAMS AND CAISSONS

Excavation for structures requiring cofferdams or caissons will be measured as the calculated volume of excavation in all material in cubic metres, with no allowance for bulking or over-break, determined from the existing ground levels and the plan dimensions, and foundation levels shown on the Drawings, or as varied by the Construction Supervisor.

Payment shall include full compensation for excavation, irrespective of subsurface conditions and for all Temporary Works and temporary stabilisation of excavations, dewatering, backfilling and disposal of excess material and the provision of all plant, labour and material necessary to complete excavation as specified in the Contract Documents and as directed by the Construction Supervisor.

12.12 TEST DRILING

12.12.1 General

When and where specified or directed by the Construction Supervisor, the Contractor shall carry out drilling, testing and sampling as required.

Bore log and test results, in prescribed form, shall be submitted by the Contractor to the Construction Supervisor within three days of completion of each borehole. Test results shall be certified by a duly licensed or authorised officer.

Complete undisturbed samples, taken in accordance with AS 1726, shall be extracted by the Contractor and provided to the Construction Supervisor in a secure form to enable transportation to a testing laboratory.

12.12.2 Equipment

The Contractor shall provide all equipment, labour, materials and technical expertise to carry out drilling of boreholes, suitable in size to facilitate Standard Penetration Testing (SPT) and removal of undisturbed soil samples, to a maximum depth of sixty (60) metres. Sufficient steel casing shall be provided for installation and removal as necessary to complete the required work.

12.12.3 Measurement and Payment

Test drilling directed by the Construction Supervisor shall be measured per borehole and payment made in
accordance with the relevant Billed Items. The rate shall include for

(a) Establishment, and removal from Site, of drilling rig and associated equipment, including transportation, erection and staff support facilities.

(b) Drilling of bore holes including supply, installation and removal of any casing required to protect the bore in poor ground.

(c) Standard Penetration Tests including certification and reporting of these test results.

(d) Undisturbed soil samples.

GROUP 13 - FALSEWORK

13.1 General 13-2
13.2 Measurement and Payment 13-2

GROUP 13

FALSEWORK

13.1 GENERAL

This Group covers Temporary Works necessary for the temporary support and erection of the Permanent Works but excludes cofferdams and temporary river crossings.

The falsework shall comply with AS 3610 subject to the exceptions, modifications and additions as listed in applicable legislation and regulations.

The Contractor shall provide the Construction Supervisor with fully detailed Drawings and supporting calculations for his proposed Temporary Works at least four weeks before work on the Temporary Works commences and shall not use the Temporary Works without the written consent of the Construction Supervisor. In no case shall the Contractor be relieved of responsibility for results obtained by the use of these Drawings. falsework shall be released only at the time and in the order and manner consented to by the Construction Supervisor.

Falsework which cannot be founded on a satisfactory footing shall be supported on piling which shall be spaced, driven and removed in a manner consented to by the Construction Supervisor. Subject to the Construction Supervisor’s consent, falsework may be supported on constructed portions of the substructure provided the structure is not overstressed or rendered unstable.

All timber shall be well seasoned and free from knotholes, loose knots and other defects. Structural strengthening rendered necessary by falsework loads shall be effected at the Contractor’s expense. falsework shall be released only at the time and in the order and manner consented to by the Construction Supervisor.

Before final acceptance, the Contractor shall remove all falsework and construction equipment. Bed logs, temporary piles and trestles, temporary concrete bases etc, used in the construction operation shall be removed. Equipment for pulling piles will not be allowed to operate from the new structure. Equipment for removing falsework shall not be operated upon or attached to any portion of the new structure except with the written approval of the Construction Supervisor.

13.2 MEASUREMENT AND PAYMENT

Falsework will not be paid for separately but shall be deemed to be included in the Billed Rate for the item supported by the falsework.

GROUP 14 - FORMWORK FOR CONCRETE

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GROUP 14

FORMWORK FOR CONCRETE

14.1 GENERAL

Formwork shall be in accordance with AS 3610 subject to the exceptions, modifications and additions as listed in applicable legislation and regulations.

All formwork shall be designed and constructed to ensure no loss of material from the placed concrete and be of the required rigidity to produce hardened concrete in the position and of the shape and dimensions described in the Contract. Where required, sealing gaskets, or an alternative acceptable to the Construction Supervisor, shall be provided.

No concrete shall be deposited in the forms until they have been thoroughly cleaned out and inspected by the Construction Supervisor. Any forms not conforming to the requirements of the Construction Supervisor shall not be used, and shall be removed without delay. This shall not relieve the Contractor of the responsibility for the design and adequacy of all formwork.

Where stated on the Drawings or directed by the Construction Supervisor, provision shall be made for the attached of external vibrators to the underside of forms.

In the case of concrete placed in earth excavations, forms shall be provided for all vertical surfaces unless otherwise shown on the Drawings or ordered by the Construction Supervisor.

In the case of columns, walls or other thin sections of considerable height, forms shall be designed and constructed with one side open from bottom to top, and the formwork of the open side shall be placed as successive layers of concrete, not more than twelve hundred (1200) millimetres in height, are placed, unless otherwise permitted by the Construction Supervisor. In the case of beams, girders and similar members forms shall be constructed so that the side forms may be removed without interference to the remaining forms.

14.2 CONSTRUCTION

14.2.1 Material

(a) Timbers

Timber for formwork shall be well seasoned and free from loose knots and other defects. Timber which becomes warped or in the opinion of the Construction Supervisor unsuitable for re-use shall be replaced.

The class of timber selected for different portions of the structure shall be appropriate to the quality of line and surface required in the work, and shall be approved in advance by the Construction Supervisor. The formwork used for exposed surfaces shall have, in contact with the concrete, either dressed timber, or undressed timber lined with an approved watertight lining not liable to warp so as to give, on stripping, a smooth and even concrete surface true to the dimensions shown on the Drawings. For the backs of abutments and wing walls timber need not be dressed or lined.

(b) Mild Steel
The design of mild steel forms shall be submitted for review by the Construction Supervisor before work on the construction of forms is commenced. All bolt and rivet heads shall be countersunk and all welds ground back to the correct dimensions.

14.2.2 Handling and Treatment

Forms shall be so designed and constructed that they may be removed without injury to the concrete or to the forms. The forms shall be built true to line and braced in a substantial and unyielding manner to maintain position and shape. Joints in forms shall be either horizontal or vertical. Timber forms shall be thoroughly soaked with water before application or release agents unless they are lined.

Where the effectiveness of external vibration, if used, is likely to be largely lost due to the nature of the contact with the supporting falsework or base, eg. where forms are to be bolted to a concrete plinth, rubber padding shall be provided between the forms and supporting surfaces to the satisfaction of the Construction Supervisor. The padding shall be securely held by bolts or other means to ensure that it remains in position during concreting. The size, thickness, shape and quality of rubber padding shall be as approved by the Construction Supervisor.

Provision shall be made for the accurate location of all fittings, eg. scuppers, reinforcement, anchorage devices, holding down bolts, tubes and bars for the formation of holes.

The use of wires and/or bolts extending to the surface of the concrete shall not be permitted. Where internal ties are permitted for support of formwork, they shall be such as to permit their extraction or that of their removable parts without damage to the concrete. All holes shall be filled with mortar to the satisfaction of the Construction Supervisor.

Forms for re-entrant angles shall be chamfered, and forms for corners shall be filleted, the bevel in each case having a width as shown on the Drawings, or if not so shown, of twenty five (25) millimetres on each side with equal angles in all cases. Alternatively re-entrant angles and corners shall be rounded to a radius equivalent to the width of bevel of the fillet of chamfer they replace.

14.2.3 Erection

Dimensions of forms, especially those affecting the construction of subsequent portions of the work, shall be carefully checked after the forms are erected. Forms shall be aligned accurately and the location of all fittings, holes formers, etc, checked prior to placing concrete.

The interior surface of the forms, except for permanent formwork, shall be coated with a release agent acceptable to the Construction Supervisor which will permit the removal of the forms without injury to the concrete and will not stain or discolour the concrete surface.

Release agents shall be applied uniformly in accordance with the manufacturer's recommendations and any surplus shall be removed prior to the fixing of reinforcement and the placing of the concrete. No release agents shall be permitted to come into contact with reinforcement, structural steelwork, shear connectors or the like. Different release agents shall not be used on visible sections of the same structure.

Bolts, pipes and bars, if used to form holes in the members, shall be well greased and so arranged that they may be removed from the concrete before removal of forms without excessive jarring or hammering.

14.2.4 Removal of Formwork

The Construction Supervisor shall be informed in advance of when the Contractor intends to strike any formwork.

The Contractor's attention is drawn to the requirements of Clause 5.4.3 and Table 5.4.1 of AS 3610. In no case shall formwork be removed before such time as the concrete has attained sufficient strength to support its own weight plus any imposed loading.

Forms shall be removed with care and without unnecessary hammering and wedging and so as no to injure the concrete or disturb the remaining supports. Centres shall be gradually and uniformly lowered in such manner as to avoid injurious stresses in any part of the structure.

Care shall be exercised that no tomming or bracing is removed, loosened or in any way altered during the removal of falsework without the Construction Supervisor's approval.

When the forms are removed and are intended for re-use, they shall be thoroughly cleaned and made good to the satisfaction of the Construction Supervisor.

14.3 FORMED SURFACES – CLASSES OF FINISH

Unless specifically indicated on the Drawings to the contrary the formwork shall provide a surface finish to the concrete as given in AS 3610.

The following Classes will be used:

Class 1 Not normally required.

Class 2 Surfaces readily visible, i.e. abutment and wing wall faces, kerbs, soffit and edge of cantilever slabs, pier columns and caps.

All surfaces shall be protected from rust stains and stains of all kinds. Unless otherwise stated on the Drawings, all formwork joints shall form a regular pattern of horizontal and/or vertical lines and all constructing joints shall coincide with these lines.

Class 3	Surface not normally visible, Soffit of deck between beams
Class 4	Surfaces not visible – pile caps to piers, back of abutments and wing walls.
Class 5	Only to be used for mass concrete.

14.4 UNFORMED SURFACES – CLASSES OF FINISH

Refer to Clause 16.11 of this Specification.

14.5 MEASUREMENT AND PAYMENT

The unit of measurement for formwork shall be the square metre (m^2). Payment shall include for supply, erection and stripping of formwork. The Contractor is to make due reduction in his rates for the scrap or re-use value of the formwork.

OR

No separate payment will be made for formwork. The costs shall be included in the pay items for Concrete.

GROUP 15 - STEEL REINFORCEMENT

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GROUP 15

STEEL REINFORCEMENT

15.1 GENERAL

This work shall consist of the supply for all reinforcing bars and fabric of the type, shape, size and grade required for concrete structures and incidental concrete construction and placing them in accordance with this Specification, as shown on the Drawings or as directed by the Construction Supervisor.

15.2 MATERIALS

Steel for reinforcement shall conform to AS/NZS 4671. The grade shall be R250N or D500N as specified on the Drawings. If not so specified, the grade shall be D500N.

If the supplier can produce a Manufacturer’s Certificate which can be identified with the steel reinforcement by numbers or identification marks, it shall be accepted as evidence that the steel complies with the relevant Specification.

If such Certificates cannot be produced the Contractor shall supply one test piece for each 5 tonnes of steel reinforcement used with a minimum of 2 test pieces from each size at time of sampling. These test pieces shall be of the sizes specified and tested in the manner given in AS/NZS 4671.

Certificates and/or samples shall be supplied at least three weeks before fixing of the steel represented by the samples in the job.

For each test piece that fails, a further two test pieces of that size shall be tested. If one or both of these test pieces fail, the steel represented by such test pieces shall be rejected.

Any test carried out as a result of the Contractor’s failure to produce Manufacturer’s Certificates shall be at the Contractor’s expense. All costs associated with any other tests requested by the Construction Supervisor or his representative shall be paid by the Contractor if the results show that the material tested is not in accordance with the Contract, otherwise these costs shall be recovered by the Contractor from the Employer.

When placed bars are shown on the Drawings and the Contractor wishes to use an equivalent fabric, his proposals, together with satisfactory supporting evidence of their structural sufficiency, shall be submitted to the Construction Supervisor for approval.

15.3 PROTECTION

Steel reinforcement shall be protected at all times from damage. It shall be stacked in racks above the ground and shall at all times be kept clear of mud. When placed in the work it shall be free from dirt, detrimental scale, paint, oil or other foreign substance.

When steel has on its surface detrimental rust, loose scale and dust which is easily removable, it shall be cleaned by a method approved by the Construction Supervisor.

15.4 CUTTING AND BENDING

Bent bar reinforcement shall be cold bent to the shapes shown on the Drawings. Bars of diameter greater than 24 mm shall not be rebent.

Unless otherwise stated on the Drawings or approved by the Construction Supervisor, bends shall be made in accordance with the following requirements. Stirrups and tie bars (encompassing bars) shall be bent around a pin having the same diameter as the bar around which the stirrup or tie bar will pass in the finished work so long as this diameter is not less than twice the diameter of the stirrup or tie bar. Bends for other bars shall be made around a pin having a diameter not less than 4 times the diameter of the bar for Grade R250N bars and not less than 6 times the diameter of the bar for Grade D500N bars.

After cutting and bending, bars shall be bundled or stacked according to their respective ‘marks’ as shown in the Reinforcement Bending Schedule prepared in accordance with the next paragraph.

At least three weeks prior to the cutting and bending of reinforcement for a section of the Works the Contactor shall prepare a Reinforcement Bending Schedule and provide a copy to the Construction Supervisor. The Contractor remains wholly responsible for the accuracy of the Schedule.

15.5 PLACING AND FIXING

All steel reinforcement shall be accurately placed in the positions shown in the Drawings and firmly held during placing and setting of the concrete.

Bars shall be held in position by wiring at all intersections with annealed wire not less than 1.25 mm diameter except where spacing is less than 300 mm in each direction when alternate intersections shall be tied. Cover to reinforcement shall be maintained by precast concrete blocks or other devices acceptable to the Construction Supervisor. Metal supports and tie wires which extend to the surface of the concrete shall not be permitted. Stirrups and ligatures shall pass around the main bars and be securely wired thereto.

Precast concrete cover blocks shall be made as small as possible, consistent with their purpose. They shall be made of concrete with 10 mm maximum aggregate size and the mix proportions shall be such as to produce the same 28 day cylinder strength as the adjacent concrete. Tying wire complying with the requirements of this Clause shall be cast into the block for the purpose of tying it to the reinforcement. The blocks shall be cured by immersion in water for at least 7 days until 24 hours before the blocks are to be used. Layers of bars shall be separated by precast concrete blocks or by other equally suitable devices. The use of pebbles, pieces of broken stone or brick, metal pipe and wooden blocks shall not be permitted.

Welding of bars to form a rigid cage shall be kept to a minimum and not more than one third of the main reinforcement at any cross section shall be so welded. Welding of reinforcement shall only be permitted with the written approval of the Construction Supervisor.

If fabric reinforcement is shipped in rolls, it shall be straightened into flat sheets before being placed.

Reinforcement in any member shall be placed and then inspected and approved by the Construction Supervisor before the placing of concrete begins. Concrete placed in violation of this provision may be rejected and removal required.

15.6 SPLICING

All reinforcement shall be furnished in the full lengths indicated on the Drawings and bar bending schedules. Splicing of bars, except where shown on the Drawings, will not be permitted without written approval of the Construction Supervisor. Splices shall be staggered as far as possible. Where bars are spliced they shall be lapped the lengths shown on the Drawings and Reinforcement Bending Schedule.

Lapped bar splices not shown in the Drawings shall have lengths not less than the following:

(a) Deformed and plain bars:

- (i) If laps are staggered and no more than 50% of the reinforcement area in any section is spliced, and the bar is not a top bar, the splice length shall be in accordance with the table below.

- (ii) If more than 50% of reinforcement area is lapped in any section, the splice lengths given in the table below shall be increased by 30%.

- (iii) Lap splices on top bars (defined as horizontal bars with 300 mm or more of concrete cast below the bar) shall be further increased by 25% of the lengths given in the preceding paragraphs. (Note: The increases due to non-staggered splices and top bars are cumulative.)

- (iv) The length of splice is governed by the smaller size bar at the splice.

- (v) Bars shall not be lapped unless the conerete cover to the nearest fitment in beams or bar in slabs exceeds the size of bars to be lapped.

Bar Type	Bar Diameter (mm)	Splice Length (mm)
Deformed	12	360
	16	480
	20	700
	24	950
	28, 32 and 36	1,250
Plain (fitment)	d_b < 13 mm	40 d_b or 300 mm whichever is the greater

Note: “d_b” is the nominal diameter of a bar or wire.

The following conditions shall apply to welded splices:

(i) Non-scheduled welded splices will only be permitted in a region where the stress in the bar is less than 75 percent of the permissible stress.

(ii) Welding electrodes used are to comply with AS/NZS 4855 or AS/NZS 4857.

(iii) Welding of reinforcing bars shall be carried out in accordance with the appropriate Clauses and with AS/NZS 1554.3.

(iv) Cold worked deformed bars shall not be welded or tack welded or heated.

(v) The welding procedure shall conform to the bar manufacturer's recommendations for control of heat input.

15.7 LAPPING OF REINFORCING FABRIC

Sheets of hard drawn steel-wire reinforcing fabric shall overlap by one full mesh plus twenty five (25) millimetres. Alternative arrangements for effecting laps in sheets of reinforcing fabric shall be subject to the Construction Supervisor's approval.

15.8 SUBSTITUTIONS

Substitution of different size or grade bars will not be permitted unless written application is made for such substitution at least 4 weeks before the reinforcing steel is to be placed. Such permission will only be given if the structure is not adversely affected. No additional payment will be made on account of these alterations.

15.9 MEASUREMENT AND PAYMENT

15.9.1 Measurement

The quantity of steel reinforcement incorporated in the work in accordance with the Drawings or as directed by the Construction Supervisor will be determined from the calculated mass of the various sizes and lengths of the bars shown on the Drawings or authorised by the Construction Supervisor. Where a continuous bar or welded or other type of splice is used instead of a lapped splice, the weight will be calculated as far a lapped splice. Additional steel required in splices authorised for the convenience of the Contractor shall not be measured for payment.

Quantity of steel wire fabric placed as shown on the Drawings or as directed by the Construction Supervisor will be determined from measurements taken of the area covered by the steel wire fabric with no allowance for laps.

Payment will be made only for the quantity of steel shown on the Drawings or authorised by the Construction Supervisor and incorporated in the work.

The mass of reinforcing steel used in precast units, and other items for which the reinforcing steel is included in the scheduled rate for the item, will not be included in the quantity of reinforcing steel for payment.

15.9.2 Payment

The Billed Rate per tonne for bar reinforcing steel measured as above shall include full compensation for furnishing all labour, materials, tools, equipment and incidentals and for doing all the work involved in preparing the Reinforcement Bar Schedule, furnishing and placing the bar reinforcing steel complete in place, as shown on the Drawings and as specified by this Specification and as directed by the Construction Supervisor.

The Billed Rate per square metre for steel wire fabric measured as above includes full compensation for furnishing all labour, materials, tools, equipment and incidentals and for doing all work involved in furnishing and placing the steel wire fabric complete in place as shown on the Drawings and as required by this Specification and as directed by the Construction Supervisor.

Full compensation for furnishing all tie wires and supporting devices shall be considered as included in the Billed Rates for bar reinforcing steel and steel wire fabric and no additional compensation will be allowed therefore.

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GROUP 16

CONCRETE FOR STRUCTURES

16.1 GENERAL

The work specified herein shall include the furnishing, placing, compacting and finishing of all Portland Cement Concrete in ordinary reinforced concrete, mass concrete and blinding concrete to the lines, levels and dimensions shown on the Drawings, or where not shown, as directed by the Construction Supervisor.

16.2 DEFINITIONS

The following definitions shall apply to this Specification:

Compressive Strength	shall mean the compressive strength of concrete 28 days after placing, determined as provided for herein.
Construction Joint	shall mean a joint provide in the concrete work as a construction necessity, whether provided for in the Drawings or not, when the concrete to one side of the joint will have set before placing concrete to the other side of the joint.
Ready Mixed Concrete	shall mean all concrete for which any or all of the constituent materials are batched or mixed away from the Site.

16.3 RESPONSIBILITY

Regardless of approvals having been given for the use of various constituents and the methods of manufacture, the Contractor shall be wholly responsible for the production of concrete in place to the specified properties and requirements. If any Governmental or other authority assists the Contractor with the design or control of the mix used, the Contractor's responsibility shall not be waived.

16.4 INSPECTION

The Contractor shall give the Construction Supervisor forty-eight (48) hours notice of his intention to proceed with the work involved in concreting. Unless otherwise required or directed by the Construction Supervisor, or requested of the Construction Supervisor by the Contractor, periodic inspections only shall be carried out on blinding concrete and the Contractor's obligations to advise the Construction Supervisor before proceeding shall be waived, provided that, as required by Clause 4.12 and 4.19 of this Specification, the Contractor has obtained the Construction Supervisor's approval of the founding surface.

16.5 MATERIALS

16.5.1 General

All concrete shall be of an approved design mix as detailed in Clause 16.6, and shall consist of materials meeting the requirements detailed in this Clause 16.5.

16.5.2 Portland Cement

All cement used shall be Portland cement of an approved brand and shall comply with AS 3972. The type of cement used shall by Type GP 'General Purpose Portland Cement' unless otherwise designated.

If the Contractor wishes to use Type HE 'High Early Strength Cement' to facilitate his operations he shall use such cement (other than where its use is designated) only on the written authority of the Construction Supervisor and no extra payment will be made for the use of such cement. Type HE cement shall not be permitted in ambient temperatures over 30°C nor in concrete of strengths greater than Grade 25. Documentary or other acceptable evidence of the quality of the cement shall be furnished by the Contractor if requested by the Construction Supervisor.

Fly ash or Type GB 'General Purpose Blended Cement' shall not be used without the written approval of the Construction Supervisor. If approved, fly ash shall comply with AS 3582.1. Type GB cement shall comply with AS 3972. Fly ash and blended cements shall not be used in concretes of strength greater than Grade 20. No more than 1 part of fly ash to 3 parts of Portland cement shall be used in any concrete mix.

16.5.3 Water

Water shall be free from matter harmful to concrete and reinforcing steel. Water shall be subject to the approval of the Construction Supervisor and shall be reasonably clear, free from oil, alkali, salts, acid and organic substances and other deleterious materials or objectionable quantities of suspended materials. The use of brackish water and/or water from the sea or tidal rivers shall not be permitted under any circumstances.

Where water as specified above is unavailable, or any suitable source is not economically feasible and/or practically available, the Contractor shall provide wells at suitable locations for water sources and in accordance to any Community Memorandum of Understanding and/or Community agreements that may be in place. These water source wells shall be located to ensure ongoing Community benefit following completion of the Contract, for example located at local Community schools and the like. The locations of all new water sources shall be approved by the Construction Supervisor.

16.5.4 Fine Aggregate

Fine aggregate shall consist of natural sand, a combination of natural sands, or a combination of natural and manufactured sands containing not less than 50 percent natural sands. Particles shall be clean, hard and durable and shall not contain harmful materials such as iron pyrites, coal, mica, shale or vegetable matter. It shall conform with AS 2758.1.

Where sand is only available from beach sources, the sand shall be stockpiled on a suitable plastic membrane at or near the batching plant and as far away from the coast as is practical. The sand stockpile shall be spread out to a maximum thickness of approximately 300mm and shall be washed with fresh water using either fixed or hand held sprinklers for a minimum overall period of 24 hours or shall undergo adequate natural rain washing as to be confirmed and approved by the Construction Supervisor. In general adequate natural rain washing is defined as a total period of 72 hours exposure to rain. Sand stockpiles shall not be covered.

16.5.5 Coarse Aggregate

Coarse aggregate shall consist of clean, durable, uncrushed gravel, crushed gravel, stone, or combinations thereof, free from coatings of clay or dirt, organic or other deleterious matter. Aggregates shall not contain harmful materials such as vegetable matter, iron pyrites, coal, mica, shale or similar laminated materials. They shall conform with AS 2758.1. The proportion of misshapen particles as determined by AS 2758.1 shall not exceed 10%.

Unless noted otherwise on the Drawings, the maximum nominal size of aggregate which may be used in all grades of concrete shall be 20 mm except in mass concrete where the maximum nominal size shall be 40 mm and for bearing plinths where the maximum size shall be 10 mm.

OR

Coronous and Scoria

16.5.6 Testing

The Contractor shall submit for approval for each concrete Grade 50 kg of coarse aggregate and 25 kg of fine aggregate. The Contractor shall, at his own expense, sample from each different source of supply and deliver the samples to the Site Laboratory. Each sample shall be clearly labelled. Aggregate testing shall be at the Contractor’s OR Employer’s expense. No material shall be used until approved in writing by the Construction Supervisor. The Construction Supervisor may waive this requirement if the concrete is to be supplied by an established ready mixed or precast concrete supplier.

16.5.7 Storage

Cement shall be stored above ground level in dry, weatherproof sheds, well protected from dampness acquired from contact with floors or walls. Bags shall be stacked so as to permit access for tallying, inspection and identification of each consignment. It shall not be stacked more than seven bags high for more than seven days, and shall never be stacked more than twelve (12) bags high.

If bulk cement is used, only watertight storage silos and weighing attachments approved by the Construction Supervisor shall be used.

As far as practicable, cement shall be used in order of receipt. If the Contractor proposes to use cement which has been stored for two months or more on site, the Construction Supervisor may require a re-test of the cement at the Contractor's expense before it is used in the work. Cement showing lumps which cannot be broken to the original fineness by finger pressure will be rejected irrespective of age, and replaced at the Contractor's expense.

Aggregates shall be stored on Site in such manner that they will not segregate, become contaminated by foreign matter or intermixed nor shall water be permitted to drain into them. Aggregates shall not be stored in direct contact with the ground. Generally, storage areas shall be surfaced with concrete slabs, which shall be removed on completion of the Works.

16.5.8 Admixtures

Admixtures shall not be used in concrete without the written approval of the Construction Supervisor. Should the Contractor desire to use an admixture he shall give the Construction Supervisor notice in writing of:

(a) type and brand of admixture to be used,

(b) rate of application,

(c) type and location of metering device,

(d) part of the structure where admixture is proposed to be used, and

(e) reasons for use.

Generally, admixtures approved will be restricted to air entraining agents, and for certain approved applications, retarders.

Where two or more admixtures are proposed for incorporation into a concrete mix, their compatibility shall be certified by the manufacturers.

Despite the use of admixtures, the quantity of cement shall in no case be reduced below the minimum value specified in Clause 16.6.

Calcium chloride shall not be used as an admixture in reinforced concrete. No admixtures shall be used for steam cured concrete.

Any air entraining agents if approved shall comply with the requirements of AS 1478.1. Concrete containing fly ash shall not be air entrained.

Where air entrainment is allowed, the air content shall be within the range 3% to 5% except where otherwise specified. The Contractor shall have a suitable air content gauging device on the job so that the air content of the freshly mixed concrete may be accurately determined in accordance with AS 1012.4. Admixture metering shall be by an approved and well maintained dispenser. Sampling and testing for air content shall be carried out at the discretion of the Construction Supervisor but shall generally be of every batch or transit-mixer delivery for the first five batches or deliveries and not more than every fifth batch or delivery if the first five comply with the specification and show evidence of satisfactory control.

16.6 CONCRETE PROPORTIONS AND DESIGN

16.6.1 Grades of Concrete

Concrete shall be described as 'Grade X' where X is the minimum 28 day compressive strength in megapascals. The compressive strength shall be determined in accordance with AS 1012.9 for 300 mm x 150 mm cylinders. Slump values, maximum water/cement ratios and minimum and maximum cement content shall be within the following values:

Grade of Concrete	Minimum 28 Day Compressive Strength (MPa)	Slump (mm)	Cement Content (kg/m^3)		Maximum Water/Cement Ratio by Weight
			Min	Max	
40	40	0-50	400	470	0.40
32	32	0-50	360	430	0.45
30	30	0-50	350	420	0.45
25	25	50-80	#325	400	0.45
20	20	25-75	*300	380	0.50
15	15	40-80	270	350	0.52

* For concretes containing fly ash or blended cement this figure shall not apply and combined cement plus fly ash content shall not be less than 335 kg/m^3.

\# For concretes containing fly ash or blended cement this figure shall not apply and combined cement plus fly ash content shall not be less than 360 kg/m^3.

Blinding (mass) concrete shall be Grade 15 minimum.

Note that compliance with this Clause shall not relieve the Contractor from its responsibility for achieving the required strengths of the concrete when placed.

16.6.2 Grouts

Grouts shall consist of a mixture of Portland Cement and water (cement grout) or of Portland Cement, sand and water (cement 0 sand grout). The water cement ratio shall be a maximum of 0.4 by weight. No admixture shall be used which contains chloride or nitrate or which entrains gaseous hydrogen. The Contractor is to provide the Construction Supervisor with details of this proposed mix and six standard test specimens for test. The tests will be carried out to the requirements of AS 3700.

The minimum compressive strength of grout shall not be less than 17.5 MPa.

Where mortar is indicated on structural drawings (other than for use in brick work and masonry). i.e. below handrail post baseplates, it shall be a stiff cement-sand grout complying with the above.

16.6.3 <u>General</u>

The Contractor shall be solely responsible for the design and production of concrete to comply with the Specification.

The Contractor shall submit for approval, details of the concrete mix he proposes to use for each particular Grade of concrete. The following information shall be forwarded to the Construction Supervisor:

(i) mix designation mark,

(ii) concrete grade,

(iii) type and source of cement,

(iv) source of aggregates,

(v) proportion by weight of individual ingredients including added water and free water,

(vi) grading of fine and course aggregates in tabular and graphical form,

(vii) grading curves of combined aggregates in tabular and graphical form together with details of proportions in which the fine and course aggregates are combined,

(viii) mixers to be used,

(ix) water/cement ratio by weight,

(x) aggregate/cement ratio by weight,

(xi) slump, and

(xii) design target strength.

Minimum target strength shall be as follows:

Grade 40 concrete – 49 MPa
Grade 30 concrete – 38 MPa
Grade 25 concrete – 33 MPa
Grade 20 concrete – 28 MPa
Grade 15 concrete – 22 MPa

These minimum target strengths have been calculated on the assumption that all solid constituents of the concrete are batched by weight, the cement is batched separately from the aggregates, and a reasonably high standard of control in the production and storing of aggregates and the batching and mixing of the concrete is maintained at all times by the job management. Mixing water is assumed to be measured, and the aggregate moisture and slumps checked. The Contractor shall nominate target strength for the Construction Supervisor's approval, which target strengths must be consistent with the degree of control provided but which shall in no case be less than the minimum tabulated above, unless, after examination of documentary records of test results of comparable mixes performed by the same plant and with the same materials, the Construction Supervisor approves slightly lower values.

The Contractor shall state his proposed degree of control when submitting details of his proposed mix design. If, during the course of the job, the proposed degree of control is not maintained, as evidenced by either the batching and mixing methods employed or by the strength of test cylinders taken on the work, a new mix design shall be prepared and tested at the Contractor's expense.

16.6.4 Preliminary Mixes

The Contractor shall make preliminary mixes of Grades 40, 30, 25, 20 and 15 concrete, using the approved materials. The mixes shall be made under closely controlled laboratory conditions in the presence of the Construction Supervisor. Nine cylinders shall be cast from each preliminary mix and tested by the Contractor at its expense.

Three cylinders shall be tested at 7 days and six at 28 days. If precast units are manufactured by an established precasting manufacturer who can produce evidence of a history of good quality control in the manufacture of concrete of adequate strength, the Construction Supervisor may waive this Clause with regard to concrete produced by that manufacturer.

If concrete is supplied by an approved supplier of ready mixed concrete, the Construction Supervisor at his sole discretion may accept the results of test cylinders cast from identical mixes produced previously by the supplier in lieu of preliminary mixes. The information relating to the mix shall nevertheless be supplied.

The strength of the preliminary mixes as represented by the crushing strength of cylinders tested at 28 days shall not be less than the following:

Grade	Average of six tests results (MPa)	Lowest test results (MPa)
40	49	40
30	38	30
25	33	25
20	38	20
15	22	15

Should cement be separately weigh batched and in the opinion of the Construction Supervisor, the batching equipment and quality control to be used on the Site be of sufficient standard, the Construction Supervisor may at his discretion accept slightly lower average strengths provided that the Contractor can provide the necessary data to justify that acceptance.

The selection of suitable target strengths will be at the Contractor's discretion but the values selected shall not be less than the average 28 day preliminary mix strengths fixed by the Construction Supervisor.

16.6.5 Approval of Mixes

No concrete shall be placed in the Permanent Works until the preliminary mixes have been made, tested and/or the mixes approved in writing by the Construction Supervisor. Upon request of the Contractor, the Construction Supervisor may give provisional approval of the mix if the average of the 7 day strengths is not less than 80% of the specified 28 day preliminary mix strengths. The Construction Supervisor may accept lower than 7 days strength at his discretion when fly ash is incorporated in the concrete mix. Notwithstanding any approval given, the concrete shall meet the specified preliminary mix strength of 28 days. No approval will be given for the use of Grade 30 or Grade 40 concrete until satisfactory 28 day results have been received. Once approved, the mix shall not be altered without the written approval of the Construction Supervisor.

16.7 CONTROL OF CONCRETE QUALITY

16.7.1 General

When trial mixes are used in design, in addition to the number of cylinders specified below, one additional cylinder shall be taken from three different batches on each of the first 6 days after the commencement of concreting, and tested at 7 days. The strengths will be adjusted to 28 day strengths assuming the ratio of 7 days to 28 days strengths is the same as that obtained from the preliminary cylinder strength tests. The mean strength shall be calculated from these first 18 cylinder tests. Should the adjusted mean strengths be less than the target strength used in the design of the mix, or should more than one of the individual results of the first 18 cylinders tested fall below the specified minimum, or any result fall below 90 per cent of the specification minimum, the mix shall be redesigned and resubmitted for approval as specified in Clause 16.6.

16.7.2 Sampling and Testing

The concrete shall be sampled and tested by the Contractor in accordance with the provisions of the appropriate parts of AS 1012 in the presence of the Construction Supervisor unless the Construction Supervisor otherwise directs.

All cylinders shall be efficiently capped to make ends truly parallel to each other and at right angles to the cylinder axis. The 28 day cylinder strength of the concrete is any portion of the work shall be determined by the average crushing strength of two cylinders taken from one batch of concrete. Both cylinders shall be moulded from the one sample of concrete taken from one batch of concrete in the manner specified in AS 1012.1. (The sample shall be obtained by taking three or more approximately equal portions regularly spaced throughout the discharge of the whole batch from the mixer or transit mixer).

The following minimum number of 300 x 150 mm diameter test cylinders shall be taken.

For cast in-situ concrete to be tested at 28 days one sample of two (2) cylinders for each 15 m^3 or part thereof placed in an essentially continuous manner with a minimum of two (2) samples of two (2) cylinders for each casting day.

For precast concrete to be tested at 28 days one sample of two (2) cylinders for each batch of units cast in an essentially continuous manner.

If the standard of control appears to have changed from that prevailing at the time of the check of quality control, in addition to the above numbers of cylinders, the Construction Supervisor may order further cylinders for testing at 7 days.

The ratio of 28 day strength to 7 day strength established by the preliminary mixes shall be applied to these 7 day tests and, if these results indicate a decrease in the standard of control or strengths obtained, the Construction Supervisor will order such remedial action as he deems necessary.

16.7.3 Failure to obtain required strength of cylinders

Should the strength of a sample representing reinforced concrete work fail to reach the specified 28 day strength, the Contractor may elect to submit for testing a core cut from the completed work. Securing and testing of the core shall be in accordance with AS 1012.14.

The form and dimensions of the core and the location in the work from which it is to be cut and the manner of restoring the cut portion of the work shall be subject to the approval of the Construction Supervisor.

The whole cost of cutting cores from work, restoring the work from which any cores have been cut, and testing the cores shall be borne by the Contractor.

Cores cut from work shall be tested at the location that the Construction Supervisor, at his absolute discretion, may direct. The Contractor shall carry out or arrange for the testing which shall be carried out in the presence of the Construction Supervisor unless the Construction Supervisor otherwise directs.

The actual test strength of the specimen cut from the work shall be adjusted to obtain the equivalent strength of a 300 mm x 150 mm diameter cylinder in accordance with AS 1012.9 and AS 1012.14.

Further, should any specimen cut from the finished work be tested at an age (i.e. number of days after pouring) greater than twenty eight (28) days its strength shall be adjusted to the equivalent 28 days strength by dividing the actual strength by the factor given in the following table:

Age of test specimen at time of testing (days)	**Adjustment factor**	
	Portland Cement	**Blended Cement**
28	1.00	1.00
35	1.02	
42	1.04	
49	1.06	
56	1.08	1.19
70	1.10	
84	1.12	
112	1.14	1.13
140	1.16	
168	1.18	
196	1.20	
224	1.22	1.42

308 >365	1.24 1.25	1.45

Notes:

(i) For intermediate ages the factor shall be determined on a pro-rata basis.

(ii) If specimens are tested at seven (7) days for the purpose of preliminary information and control, the approximate equivalent strength at twenty-eight (28) days may be obtained by dividing the actual strength of seven (7) days by the factor 0.70.

Seven day tests are not to be regarded as acceptance tests.

(iii) Concrete containing high early strength cement, additives or specially cured shall be adjusted for age as set out above for ordinary Portland cement unless determined otherwise by the Construction Supervisor.

16.7.4 Determination of Strength for Acceptance of Concrete

After tests of concrete specimens cut from the work have been made, if any, the Construction Supervisor will consider the test results and other information and may at his absolute discretion determine the strength of the concrete to be taken for acceptance (necessary adjustments for form and age of specimens being made as herein specified) as one of the following:

(i) the average strength of the pair(s) of cylinders moulded at the time of pouring if no specimens are cut from the work; or

(ii) the average strength of the pair(s) of cylinders moulded at the time of pouring (i.e. rejecting the specimens cut from the work on the grounds of being unsatisfactory in some respect); or

(iii) the mean of the average strength of the pair(s) of cylinders moulded at the time of pouring and the equivalent strength of the specimens cut from the work; or

(iv) the equivalent strength of the specimens cut from the work, (i.e. rejecting tests on cylinders moulded at the time of pouring on the ground that such cylinders do not truly represent the concrete as placed).

16.7.5 Basis of Acceptance

The basis of acceptance of concrete in the Works will be the twenty-eight (28) day strength determined by the Construction Supervisor in accordance with Sub-clause 16.7.4 for each continuous section of the work or one day's pour as directed by the Construction Supervisor.

Concrete having a deficiency in strength will be treated as follows:

(a) should the strength of the concrete fail to reach the specified value by more than ten (10) per cent, the Construction Supervisor shall reject the whole or part of the concrete represented by the test specimen unless the Construction Supervisor determines that in the particular case the deficiency is not critical to the structural adequacy of the element;

(b) the Construction Supervisor shall give consideration to the acceptance of the whole or part of such concrete, subject to a deduction as set out in the following table:

Deficiency	**Deduction**
Up to 5%	2% of the Billed Price for each 1% (or fraction thereof) deficiency in strength.
Over 5% and up to 10%	10% of the Billed Price for the first 5% deficiency plus 5% of the Billed Price for each 1% (or fraction thereof) deficiency in strength in excess of 5%.
Over 10%	100% of the Billed Price.

Notwithstanding acceptance strength, any concrete used in the Works not of the Grades shown on the Drawings or specified, and/or not made and placed in accordance with this Specification as and where shown on the Drawings or directed by the Construction Supervisor, may be rejected. Also, hardened concrete which is porous, segregated, honeycombed or in which the placing was so interrupted as to require a construction joint which was not specified, or where concrete or embedded steel has been disturbed by vibration or movement of forms after initial set has taken place, or which in the opinion of the Construction Supervisor is otherwise defective, may be rejected.

Concrete rejected for any reason shall be removed in accordance with the Construction Supervisor's directions.

16.7.6 Cost of Testing

Unless otherwise directed by the Construction Supervisor, all test cylinders shall be manufactured, handled and cured by the Contactor and delivered to the Contractor's laboratory or if no such laboratory, a testing laboratory approved by the Construction Supervisor, in sufficient time for testing at 7 or 28 days as determined by the Construction Supervisor. The cylinders shall be marked for identification purposes according to the system directed by the Construction Supervisor. All costs of testing shall be borne by the Contractor, including but not limited to, sampling the concrete, manufacturing, handling and curing the cylinders, delivery to the testing laboratory and capping, testing and reporting. The cost shall be deemed to be included in the unit rate for concrete.

Subject to approval by the Construction Supervisor, the Contractor may arrange for his own convenience to have cylinders tested at other locations provided all such tests are carried out in the presence of the Construction Supervisor and provided a current and valid certificate of calibration by a recognised authority is submitted in respect of any testing machine used. All cylinders tested by the Contractor shall be sulphur capped before testing and the complete cost of such testing shall be borne by the Contractor.

16.8 BATCHING AND MIXING

16.8.1 On site

All aggregates for concrete, other than Blinding Concrete, shall be proportioned by mass unless otherwise specified.

The mechanism of delivery of material to the weigh-hopper shall be such that there is the least reasonable time lag between the closing of the material hopper and the entry of the material into the weigh-hopper.

Cement for Grades 25, 30, 32 and 40 concrete shall be batched by weight and shall be weighed separately from the aggregates. Cement for other grades shall be batched by weight or by bag. If it is batched by weight, the cement shall be weighed separately, if it is batched by gab, a minimum of 1 in 20 bags used shall be weighed.

Batches involving the use of fractional bags will not be permitted. Water and admixtures may be batched by weight or volume. If batched by volume, water shall be measured in vessels clearly calibrated in litres or in a manner approved by the Construction Supervisor.

All weighing equipment used in batching the materials shall be in accordance with the requirements wet out in AS 1379.

The quantity of water and aggregate added to the mix shall be adjusted to allow for the water content of the aggregates. The Contractor shall keep on Site and at the Works an approved device for determining the water content of the Fine aggregates.

(a) Mixing

Concrete shall be mixed in a batch mixer of approved type and capacity with the drum rotating at the speed recommended by the manufacturer. The capacity of the mixer shall be such that one or more whole bags of cement can be used per batch of concrete. The mixer shall be set up level and the volume of mixed concrete in a batch shall not exceed the rated capacity of the mixer.

When concrete is to be placed at a rate of 15 or more cubic metres per day, a spare mixer, in serviceable condition, shall be kept on site. All mixers shall be equipped with adequate water storage and a device for accurately measuring and automatically controlling the amount of water used in each batch. The batch shall be charged into the mixer so that some water will enter in advance of any aggregate. Materials shall be so placed in the hopper that at least two-thirds of the sand and gravel comprising the batch will enter the drum before the cement. Mixing shall continue until the concrete is thoroughly mixed.

The minimum mixing time after all materials, including water, have entered the mixer shall be two minutes for drum type mixers. For pan or other type mixers, the minimum time shall be as directed by the Construction Supervisor after conducting tests.

Upon cessation of mixing for any period exceeding 45 minutes, the mixer shall be cleaned thoroughly. Upon resumption of mixing, the first batch of concrete materials charged into the mixer shall contain sufficient excess sand, cement and water to coat the inside surface of the drum without diminishing the required mortar content of the mix. The entire contents of a batch shall be discharged from the mixer before any materials are placed therein for the succeeding batch.

Hand mixing shall be permitted only in the case of emergency and only then with the approval of the Construction Supervisor. Where permitted, the quantity of hand mixed concrete shall be limited to that required to complete a member or reach a construction joint. Hand mixing shall be carried out on a water-tight platform and the batch shall be turned a minimum of three times dry and three times wet. Cement content shall be increased by 20% over that for the approved mix.

(b) Placing Time

Site mixed concrete shall be placed and compacted with 45 minutes of charging the mixer for concrete temperatures up to 32°C and within thirty minutes of charging the mixer for concrete temperatures exceeding 32°C.

16.8.2 Ready Mixed Concrete

Only those manufacturers approved by the Construction Supervisor shall supply ready mixed concrete and the Construction Supervisor at his sole discretion may withdraw approval from any supplier.

The production, delivery and testing of the ready mixed concrete shall be carried out in accordance with the requirements of AS 1379, except that Clauses 16.5, 16.6, 16.7 and Sub-clause 16.8.3 of this Specification shall apply. Mixing speeds shall be from 12 to 20 rpm. Notwithstanding the provisions of AS 1379, the slump of the concrete immediately prior to placing shall comply with the Sub-clause 16.6.1 of this Specification.

Ready mixed concrete shall be placed and compacted within the time limits specified in the following table. The temperatures in the table shall be the temperatures at the time of discharge from the mixer.

Concrete temperature at time of placing	**Maximum elapsed time from charging of mixer**
<32°C	60 minutes
32°C - 35°C	45 minutes
>35°C	Not Acceptable

These times may be varied at the Construction Supervisor's discretion where set-retarding admixtures are used in accordance with Clause 16.5.8 of this Specifications.

For truck mixed concrete, water shall be added under supervision, either at site or at the batch plant as agreed by the Construction Supervisor. In no circumstance shall water be added in transit.

16.8.3 Hot Weather Concreting

The Contractor shall take all practical precautions to maintain the concrete at a temperature not exceeding 33°C at the time of placing and to prevent shrinkage, settlement and presetting cracks. Precautions shall include any or all of the following:

(a) Crushed ice (where available) may be added in lieu of mixing water, under the supervision of the Construction Supervisor. No ice particle shall be larger than that which will allow complete melting and mixing of the ice prior to discharge from the mixer;

(b) Shading and watering aggregate stockpiles;

(c) Insulating or burying pipelines;

(d) Painting water pipes white;

(e) Cooling formwork by damping with water sprays;

(f) Shading work areas;

(g) Erection of wind breaks;

(h) Placing the concrete at a time when the temperature is at a minimum; or,

(i) Reducing the time for placing and finishing.

No concrete with a temperature higher than 35°C shall be placed, except that no Grade 40 concrete having a temperature greater than 33°C shall be placed. When concrete has been rejected under this Clause, ice shall be added, in accordance with (a) above, to subsequent mixings carried out in the same or similar conditions.

The temperatures of formwork and steel reinforcement at the time of placing shall be less than 35°C.

16.9 PLACING AND COMPACTING

16.9.1 Program

At least seven (7) days prior to proposed commencement of pouring of concrete for a structure the Contractor shall submit a program detailing the sequence and timing of all concrete pours, for that structure, for the approval of the Construction Supervisor. Special consideration shall be given to the curing periods between pours, and subsequent loading of these sections. The approved curing periods shall not be reduced without the written approval of the Construction Supervisor.

16.9.2 Placing

Except as provided below, all concrete shall be placed in the dry and no concrete shall be placed until the forms and reinforcement have been inspected and approved by the Construction Supervisor.

When rain threatens or seepage exists in excavations, the Contractor shall have on Site sufficient de-watering equipment and covers as applicable to prevent any additional water entering the concrete.

Concrete shall be placed in an essentially continuous manner between approved construction joints so as to avoid being placed against partially set concrete.

Any troughs and chutes used as aids in placing concrete shall be metal or metal lined and shall be arranged and used in a manner that does not cause segregation. The use of water to facilitate the movement of concrete along troughs or chutes is expressly prohibited, but all troughs and chutes shall be kept clean and free of coatings of hardened concrete by flushing thoroughly with water, which shall be discharged well clear of concrete in place.

Troughs and chutes shall discharge into vertical downpipes at least 1 metre in length. Where steep slopes are required, the chutes shall be equipped with baffles or be in short lengths that reverse the direction of movement so that the concrete slides without segregation.

Pneumatic placers shall be used only if authorised by the Construction Supervisor. Concrete pumps may be used subject to the approval by the Construction Supervisor of the pump and equipment. Such equipment shall be arranged so that no vibrations will damage freshly placed concrete. The delivery end of the pipe shall terminate in a fitting of approved design which shall prevent segregation of the concrete. After completion of any concreting operations the equipment shall be thoroughly cleaned.

Concrete shall not be dropped from a height, or in such a manner as will cause segregation or loss of material on the steel reinforcement or forms.

Concrete shall not be moved horizontally more than 1.0m by the use of vibrators.

When placing operations would involve dropping the concrete more than 2 metres it shall be deposited through a sheet metal or other approved downpipe in such a way that the concrete does not segregate. As far as practicable, the pipes shall be kept full of concrete during placing and their lower ends shall be kept buried in the newly placed concrete. The depositing of a large quantity of concrete at any point with the intention of moving it along the forms will not be permitted.

After initial set of the concrete, the forms shall not be jarred and no strain shall be placed on the ends of reinforcing bars which project.

16.9.3 Placing Concrete under Water

Concrete shall not be placed under water unless specifically approved by the Construction Supervisor. The work shall only be carried out under the immediate supervision of the Construction Supervisor and as specified hereunder.

The quantity of cement in the concrete shall be increased by 25% above the approved minimum cement quantities for the grades of concrete designated.

Concrete shall not be placed in running water. Any pumping must cease and the water level must be constant where placement commences. The concrete shall be placed carefully in a compact mass in its final position by a tremie, a closed bottom dump bucket or by other approved means. Concrete seals shall be placed in one continuous operation, the concrete shall not be disturbed after being deposited and the placing shall be regulated so as to continually maintain an approximately horizontal surface.

When a tremie is used it shall consist of a watertight tube and at no time shall concrete in the tube come in contact with water when it is being filled. The means of supporting the tremie shall be such as to permit free movement of the discharge end and to permit its being lowered rapidly when necessary to choke off or retard the flow of concrete. No water shall enter the tremie tube. The discharge end shall be completely submerged in concrete at all times and the tremie tube shall always be filled to a height to overcome the head of water.

When concrete is placed with a bottom-dump bucket, the bucket shall be lowered gradually and carefully until it rests upon the prepared foundation or upon concrete already placed. It shall then be raised slowly during the discharge travel so as to maintain as far as it practicable still water at the point of discharge and to avoid agitating the mixture. The concrete so placed shall not be disturbed.

16.9.4 Use of Spalls

Spalls (plums) of solid approved rock not exceeding 12 kg in mass may be used in mass concrete if approved by the Construction Supervisor. The spalls shall not be placed closer together, nor nearer the face of the forms than 150 mm. Spalls shall be surface wetted before placing. They shall be well bedded by hand and the concrete vibrated in place around them.

16.9.5 Compaction of Concrete in the Forms

Concrete during and immediately after deposition shall be thoroughly compacted. Concrete other than no-fines concrete shall be compacted with high frequency internal vibrators in the manner described below. Hand compaction in lieu of mechanical vibration will be allowed only as an emergency measure when approved by the Construction Supervisor.

(a) The vibration shall be internal except as provided in (h).

(b) Vibrators shall be of approved type, capable of transmitting vibration to the concrete at frequencies of not less than 8,000 impulses per minute at such an intensity to visibly affect a 25 mm slump concrete at a radius of 300 mm. Vibrators for Grade 40 and Grade 30 concrete shall be capable of transmitting vibration to the concrete at frequencies of not less than 12,000 impulses per minute at an intensity to visibly affect a zero slump concrete at a radius of 300 mm.

(c) The Contractor shall provide a sufficient number of vibrators to properly compact each batch immediately after it is placed in the forms. The minimum number of vibrators to be provided will depend on the rate of placing concrete but in no case shall be less than 1 vibrator for each 5 cubic metres of concrete or part thereof placed per hour with a minimum of 2 vibrators

    At least one vibrator shall be in reserve at all times, in proper working order.

(d) A vibrator shall be inserted into the concrete at successive positions not more that 500 mm apart and vibration shall continue at each position until air bubbles cease to emerge. It shall then be withdrawn slowly.

(e) Vibrators shall be inserted so as to thoroughly compact the concrete around the reinforcement and embedded fixtures and into the corners and angles of the forms. Vibrations shall be applied at the point of deposit and in the area of freshly deposited concrete.

    Where more than one layer is being placed in a continuous operation the vibrator shall be inserted through the layer into the layer below.

(f) The vibrators shall be inserted into and withdrawn from the concrete slowly. The vibration shall be of sufficient duration to thoroughly compact the concrete with a minimum of 7 seconds, but shall not be continued so as to cause segregation.

(g) Vibration shall not be applied directly or through the reinforcement, to sections or layers of concrete which have hardened to the degree that the concrete ceases to be plastic under vibration. It shall not be used to make concrete flow in the forms over distances so great as to cause segregation and vibrators shall not be used to transport concrete in the forms.

(h) The provisions of this Clause 16.9.5 shall also apply to precast members except that if approved by the Construction Supervisor, the manufacturer's method of vibration may be used. For precast slab units internal vibration shall be used in conjunction with external mould vibration.

Except when authorised by the Construction Supervisor, and in thin web sections, concrete shall be placed in horizontal layers not more than 300 mm thick. Each layer shall be placed and compacted before the preceding layer has taken its initial set, unless an approved construction joint has been approved.

Immediately following the discontinuance of placing concrete, all accumulations of mortar splashed upon steel reinforcement and the surfaces of the forms shall be removed.

Special care shall be taken to ensure complete compaction behind prestressing anchorages

16.9.6 Concrete Deck Slabs for Bridges

Deck slabs for bridges shall be cast full length without construction joints other than any specifically shown on the Drawings. Concrete in deck slabs shall be placed in strips not more than 2 metres wide running transversely to the girders. The maximum time which shall elapse between the pouring of the first and last concrete in a deck slab shall be 5 hours, unless otherwise permitted by the Construction Supervisor.

Where segmental pours are indicated on the Drawings the Contractor shall submit a pouring schedule for the Construction Supervisor's approval at least three (3) days prior to the proposed commencement of pouring.

16.9.7 Construction Joints

Construction joints shall be constructed only where shown on the Drawings or specified hereunder unless otherwise approved by the Construction Supervisor. If not detailed on the Drawings, specified hereunder or in case of an emergency, construction joints shall be placed as directed by the Construction Supervisor.

Construction Joints shown on the Drawings are mandatory unless specifically exempted by the Construction Supervisor.

Construction Joints shall not be made within 500 mm of the top of any wall or pier unless shown on the Drawing or otherwise approved by the Construction Supervisor. Pile caps, headstocks, in-situ diaphragms, if any, and similar sections shall be cast in one operation without construction joints. Spacing of horizontal construction joints shall be to the approval of the Construction Supervisor but shall not in any case be less than one metre.

At horizontal construction joints, dressed timber strips approximately 25 mm square shall be placed inside the forms for all exposed surfaces. The surface of the concrete shall be stopped slightly above the lower edge of the strips.

The placing of the concrete shall be carried out continuously from joint to joint.

Should the Contractor wish to cast a wall or similar section in one continuous pour, he shall submit proposals to the Construction Supervisor for achieving compaction of the concrete, particularly near the bottom.

Before depositing new concrete on or against concrete which has hardened, the forms shall be retightened. Wherever possible laitance shall be removed whilst the concrete is still green. Where this is not possible the surface of the hardened concrete shall be roughened as required by the Construction Supervisor in a manner that will not leave loosened particles at the surface. The roughened surface shall be thoroughly cleaned of foreign matter and saturated with water. To ensure an excess of cement at the joint, the surface shall first be thoroughly covered with a coating of cement and water with a water/cement ratio of approximately 0.5 by weight, against which the new concrete shall be placed before the grout has attained its initial set.

Where noted on the drawings, construction joints may be required to have a bond break applied. At these locations the joint surface of the initial pour shall be trowelled to a smooth finish. Prior to pouring the adjacent section the joining surface shall be coated with a bond breaking agent approved by the Construction Supervisor. Any such bond breaking agent shall be a thin film and shall be of a type that does not subsequently leach out and stain any exposed surfaces.

16.10 PLACING OF GROUT AND MORTAR

Unless otherwise indicated on the Drawings, grout shall normally be placed using a pressure gun. At the Construction Supervisor's discretion alternative means may be used provided that the Contractor demonstrates that the proposed method will ensure complete filling of all cavities. Mortar placed under bearing pads and bearings where the surface is levelled before the placing of the items should be placed and levelled by trowel.

16.11 FINISHING AND CURING

16.11.1 Formed Surface

Refer to Clause 14.3 of this Specification.

16.11.2 Unformed Surfaces

The following Classes of finish are appropriate to unformed surfaces:

Class 1U When the moisture film has disappeared and the concrete has hardened sufficiently to prevent laitance from being worked to the surface, a Class U3 surface shall be steel-trowelled under firm pressure to produce a dense, smooth uniform surface free from trowel marks.

This finish will only be required where specifically noted on the Drawings.

Class U2 After the concrete has hardened sufficiently, the concrete Class U3 surface shall be floated by hand or machine sufficiently only to produce a uniform surface free from screed marks.

This finish will be required to all surfaced, except as noted for Class U1, and for the road surface of bridge decks including any integrally cast footways and kerbs.

Class U3 The concrete shall be uniformly levelled and screeded to produce a plain or rigged surface as described in the Contract. No further work shall be applied to the surface unless it is used as the first stage of a Class U2 or Class U1 finish

Unless otherwise noted this finish will only be required for faces of horizontal construction joints not requiring a bond break.

16.11.3 Finishing a Road Surface of Bridge Deck Slabs

Concrete in bridge deck slabs shall be finished by hand screeding followed by power floating and stiff brooming.

A grid of removable spot levels shall be set up over the top of the girders at the correct level and profile of the top of the deck (allowing for deflection) prior to casting the deck. The grid shall be at not more than 3 metre centres. The concrete shall be placed and compacted by immersion vibrators and screeded to profile with hand screeding boards. The concrete surface shall be finished with power floats. At least five passes shall be made with the power float, each successive pass being in a direction perpendicular to the previous pass. After floating, the surface shall be checked with a 3 metre straight edge. Any deviation in excess of 3 mm shall be made good.

Finally, the surface shall be vigorously broomed transversely with a stiff broom when the surface has started to stiffen. Brooming shall continue until a fine but roughened surface has been achieved to the satisfaction of the Construction Supervisor. A smooth deck surface producing low tyre friction will not be accepted and the Contractor will be required to roughen the surface to the Construction Supervisor’s satisfaction.

16.11.4 Curing

Concrete surfaces other than slabs shall be cured for a period of not less than 7 days. Slabs shall be kept cured for a period of not less than 14 days.

Horizontal surfaces shall be wet cured by water sprays or wet sand. Alternatively the concrete may be covered by canvas, hessian or plastic sheets or other suitable materials provided it is kept continually wet. Other surfaces shall be wet cured or membrane cured.

The Surfaces shall be cured 24 hours a day for the full period specified without any breaks at weekends or holidays. Curing shall be commenced immediately on completion of finishing of exposed surfaces or within half an hour of removal of the forms from other surfaces.

Generally, the only membrane curing compound which will be approved is paraffin wax emulsion in water – Class to AS 3799. The compound shall be applied at the rate recommended by the manufacturer. Slabs shall be sprayed with curing compound as soon as possible after finishing and before plastic cracking occurs, and shall be immediately covered with an approved building paper. Should the building paper be lifted by wind or other action, the area uncovered shall be resprayed and the paper replaced. When wet curing of the slabs is to be used it shall commence on completion of finishing of the slab.

16.12 BITUMINOUS PAINTING TO CONCRETE SURFACES

Where shown on the Drawings, concrete surfaces to the earth retaining faces of the abutment walls and wingwalls, or any other concrete as directed by the Construction Supervisor, shall be painted with two coats of bituminous paint. Bituminous paint shall be approved by the Construction Supervisor and shall be applied strictly in accordance with the manufacturer's recommendations and instructions.

16.13 NO-FINES CONCRETE

No-fines concrete shall consist of Portland cement and coarse aggregate. Portland cement and coarse aggregate shall comply with Clause 16.5 of this Specification.

Course aggregate shall comply with the following grading:

AS Sieve size AS (mm)	**Percentage Passing by Weight**
26.5	100
19.0	95 - 100
9.5	0 - 5

No-fines concrete shall be proportioned as follows:

(a) Aggregate/cement ratio shall be 8 parts of aggregate as specified above to 1 part of Portland cement by mass.

(b) The water /cement ratio shall be from 0.38 to 0.40 by mass.

No-fines concrete shall be screeded to the required surface levels without tamping, rodding or vibrating. It shall be moist-cured for at least 4 days by covering with wet Hessian cloth, building paper or other similar material. Sand or other material likely to enter the voids shall not be permitted for curing.

Before normal concrete is poured over no-fines concrete, building paper or other similar material approved by the Construction Supervisor shall be placed over the no-fines concrete. Any tears or holes shall be repaired to the satisfaction of the Construction Supervisor.

16.14 MISCELLANEOUS DETAILS

The Contractor shall build into the concrete all ducts, unistruts, pipes, water stops and other details shown on the Drawings or specified herein.

Where these items are not shown separately in the Bill of Quantities, the cost of supplying and placing thereof shall be included in the Billed Rate for concrete or for precast elements.

16.15 TOLERANCES

Tolerances, being the allowable deviation from plumb or level and from the alignment, profile, grades and dimensions shown on the Drawings, shall be as shown on the Drawings, specified elsewhere in the Contract or shall be not greater than the requirements hereunder. The Contractor shall be responsible for ensuring that the work is completed within the tolerances specified.

16.15.1 Tolerances for reinforced concrete structures:

(a) Variations from plumb in the lines and surfaces of columns, piers, walls and in arrises or variations from the level of the grades indicated:

- 6 mm in 3 m plus 2 mm per metre up to a maximum of 20 mm

(b) Variation in the sizes of locations of sleeves or blockouts or the placing of embedded metalwork

- 6 mm

(c) Variations in cross sectional dimensions of columns and beams and in the thickness of slabs and walls

- minus 6 mm
- plus 12 mm

(d) Footings

Variation in dimensions in plan	- minus 12 mm
Misplacement of eccentricity	- 2% of the footing width to a maximum of 50 mm
Reduction in thickness	- 5% of specified thickness

16.15.2 Tolerances for reinforcing steel.

(a) Variation in cover - 6 mm

(b) Variation in indicated position of bars;

Starter Bars - 6 mm

Slabs and Walls - 15 mm or 10% of the indicated space, whichever is the greater

(c) Dimensions of bent bars;

Stirrups and ties - 6 mm

Other bars -12 mm

Where in the opinion of the Construction Supervisor the application of the above tolerances would adversely affect the serviceability of the structure, he may at his discretion reduce the magnitude of the tolerances. Where appearance or serviceability of the structure will not be impaired (e.g. in concrete to be subsequently buried below ground level), the Construction Supervisor may at his discretion relax the above tolerances.

16.16 MEASUREMENT AND PAYMENT

Only work completed in the Permanent Works in accordance with the Contract Documents and accepted by the Construction Supervisor will be measured for payment. No measurement will be made for concrete required to fill overbreak in excavation.

The quantity of concrete for structures will be calculated from dimensions on the Drawings or as revised by the Construction Supervisor. Deductions will not be made for the volume occupied by reinforcing steel, drainage facilities or expansion and contraction joint material. No deduction will be made for fillets and chamfers 40 mm or less nor for conduits 100 mm or less encased in the concrete.

Payment shall be made separately for grout and mortar used in association with holding down bolts and bearings but shall be deemed to be included in the item for holding down bolts and bearings

The work measured as provided above for the various Grades of concrete shall be paid for at the unit price tendered according to the particular purpose provided in the Bill of Quantities per cubic metre. The payment shall include full compensation for furnishing all labour, material, plant, tools, equipment and all miscellaneous items necessary for the finished concrete including supply and storage of material, mixing, transporting, placing, finishing, curing and the furnishing and placing of all other incidental construction items not otherwise covered as a separate schedule item, all as required by this Specification and as directed by the Construction Supervisor.

The unit rates provided in the Bill of Quantities for the various Grades of concrete will be inclusive for finishing of unformed surfaces to all finishes and shall included for falsework and formwork as appropriate.

Bituminous painting to concrete surfaces shall be measured as the concrete area, in square metres, shown on the Drawings, or as directed by the Construction Supervisor, requiring painting and shall be allowed for in addition to the requirements for placing and finishing of concrete.

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GROUP 17

STRUCTURAL STEELWORK

17.1 GENERAL

This Specification covers the supply, fabrication delivery to site, erection, testing and inspection of structural steelwork for bridges and other structures of a minor nature associated with roadworks

17.1.1 Drawings, Procedures and Program

At least one month prior to commencement of fabrication of any portion of the Permanent Works, the Contractor shall submit three copies of the relevant Workshop Drawings to the Construction Supervisor for review. These Drawings shall clearly show all sizes, dimensions, markings and connections including loose packs, and shall set out the position sizes and length of all welds, nuts, bolts and washers as are necessary for the complete fabrication, assembly and erection of the steelwork.

Splices other than those indicated on the original drawings shall not be included in steel sections without the prior written consent of the Construction Supervisor. Such splices in flanges and webs shall be staggered. If such additional splices are consented to, testing will be carried out at the discretion of the Construction Supervisor and costs incurred for this testing will be borne by the Contractor.

At least four (4) copies of reviewed Drawings of portions of the work shall be supplied to the Construction Supervisor before fabrication on those portions is commenced. The Drawings should, in general comply with AS/NZS 1100.501. The Contractor shall be responsible for the correctness of the Shop Drawings and the Construction Supervisor's consent to the Shop Drawings shall not relieve the Contractor of this responsibility.

At least fourteen (14) days before the commencement of fabrication, the Contractor shall submit his complete program of work, including details of procedures entailing weld sequences, distortion control, preheating etc, to the Construction Supervisor for his review. Any departure from the agreed Program and procedures as may be found necessary during the progress of the work shall be subject to the Construction Supervisor's review.

17.1.2 Facilities for Inspection

The Contractor shall furnish all facilities for the inspection of material and workmanship at the place of fabrication and the Construction Supervisor shall be allowed free access to the necessary parts of the premises when required.

17.1.3 Notice of intention to Commence Work

The Contractor shall advise the Construction Supervisor of the location where the structural steelwork will be fabricated at least 6 weeks before the date when he intends to commence the fabrication.

At 7 days before he proposes to commence fabrication of the structural steel, the Contractor shall confirm the date and place with the Construction Supervisor.

17.1.4 Sub-Contractors

The Contractor shall not sub-let the fabrication of structural steelwork or any part thereof without prior consent in writing of the Construction Supervisor, notwithstanding that the Contractor may have listed the proposed Sub-Contractor in its Bid. Only those workshops that have been specifically approved by the Construction Supervisor to carry out the work will be authorised to perform the work on the structural steel.

17.2 MATERIALS

17.2.1 General

Steel shall be ordered at the earliest possible time in consultation with the Suppliers and according to the fabrication priorities. The order shall be submitted to the Suppliers with the name of the project for which the steel is to be used and the nature of the work e.g. ‘weld steel plate girder’.

Prior to the purchase order being made, the Contractor shall furnish the Construction Supervisor with a copy of the order. Should delays be experienced in the supply of the steel, no extension of time will be allowed to the Contract, if, in the opinion of the Construction Supervisor, such delay could have been reasonably avoided by the earlier placement of the purchase order.

17.2.2 Standards of Materials

17.2.2.1 Plates, Sections, Bars and Bar Sized Sections

Plates, sections, bars and bar sized sections shall comply with AS/NZS 3678 and AS/NZS 3679, and shall be of the grade shown on the Drawings.

The Contractor shall supply test certificates of chemical and physical properties of the steel in accordance with AS/NZS 3678 and AS/NZS 3679.1.

The Contractor may propose an equivalent structural steel in compliance with the standard specification of the country of origin for approval of the Construction Supervisor. A complete description of the material, including chemical composition, mechanical properties, etc shall be provided with the proposal together with a detailed report on the differences between the relevant Australian Standard and the proposed standard, highlighting any areas where the proposed standard has less stringent requirements.

Structural steel flats of lesser width than 450 mm shall be cut from plate of width greater than 450 mm.

17.2.2.2 Hollow Sections

Structural steel hollow sections shall comply with AS 1163.

17.2.2.3 High Strength Steel Bolts

High strength steel bolts with associated nuts and washers shall comply with AS/NZS 1252. If specified to be galvanised, they shall also comply with AS 1214 and AS/NZS 4680 as appropriate.

17.2.2.3 Commercial Bolts and Screws

Commercial grade bolts shall comply with AS 1111.1, property class 4.6.

Commercial grade screws shall comply with AS 1111.2, property class 4.6.

Commercial grade nuts shall comply with AS 1112.3, property class 5.

Black steel washers shall comply with AS 1237.1 and AS 1237.2.

If specified to be galvanised, they shall be hot-dip galvanised in accordance with AS 1214.

17.2.3 Storage of Materials

All steel, whether fabricated or not, shall be stored above the ground on platforms, skids, or other supports and adequately protected against corrosion.

Excessively rusted, bent, corroded or damaged steel shall be rejected.

Steel surfaces, having undergone the treatment recommended in Group 18 of this Specification shall not be stored with surfaces in contact, but shall be separated by an adequate numbers of spacers.

17.2.4 Identification

Steel shall be marked as it is taken into stock. At all stages of fabrication all pieces shall be identifiable by Grade, by an appropriate colour marking or other marking, acceptable to the Construction Supervisor or it shall be classed as unidentifiable steel.

Unidentifiable steel shall be used only for minor parts that do not carry stress.

17.2.5 Test Certificates

The Certificates shall be supplied to the Construction Supervisor, before work on the material commences, to prove compliance of the steel with the appropriate standards above.

17.2.6‘ Defective Material

Defects arising from the manufacture of the steel which became evident at any stage of fabrication shall be inspected by the Construction Supervisor who will decide whether the material may be repaired by the Contractor or will be rejected. The cost of the repairs or replacement will be the Contractor’s responsibility.

17.3 FABRICATION

17.3.1 General

Fabrication shall be carried out generally in accordance with the requirements of AS 4100 as amended by this Specification.

All templates, jigs and other equipment necessary for the accurate fabrication of the work shall be provided by the Contractor at his own expense.

17.3.2 Cutting of Steel

Edges may be cut by either planing, flame cutting or shearing, but edges to be welded shall nevertheless comply with the welding sub-section of this specification. Cut edges shall be free of gouges, burrs and other defects which are greater than 5 mm deep, or which would otherwise adversely affect the serviceability of the member.

Shearing shall not be used for main plates, reinforcing plates, main gussets, splice plates and diaphragms except in a direction perpendicular to the direction of their main stresses. Shearing of items over 16 mm thick shall not be carried out when the item is to be galvanized and subject to tensile stresses unless the item is subsequently stress relieved. Distortions caused by shearing shall be removed.

Oxygen cutting of steel and weld metal shall be permitted provided a smooth and regular surface free from cracks and notches is secured, and provided that an accurate profile is secured by the use of a mechanical guide. Free–hand oxygen cutting shall be done only where approved by the Construction Supervisor.

In all oxygen cutting, the cutting flame shall be so adjusted and manipulated as to avoid cutting inside the prescribed liners. The surface roughness of oxygen cut surfaces shall comply with the requirements of AS 4100 Clause 14.3.3.

All corners on exposed edges, whether cut or rolled shall be treated to provide a radius of approximately 2 mm.

Roughness exceeding these values and occasional notches or gouges not more than 3 mm deep, on otherwise satisfactory surface, shall be removed by machining or grinding. Cut surfaces and edges shall be left free of adhering slag. Corrections of defects shall be faired to the oxygen cut surface with a slope not exceeding 1 in 10. Defects of oxygen cut edges shall not be repaired by welding except with the express approval of the Construction Supervisor for occasional notches or gouges less than 5 mm deep. Such weld repairs shall be made by suitably preparing the defect, welding with low hydrogen electrodes not exceeding 4 mm in diameter, observing the applicable requirements of the welding sub-section of this Specification, and grinding the completed weld smooth and flush with the adjacent surface to produce a workmanlike finish.

Re-entrant corners, except for the corners of the weld access cope holes adjacent to a flange, shall be filleted to a radius of not less than 20 mm. The fillet and its contiguous cuts shall meet without offset or cutting past the point of tangency.

Air carbon arc or oxygen gouging shall be permitted for joint preparation, back gouging, or the removal of defective work or material, provided the following provisions are complied with.

Oxygen cut or air carbon arc gouged edges conforming with the other requirements of this Specification shall be permitted in the fabrication of the steelwork provided that:

(a) The hardness in the heat affected region adjacent to the cut edge is less than 350HV5 (Vickers Harness Number) when tested in accordance with AS 1817.1.

(b) The ductility developed in the bending with the cut edge in tension is sufficient to accommodate bending around a former of radius equal to twice the plate thickness.

If the hardness of flame cut edges exceeds the specified value, or the specified ductility is not achieved, the Construction Supervisor shall have the right to order machining of the edge until the hardness is less than the specified value, or to direct that the edge be re-prepared on a new plate if such machining would result in undersized plates.

17.3.3 Straightening

All material, before being assembled, shall be straightened or formed to the specified configuration by methods specified below.

Straightening or bending of either fabricated or un-fabricated steel, if necessary shall be done by means of steady pressure applied by rolls or passes. Straightening and bending shall be done by hammering or, unless the Construction Supervisor’s approval has been obtained, by heating.

If straightening by heating is allowed, the steel shall in no case be heated to a higher temperature than 600^{o}C as measured by indicating crayons, liquids or bimetal thermometers. After heating the metal shall be cooled slowly in air without any forced cooling.

Following the straightening of a bend or buckle, the surface of the metal shall be carefully inspected for evidence of fracture. Depending on the location in the work, the Construction Supervisor shall have the right to reject the metal or to direct that the defects be repaired in a manner that shall be approved by the Construction Supervisor. The cost of replacement or repair shall be borne by the Contractor.

17.3.4 Welding

17.3.4.1 General

This Sub-Clause covers electric arc welding by manual shielded metal-arc, submerged arc, gas metal arc, or flux-cored arc of weldable structural grade, low carbon steels not more than 100 mm thick, and the welding of reinforcing steel and stub shear connectors. It does not cover the welding of weldable low and medium alloy steels.

Except where otherwise herein specified or shown otherwise on the Drawings, all welding shall conform to the following standards:

Steel structures	AS/NZS 1554.1 category SP
Stud welding (steel studs to steel)	AS/NZS 1554.2
Welding of reinforcing steel	AS/NZS 1554.3
Welding of high strength quenched and tempered steels	AS/NZS 1554.4
Welding of steel structures subject to high-levels of fatigue loading	AS/NZS 1554.5
Welding of stainless steel for structural purposes	AS/NZS 1554.6
Welding of sheet steel structures	AS/NZS 1554.7

Where this Specification refers only to AS/NZS 1554, this shall mean a reference to the appropriate part of this Standard listed above.

The whole of the metallic arc welding shall be carried out in strict accordance with the Drawings, this Specification and the entire satisfaction of the Construction Supervisor. Any weld not in accordance with the Specification shall be cut out and the work re-welded or otherwise rectified to the satisfaction of the Construction Supervisor at the Contractor’s expense.

Where seal welds or category GP welds are specified on the Drawings, they shall comply with AS/NZS 1554.1.

Where in AS 1554 there is reference to the Principal it shall be reference to the Construction Supervisor unless otherwise specified or the context otherwise requires.

17.3.4.2 Equipment

All welding equipment and plant used shall comply with AS/NZS 1554 (e.g. AS/NZS 1554.1 Clause 1.8.2).

Portable equipment for electric arc welding shall satisfy the requirements of AS 60974.6.

17.3.4.3 Consumables

All welding consumables shall conform to the requirements of AS/NZS 1554.1 Clause 4.6. The hydrogen content of deposited weld metal must not exceed 10 ml H_2 per 100 g weld metal. Only hydrogen controlled (low hydrogen) consumables and/or processes shall be used in order to meet this requirement (i.e. H_{10} classification or better except for gas metal arc welding consumables which may be H_{15}).

The minimum nominal tensile strength of weld metal used shall be 480 MPa (e.g. E48XX, W502, W503 etc. or stronger) for all steels other than reinforcing steel for concrete. For reinforcing steel refer to Clause 17.3.4.11.

The Contractor shall obtain a certificate or letter of conformity from the manufacturer that the batch of consumables supplied and used in the work conform to the relevant Australian Standard and classification as described in Table 4.6.1(A) of AS/NZS 1554.1.

If prequalified consumables are to be used outside of their manufacturer's specifications for which they are prequalified, these consumables shall be deemed non-prequalified and additional qualification tests shall be undertaken to establish suitability for the application (e.g. Table 4.7.1 of AS/NZS 1554.1).

Notwithstanding the requirements of AS/NZS 1554.1, for the qualification of consumables for welding processes incorporating shielding gas, the specific combination of gas and wire shall be qualified as certified by Lloyds or other ship classification societies.

All consumables shall be stored and dried (if required) in accordance with the manufacturer's instructions prior to and during use.

17.3.4.4 Welding Procedures

Welding shall be carried out using approved qualified welding procedures.

All welding shall be inspected by a qualified Welding Inspector The Welding Inspector shall be responsible for ensuring that all welding conforms to the requirements, provided that this shall not act to limit the rights of the Construction Supervisor to carry out inspections and audits of the welding work at any time in accordance with the Contract.

The benefits of increased penetration from fully automatic arc welding processes may be utilised in accordance with the conditions of Clauses 3.2.2 and 3.3.2 of AS/NZS 1554.1.

17.3.4.5 Safety Requirements for Personnel

The Contractor shall:

(a) Carry out welding in accordance with the safety requirements of AS/NZS 1554 (e.g. AS/NZS 1554.1 Clause 1.8.1).

(b) Take precautions to protect all those associated with the welding and persons working in the vicinity of the welding operation (including visitors). Include in such precautions the prevention of electric shock, exposure to arc radiation, exposure to hot metal and exposure to concentrations of welding fume exceeding the recommendations of NOHSC:1003 ‘National Exposure Standards for Atmospheric Contaminants in the Occupational Environment’ (Australian National Occupational Health and Safety Commission) or other appropriate standards to the approval of the Construction Supervisor.

(c) Satisfy the requirements of AS 1674.2 for electrical safety for welding in confined spaces and/or in similar conditions where there is a high risk of electric shock to personnel.

(d) Where exposure to welding fume is likely to exceed NOHSC:1003 limits, provide all affected people with suitable personal protective equipment (PPE).

(e) Provide adequate protection for all personnel within 10 m of any open arc welding process and any plasma cutting operation. Such protection may include the use of welding screens to shield persons in the vicinity of welding operations from the effects of optical and ultraviolet radiation.

17.3.4.6 Qualification of Welding Procedures

(a) General

Procedures shall be qualified by any of the methods allowed in AS/NZS 1554 (e.g. Clause 4.2 of AS/NZS 1554.1).

All procedures (i.e. the preparation, welding consumables and welding parameters) must be qualified and approved by the Welding Inspector.

The procedure shall be documented in a welding procedure qualification record (PQR or WPQR) and a welding procedure specification (WPS).

A procedure shall only be deemed qualified after the Welding Inspector examines and/or witnesses the procedure documentation and/or testing and certifies such a procedure as qualified. Such certification shall contain the Welding Inspector’s signature and registration number of the Welding Inspector’s accreditation. A copy of the certified qualified welding procedure shall accompany each welding test piece submitted for destructive or nondestructive testing.

The extent of testing and/ or documentation of a welding procedure is dependent on the details of such a procedure as shown hereunder.

Category SP fillet welds shall be qualified with a macro test.

(b) Prequalified Procedures

Welding procedures prequalified in accordance with AS/NZS 1554 shall be deemed qualified for this work upon certification by the Welding Inspector of the submitted Welding Procedure Specification(s).

(c) Qualification by Testing

The welding of all test pieces shall be done under the direct supervision of the Welding Supervisor and in the presence of the Welding Inspector.

The Welding Inspector shall examine the Welding Procedure Specification and ensure that all test pieces have been welded accordingly. Upon receiving conforming test results, the Welding Inspector shall certify the procedure as qualified.

Where electroslag or electrogas welding methods are to be used, the tolerances for butt welded joints shall be determined on the basis of the results of the qualification tests carried out in accordance with AS/NZS 1554.1.

Records shall be kept of all qualification tests associated with all welding procedures, together with the relevant Welding Procedure Specifications, and shall be made available to those authorised to examine them.

A photograph or sketch of the macro test is to be included in the records unless the testpiece is to be retained by the Contractor. Where a macro test only is required, the test piece may be prepared and examined instead of referring it to a NATA laboratory, provided that the test piece is prepared and examined by the Welding Inspector in accordance with Clause 4.7.4 of AS/NZS 1554.1 and prior approval for this has been given by the Construction Supervisor.

The test pieces and/or assemblies shall represent the actual conditions of fabrication including anticipated weather and other environmental conditions, degree of restraint, welding through holes, welding with the aid of mirrors, welding at floor level etc.

Where 'GP' category welding or seal weld is specified, welding procedures shall be qualified as required by AS/NZS 1554 for GP category welds. Where testing is not required by AS/NZS 1554 the procedure shall still be documented and approved as detailed in this Clause 15.3.4.

Where the weld arc energy exceeds the limitations accepted for prequalified consumables in accordance with Clause 4.6 of AS/NZS 1554.1, the Contractor shall carry out impact tests on the heat affected zone (HAZ) of the parent steel to verify that the impact properties of the HAZ continue to meet the minimum requirement for that steel as in AS/NZS 1554 or other applicable material Standards as specified on the Drawings.

Hardness tests on the HAZ are only required when the requirements for preheating temperature related to arc energy input do not comply with Clause 5.3.4 of AS/NZS 1554.1.

Use of a steel type which is not specifically provided for by AS/NZS 1554.1 shall be treated as using non-qualified consumables for the purpose of qualifying by testing.

(d) Previously Used Welding Procedure

Welding procedures previously qualified and used on other work shall be deemed qualified for this work upon certification of the relevant documentary evidence by the Welding Inspector provided that:

(i) the procedure is being used within the limits of its essential variables as defined by AS/NZS 1554;

(ii) all qualification documents as required by AS/NZS 1554 (or the applicable Standard to which the procedure was qualified) are available to support the procedure qualification record;

(iii) the welder demonstrates an ability to produce a weld procedure specification (WPS) sample, verified by NATA accredited testing; and

(iv) NDE records are available demonstrating successful use of that procedure.

17.3.4.7 Qualification of Welding Personnel

(a) General

The Contractor shall ensure personnel qualifications which are partly or wholly obtained outside Australia or New Zealand are equivalent to the specified requirements for Australian qualification. Where the use of persons with qualifications obtained outside Australia or New Zealand is proposed the Contractor shall provide details of the qualification and Welding Technology Institute of Australia's (WTIA's) assessment and certification of equivalency with Australian requirements to the Construction Supervisor at least ten working days prior to commencement of using such persons.

(b) Welding Inspector

The Welding Inspector shall be a person with suitable training and experience in the fabrication and inspection of welded structures:

(i) Satisfying the requirements of Clause 7.2 of AS/NZS 1554.1; or

(ii) Having equivalent overseas qualifications.

For the purposes of AS/NZS 1554.1 Clause 1.5.3, the Welding Inspector shall be an employee or agent of the Contractor. The Welding Inspector shall not be the same person as the Welding Supervisor and shall not carry out welding of the Works.

The Welding Inspector may examine backgouge areas and issue a report giving the results of such an examination (NATA accreditation is not required), using the Magnetic Particle Examination method (MPE - refer to AS 1171) or Liquid Penetrant Examination method (LPE - refer to AS 2062).

(c) Welding Supervisor

The Welding Supervisor(s) shall have a thorough working knowledge and understanding of the AS/NZS 1554 series of Standards. Such a person shall satisfy the requirements of Clauses 4.12.1(a), (b), (c) or (d) of AS/NZS 1554.1.

(d) NDE Technicians

All various non-destructive examinations (NDE, e.g. ultrasonic examination, radiography etc.) shall be carried out by technicians suitably qualified and accredited for carrying out the examination method employed (see Clause 7.4 of AS/NZS 1554.1). Such a technician shall be accredited by:

(i) Australian Institute of Non-destructive Testing (AINDT); or

(ii) Certification Board of Inspection Personnel, New Zealand (CBIP-NZ); or

(iii) An equivalent overseas institution.

The currency of the above qualifications and accreditations must comply with the requirements of the issuing institution. Lapsed qualifications and accreditations will not be acceptable.

All non-destructive examination reports must be prepared by qualified and accredited NDE technicians, and must contain the NDE technician's signature and registration number of the NDE technician's qualification and accreditation. In such instances NATA-endorsed examination reports will not be required.

(e) Welders

A welder cannot be a Welding Supervisor or a Welding Inspector for the Works.

Only qualified welders with proven ability to produce sound welds shall be used in welding of the Works. Such welders are those who:

(i) satisfy the requirements of Clause 4.12.2 of AS/NZS 1554.1 and can produce documented evidence (e.g. NDE records traceable to the welder) of having successfully and consistently produced welds to 'SP' quality during the previous six months; or

(ii) meet the requirements of AS/NZS 3992 Clause 9.2 or AS/NZS 2980; or

(iii) hold equivalent overseas qualifications; or

(iv) whilst not satisfying the requirements of item (a), (b) or (c) above, can demonstrate compliance with 'SP' requirements by means of a macro test for the welding procedures similar to and representative of those to be used in the work, particularly in terms of welding positions.

In special cases including, but not limited to:

(i) welding through holes;

(ii) welding with the assistance of mirrors;

(iii) restricted access to the weldment;

(iv) welding at or near ground level; and

(v) where environmental circumstances are likely to interfere with the welding process,

each welder who is required to weld on such occasions shall demonstrate an ability to produce sound welds under those conditions by carrying out welding in a simulated working position, verified by means of a macro test conducted as above.

Any welder who during fabrication, produces at most three non-conforming welds shall be removed from the work and the reason(s) for failure determined. Where the cause of the failure has been rectified through retraining, the welder shall demonstrate competency to produce sound welds before submitting for re-approval as specified in AS 1554.1 Clause 4.12.2.

17.3.4.8 Workmanship

AS 1554.1, Clause 5.7 shall be complied except that:

(i) Parts that are stressed shall not be cut or welded.

(ii) Distortion may be corrected by mechanical or thermal means provided that the process used does not damage the components or impair its intended use.

(iii) In addition, the following requirements apply where flame or heating methods are to be used:

a. The temperature of the steel shall not exceed 600^0C. Measure and record this temperature.

b. The steel shall not be artificially cooled until the temperature of the steel has dropped below 300^0C.

c. Heated parts shall not be cooled with solid water jets. Water fog nozzles may be used.

17.3.4.9 Inspection of Welds

Welds shall be inspected accordance with the methods nominated in AS/NZS 1554.1. In addition, the following requirements apply:

(a) For welds where category ‘SFP’ is specified, the minimum extent of testing shall be as provided for ‘SP’ category below and/ or as given in Table 7.4 of AS/NZS 1554.5 whichever is the greater.

(b) For ‘SP’ category welds, the minimum extent and type of inspection shall be as given in the following table. Where not specified in this table, on the Drawings or in other documents associated with the work, the maximum suggested extent of non-destructive examination in Table 7.4 of AS/NZS 1554.1 shall apply.

Weld Location	**Minimum Extent of Inspection for each Weld**
VISUAL SCANNING	
All joints	100%
VISUAL EXAMINATION	
All joints	100%
MAGNETIC PARTICLE EXAMINATION / LIQUID PENETRANT EXAMINATION	
Bridge Components • Stiffener welds at crucifix locations (single run fillet welds) • Stiffener fillets at side joints • Edges of flange butt joints • Single pass fillet welds • All stiffeners, diaphragms or diaphragm stiffeners to tension flange; Diaphragm stiffener to diaphragm	100% (MPE only) 100% (MPE only) 100% (MPE only) 100% (MPE only)

• All stiffeners, diaphragms or diaphragm stiffeners to compression flange or web plates; End plates to tension flange, compression flange and web plate	20% (MPE only)
• Back gouging • All other welds	20% (MPE only) 2% (MPE only)
All Other Structural Members	The maximum of AS/NZS 1554 suggestions
Repairs • Repaired defects in base metal • Remaining weld after removal of defected weld • Repaired or replaced weld	 100% 100% (MPE only) 100%
ULTRASONIC OR RADIOGRAPHIC	
Bridge Components • Flange Butt joints • Web butt joints • Web to flange butt joint • Web to flange multipass fillet welds (Note 1) • All stiffeners, diaphragms or diaphragm stiffeners to tension flange (butt and multipass fillet welds) (Note 1) • All stiffeners, diaphragms or diaphragm stiffeners to compression flange or web plates; Diaphragm stiffener to diaphragm; End plates to tension flange, compression flange and web plate (butt and multipass fillet welds) (Note 1) • All other welds	 50% 300mm minimum each end of joint (i) 100% within 500mm each side of diaphragms (ii) 10% for other locations in addition to all ends of welds 10% in addition to all ends of welds, lifting lug locations and at diaphragm locations 100% 10% 10%
• All site joint welds	100%
All Other Structural Members	The maximum of AS/NZS 1554 suggestions

(c) For ‘GP’ category welds, 100% visual scanning and 100% visual examination shall be carried out. Other inspection methods are only required if specified on the Drawings or in other documents associated with the work.

(d) For radiographic and ultrasonic examination, “h” shall be determined by sectioning or vertical ultrasonic sizing in accordance with AS 2177 and AS 2207 respectively.

(e) For NDE, only those techniques that are covered by Section 6 of AS/NZS 1554.1 shall be used except that the ultrasonic examination method shall comply with AS 2207. Remove weld tabs prior to NDE inspection.

(f) The value “L” of a continuous weld length for the assessment of weld imperfections as detailed in Section 6 of AS/NZS 1554.1 shall be 1.0 m or the actual weld length (whichever is the lesser).

(g) Unless otherwise specified, weld inspections to be covered by test certificates shall be carried out at least 48 hours after the joint and all adjacent welds have been completed and have cooled to ambient temperature, and where post weld heat treatment is specified or applied, such testing must occur only after completion of the heat treatment.

(h) Where unacceptable imperfections are detected during audit testing or surveillance carried out by the Construction Supervisor, repair such imperfections and 100% retest, including 100% testing of a further 300 mm each side of the repair zone, all at the Contractor's expense.

(i) Examine multi-pass welds in plates with thicknesses greater than 20 mm for transverse cracking by ultrasonic methods as specified in the above table.

17.3.4.10 Web Defects

Where a defect is detected in a weld, the remainder of the weld shall be inspected as follows:

- For manual and semi-automatic processes (i.e. FCAW, GMAW, MMAW etc.), 100% inspect the weld metal adjacent to the non-conforming weld section for an additional 300 mm minimum in each direction. Examine the remaining part of the weld in accordance with Clause 17.3.4.8 of this Specification. Where another non-conforming weld is detected, repeat the same cycle of inspection until no more non-conforming welds are found.

- For automatic processes (e.g. SAW), if any defect is found, 100% test the remainder of the weld in accordance with the methods given in Clause 17.3.4.8 of this Specification.

17.3.4.11 Welding or Reinforcing Steel

Welding (including tack welds) of reinforcing steel shall comply with AS/NZS 1554.3. In addition, for steel grades not qualified or covered by AS/NZS 1554.3, the bar manufacturer's recommendations shall be followed.

All requirements of the previous sub clauses of this Clause 17.3.4 shall apply to the welding of reinforcing steels, where relevant. Where reference is made in those sub clauses to AS/NZS 1554 or AS/NZS 1554.1, the corresponding Clauses in AS/NZS 1554.3 shall be applied.

The following requirements apply to the welding of reinforcing steel bars. They override the previous Clauses of this Clause 17.3.4 or AS/NZS 1554 when they are in contradiction:

(a) Consumables for locational tack welds (refer to Figure B1 of AS 1554.3) may be nonhydrogen controlled, as permitted by AS/NZS 1554.3. Conform also to Clause 3.3.4 of AS 1554.3.

(b) Locational tack welding need not be supervised by a Welding Supervisor, provided:

  - Welders are qualified in the presence of a Welding Supervisor and in accordance with the requirements of AS/NZS 1554.3;

- Audits of locational tack welding performed by qualified welders are carried out by a Welding Supervisor at least every 6 months; and

- The Contractor carries out regular inspections of the locational tack welding to verify conformity with AS/NZS 1554.3;

(c) Non-qualified personnel shall not perform any locational tack welding or other welding.

(d) Butt welded splices shall only be used if acceptable to the Construction Supervisor;

(e) Any welding procedure, regardless of the method used for its qualification, shall be tested in accordance with Clause 7 of AS/NZS 1554.3 before it is used for the first time on the Works. Subsequent use of such a procedure is acceptable without these additional tests provided that records of these tests and their results are available and meet the requirements of Clause 7.3 of AS/NZS 1554.3.

(f) Carry out preparation or cutting of the fusion face, where appropriate, by a method complying with the submitted technical procedure.

(g) The extent of inspection shall be 100% visual scanning and 100% visual examination with permissible levels of imperfection equivalent to those of Table 9.2 of AS/NZS 1554.3.

17.3.5 Shear Connectors

17.3.5.1 General and Definitions

Stud shear connectors are specified in this Clause 17.3.5. This does not preclude the use of other types of shear connector. Should the Contractor wish to use another type, he shall seek the Construction Supervisor's consent and provide full supporting calculations.

Stud shear connectors shall be supplied, welded and inspected in accordance with AS/NZS 1554.2 as modified by this Specification.

Welding of studs shall not commence until the certifications required by Clauses 17.3.5.2 and 17.3.5.3 have been received and accepted by the Construction Supervisor.

For the purposes of Clause 1.4 of AS/NZS 1.554.2 the following apply:

- The Fabricator is the Contractor.
- The Inspection Authority is the Construction Supervisor.
- The Inspector is the Construction Supervisor.
- The Principal is the Employer.

17.3.5.2 Certification of Studs

The Contractor shall obtain certification from the stud supplier that the materials of the studs and their bases comply with the appropriate specification as required by Clause 2.2.3 and Paragraph C10, Appendix C of AS/NZS 1554.2.

17.3.5.3 Certification of Operators

The Contractor shall provide certification that each operator has passed a qualification test in accordance with Clause 4.3 of AS/NZS 1554.2.

17.3.5.4 Testing of Finished Stud Welds

Each stud in the work shall be tested by striking it with a light hammer (ring test) in the presence of the Construction Supervisor. The ring test shall be carried out by taking a steel hammer of approximately 1 kg in weight and using a free swing to strike the stud, then striking it again in the opposite direction.

Any studs that do not give a consistent ringing sound shall then be tested, in accordance with AS/NZS 1554.2 (bend test). In addition, bend tests shall be performed on a random selection of 5% of studs on each member in addition to those tested in accordance with Section 6 of AS/NZS 1554.2. The bend tests shall be carried out in the presence of the Construction Supervisor.

In the bend test, the stud shall be bent at an angle of 30° to its original axis and only in the longitudinal direction of the member and towards its centre. After bending, the stud shall be examined for cracks. Any stud which exhibits cracks shall be removed and replaced using the arc stud welding process or the alternative process below. Additional studs in the near vicinity of a failed stud shall be bend tested.

Studs which have been bent shall not be bent back unless required for clearance.

Studs may be welded or repaired using qualified flux cored arc, gas metal-arc or manual metal-arc welding subject to the following:

(a) The weld repairs must be at least category SP;

(b) The parent material must be free from loose or thick scale, slag, rust, moisture or other material that prevents conforming welds or produces unsafe fumes;

(c) The stud base must be clean and prepared so that the outside circumference fits tightly against the parent material.

(d) Minimum fillet weld sizes must conform to the following table.

Stud Diameter (mm)	Minimum Size Fillet (mm)
6.4 to 11.1	5
12.7	6
15.9 to 19.0	8
22.2 to 25.4	10

17.3.6 Holes for Bolts

17.3.6.1 General

All holes shall be drilled. Punching of holes shall not be permitted. Reamed and fitted holes shall be sub-drilled 3 mm less in diameter than that of the finished holes and reamed to size.

Reamed and fitted holes and drilled holes shall be through steel templates or after assembly or by other approved means, to ensure complete matching between plies of the joints.

All steel templates shall have hardened steel bushings in holes accurately dimensioned from the centre lines of the connection.

The centre lines shall be used to accurately locate the template.

Reaming or drilling full-sized holes for field connections through templates shall be done after the templates have been located with the utmost care as to position and angle, and firmly bolted. Templates used for the reaming of holes in matching members, or of opposite faces of one member, shall be exact duplicates.

Templates for connections which duplicate shall be so accurately located that like members are duplicates.

All finished holes shall by cylindrical and perpendicular to the member unless otherwise specified. All burrs and other defects shall be removed

17.3.6.2 Sizes

The diameter of the completed hole shall be 2 mm larger than the nominal diameter of the bolt unless otherwise specified except that for the inner plies of a structural connection fastened by high-strength bolts the diameter of the hole shall not be more than 3 mm larger than the nominal diameter of the bolt.

17.3.6.3 Alignment

All matching holes shall register with each other so that a gauge or drift 2 mm less in diameter than the holes shall pass freely through the assembled contact faces at right angles to them.

17.3.6.3 Sizes

Burrs, fins and other defects shall be removed. Drifting to align holes shall be done in a manner that will not distort the metal or damage the hole

17.3.7 Marking for Final Assembly

Each part shall be carefully marked to facilitate final erection. Such marking shall be durable but shall not injure the material.

Such marks shall not be injured, defaced or removed by any person. The marking of components shall be in accordance with that shown on the Shop Drawings submitted.

17.4 TRIAL ASSEMBLY

17.4.1 General

All work shall be trail assembled at the shop or other location approved by the Construction Supervisor prior to dispatch to the site. The components shall be assembled together into such parts of the whole at any one time as the Construction Supervisor shall order.

The general minimal assemblies shall be as follows

Simply supported beams	A complete beam
Continuous beams	Not less than one and a half spans of beam at any one time
Cross girders	Each complete cross girder together with connecting parts of main beams
Trusses	Complete trusses
Floor system bracing and other parts	As the Construction Supervisor shall direct

However, nothing in the above schedule shall imply that the whole of the steelwork shall not be shop assembled in consecutive stages and that all joints shall not be trial assembled.

All components shall be match marked prior to dispatch so that they may be reassembled in the same position. The parts shall not be interchanged. Diagrams showing such match marks shall be furnished to the Construction Supervisor prior to dispatch.

All bolts used in the trial assembly shall be of the same size as those to be used in the final assembly.

All trail assemblies shall be fitted in the presence of the Construction Supervisor.

17.4.2 Acceptance

Notwithstanding any prior inspection and approval of the work, any material or finished work found to be defective shall be rejected.

Rejected material or work shall be promptly replaced or made good by the Contractor at his own expense, to the satisfaction of the Construction Supervisor.

Acceptance of a trial assembly by the Construction Supervisor in no way relieves the Contractor of the responsibility to ensure that the final assembly in within tolerance and true to line, level and position.

17.5 TOLERANCES

All fabrication shall be executed accurately to the shapes and dimensions shown on the Drawings, and, unless otherwise indicated on the Drawings, shall be within the tolerances set out in Clause 14.4 of AS 4100.

Where, in the opinion of the Construction Supervisor, there is evidence that the application of the specified tolerances would adversely affect the serviceability of the structure; the Construction Supervisor shall have the right to reduce the tolerance.

17.6 INSPECTION AND TESTING

If work is to be carried out beyond Vanuatu, the Construction Supervisor will advise the Contractor whether the supervision shall be carried out by the Construction Supervisor or by a Testing and/or Inspection Authority or other person appointed by the Construction Supervisor.

The Contractor shall allow the Construction Supervisor access to all areas in which structural steelwork is
being fabricated and related work is being carried out, and to all materials, plant and fabrications connected with the work at all reasonable times.

The Contractor shall programme his work to the satisfaction of the Construction Supervisor in order to keep visits to a minimum.

The Contractor shall lay out and arrange the individual members or units to be inspected so that each member or unit is accessible for such inspection as the Construction Supervisor may deem necessary.

The Contractor shall assist the Construction Supervisor by turning the members or parts to permit examination on all sides. The Contractor shall supply free of charge all labour and tools required.

17.7 DELIVERY TO SITE

All materials shall be delivered to the site at such time or times as they are required for incorporation in the Works. Bolts and small or loose pieces shall be bagged and close crated. Bolts, nuts and washers shall be separately bundled for each size and each bundle clearly marked with the size and purpose of the bolts. The batch number of each bag of bolts shall be clearly marked to facilitate reference to the test certificates.

During delivery all component materials shall be adequately protected from damage and the Contractor shall be responsible for any damage which may occur. In particular, the Contractor shall adequately strut the bottom flanges of plate girders.

All straps and chains used in lifting shall be adequately padded to prevent damage to the steel work and its protective coating.

No fabricated steel shall leave the Contractor's work without being inspected and passed by the Construction Supervisor at the place of fabrication or be placed in the Works without being inspected and passed by the Construction Supervisor after delivery.

17.8 ERECTION OF STRUCTURAL STEELWORK

17.8.1 Erection Procedures.

The Contractor shall ensure that erection procedures do not overstress the Permanent Works or are in not way detrimental to the Permanent Works. The Contractor shall to pay particular attention to ensuring the stability of his Temporary Works, the Permanent Works and all components thereof at all times.

The Contractor is to submit his detailed erection proposal to the Construction Supervisor for approval at least 14 days before erection is to commence. Where an erection procedure is detailed in the Drawings it is only a suggested method of erection. Notwithstanding approval by the Construction Supervisor of the Contractor's erection proposal, the Contractor shall be fully responsible for the safe erection of the steelwork.

Where required by the Construction Supervisor, the Contractor shall provide with his detailed erection
proposal the following:

- A certificate and calculations by an Construction Supervisor experienced in such work and acceptable to the Construction Supervisor to verify that the equipment nominated will be used within safe working capacities.

- Falsework details including design calculations and certification by an Construction Supervisor experienced in such work and acceptable to the Construction Supervisor stating that the falsework has been designed in accordance with the relevant Australian Standards.

17.8.2 Additional Members

Additional members and attachments used to facilitate erection shall be approved by the Construction Supervisor and affixed in a manner which does not weaken permanent steelwork. Welded outstands and attachments to assist the erection will be permitted providing that in the opinion of the Construction Supervisor such attachments neither adversely affect the serviceability nor mar the final appearance of the structure. In general, such final attachments will not be permitted on the outside face of the structure or in parts of high stress. They shall be removed from the structure after erection and any holes sealed against corrosion to the Construction Supervisor's satisfaction.

Tack welds will not be permitted across members or parts which will carry tension in the structure's working conditions.

Any tack welds used in the erection of the structure shall be ground flush after removal of the affixed parts.

17.8.3 Storing of Steelwork

Steelwork shall be stored on timber bearers, clear of the ground and in such a way as to permit checking and to avoid excessive handling and damage to the steelwork or its protective coating

17.8.4 Straightening of Bent Members

The Contractor shall comply with the requirements of Clause 17.3.3 and this Clause.

Any member bent out of the fabricated shape, shall be straightened by methods which will not cause fractures, injury or excessive residual stresses. The steelwork shall not be heated unless otherwise approved by the Construction Supervisor and if so approved the Contractor shall make good at his own expense any damage caused to the steelwork or its protective coating by such heating. The temperature of such heated areas shall not exceed 600^0C.

The Construction Supervisor's approval shall be obtained prior to commencing straightening of any bent members.

17.8.5 Preparation of Contract Surfaces

Unless otherwise directed by the Construction Supervisor,, all surfaces to be brought together to form a joint or splice shall be free of paint or any other applied finish, oil, dirt, loose rust, loose scale, burrs, and other defects which would prevent solid seating of the parts or would interfere with the development of friction between them.

17.8.6 Assembly

Steelwork shall be placed and assembled in accordance with the Drawings and the approved method; all match marks shall be followed.

Each joint shall be bolted up with service bolts and parallel drifts so that the various sections and plates are in close contact throughout. Service bolts shall not remain in the completed structure.

Drifts shall be parallel barrel drifts. The barrels shall be drawn or machined to a diameter equal to the full diameter of the hole subject to a tolerance of + 0 to - 0.13 mm.

The length of the barrels shall not be less than the combined thickness of the material, plus one diameter. The ends of the drift, for a length of 1 ½ barrel diameters, shall be tapered down to an end diameter equal to half the barrel diameter. Heavy drifting that would distort the holes shall not be carried out.

High tensile bolts shall be assembled with one hardened washer under the turned element (nut or bolt head). The washer shall be assembled with any convexity outwards. The inserting and tensioning of the high tensile bolts shall be so arranged that the close contact established by the service bolts is maintained at all times. The tensioning of the high tensile bolts shall not commence until the joint has been inspected by the Construction Supervisor.

The slope of surfaces of bolted parts in contact with the bolt head and nut shall not exceed 1:20 ($2^0$52') with respect to a plane normal to the bolt axis; in cases where the shape of the member is such that this slope is exceeded, taper washers shall be used.

17.8.7 High Strength Friction Grip Bolts

17.8.7.1 Supply

HSFG bolts shall comply with the requirements of AS/NZS 1252. The Contractor shall supply test certificates for each batch of bolts at least one month before they are to be used.

17.8.7.2 Assembly of a Connection Involving Tensioned Bolts

a) Placement of a nut: The nut shall be placed so that the mark specified in AS/NZS 1252 to identify a high strength nut is visible after tightening.

b) Packing: Packing shall be provided wherever necessary to ensure that the load transmitting plies are in effective contact when the connection is tightened to the snug-tight condition defined in Clause 17.8.7.3 (b) (i). All packing shall be steel with a surface condition similar to that of the adjacent plies.

c) Tightening Pattern Snug–tightening and final tensioning of the bolts in a connection shall proceed from the stiffest part of the connection towards the free edge.

   High strength structural bolts that are to be tensioned may be used temporarily during erection to facilitate assembly, but if so used, they shall not be finally tensioned until all bolts in the connection have been snug-tightened in the correct sequence.

d) Re-Tensioning Re-tensioning of bolts which have been fully tensioned shall be avoided, except that if re-tensioning is carried out, it shall only be permitted once and only where the bolt remains in the same hole in which it was originally tensioned and with the same grip.

   Re-tensioning of galvanised bolts shall not be permitted. Under no circumstances shall bolts which have been fully tensioned be re-used in another hole.

Touching up or re-tensioning of previously tensioned bolts which may have been loosened by the tensioning of adjacent bolts shall not be considered as re-tensioning.

e) Bolts shall protrude beyond the nuts by not less than two (2) millimetres and not more than ten (10) millimetres.

17.8.7.3 Method of Tensioning

(a) General

The method of tensioning shall be in accordance with either Clause 17.8.7.3 (b) or Clause 17.8.7.3. (c).

In the completed connection, all bolts shall have at least the minimum bolt tension specified in Table 1 when all bolts in the bolt group are tightened.

Nominal Diameter of Bolt	Minimum Bolt Tension (kN)
M16	95
M20	145
M24	210
M30	335
M36	490

Table 1 minimum Bolt Tension

Note: The minimum bolt tensions given in this table are approximately equivalent to the minimum proof loads given in AS 4291.1.

(b) Part Turn Method of Tensioning:

Tensioning of bolts by the part turn method shall be in accordance with the following procedure:

(i) On assembly, all bolts in the connection shall be first tightened to a snug-tight condition to ensure that the load –transmitting plies are brought into effective contact.

Snug-tight is the tightness attained by a few impacts of an impact wrench or by the full effort of a person using a standard podger spanner.

(ii) After completing snug-tightening, location marks shall be established to mark the relative position of the bolt and the nut and to control the final nut rotation.

Observation of the final nut rotation may be achieved by using marked wrench sockets, but location marks on bolts and nuts shall be permanent when required for inspection.

(iii) Bolts shall be finally tensioned by rotating the nut by the amount given in Table 2. During the final tensioning the component not turned by the wrench shall not rotate.

Bolt Length (Underside of head to end of bolt)	**Disposition of Outer Face of Bolted parts (See notes 1, 2, 3 and 4)**		
	Bolt faces normal to bolt axis	**One face normal to bolt axis and other sloped**	**Both faces sloped**
Up to and including 4 diameters	1/3 turn	½ turn	2/3 turn
Over 4 diameters but not exceeding 8 diameters	½ turn	2/3 turn	5/6 turn
Over 8 diameters but not exceeding 12 diameters	2/3 turn	5/6 turn	1 turn

Table 2 Nut Rotation from the Snug-Tight Condition

Note:

1. Tolerance on rotation: for ½ turn or less, one-twelfth of a turn (30^0) over and nil under tolerance; for 2/3 turn or more, one-eight of a turn (45^0) over and nil under tolerance.

2. The bolt tension achieved with the amount of nut rotation specified in Table 2 will be at leat equal to the minimum bolt tension specified in Table 1.

3. Nut rotation is the rotation relative to the bolt, regardless of the component turned.

4. Nut rotations specified are only applicable to connections in which all material within the grip of the bolt is steel.

5. For either the Part Turn Method or the Direct–Tension Indicating Device Method, a lubricant acceptable to the Construction Supervisor, may be applied sparingly to the threads. Care is required so that it does not get onto the contact surfaces of the joint.

6. No research has been performed to establish the turn-of-nut procedure for bolt lengths exceeding 12 diameters. Therefore, the required rotation should be determined by actual test in a suitable tension measuring device which simulates conditions of solidly fitted steel.

(c) Direct-Tension Indication Device:

(a) The suitability of the device shall be demonstrated by testing a representative sample of not less than three bolts for each diameter and grade of bolt in a calibration device capable of indicting bolt tension. The calibration test shall demonstrate that the device indicates a tension not less than 1.05 times the minimum bolt tension specified in Table 1.

(b) On assembly, all bolts and nuts in the connection shall be first tightened to a snug-tight condition defined in Clause 17.8.7.3 (b) (i).

(c) After completing snug-tightening, the bolt shall be tensioned to provide the minimum bolt tension specified in Clause 17.8.7.3 (a). This shall be indicated by the tension indication device.

Note: Tensioning of bolts using a direct-tension indication device shall also be in accordance with the manufacturer’s specifications.

17.8.7.4 Air Impact Wrenches

(a) General

Where air impact wrenches are used, they shall be of suitable size. Where the use of an extension bar is necessary, it must be a part manufactured specifically for the wrench. The wrench shall be supplied with compressed air from a compressor capable of developing seven hundred kilopascals (700 kPa) line pressure, and of maintaining six hundred and fifty kilopascals (650 kPa) under all loading conditions.

The layout and sizes of supply lines, shall be determined to give a suitable air pressure to each wrench; where the work is far distant from the compressor, extra receiver tanks may be needed to cut down surge, moisture etc.

An air regulator reducing valve shall be inserted within ten (10) metres of the air wrench, in the hose connecting the wrench to the supply line. The regulator, connecting hose and wrench shall be tested and calibrated as a unit.

(b) Tightening with Impact Wrenches

The wrench shall be held in a position normal to the plane of the washer wherever possible and the operator shall assume a suitable position to apply normal operation pressure. Adequate staging shall be provided for this purpose.

17.8.8 Erection of Steel Handrailing

Hand rails shall be packed up on level packs and all adjustments necessary to the levelling bolts made before mortaring up.

Posts shall be vertical and the rails shall form a straight line between their ends. End panels shall be set first and used as a datum for the erection of the remainder of the handrails. Rails shall be set to a tolerance of ± 3 mm vertically and horizontally.

17.8.9 Site Welding

Unless shown on the Drawings, site welding will not normally be permitted for butt welding of piles. If the Construction Supervisor permits site welding, it will be restricted to minor joints and the requirements of Clause 17.3.4 shall apply.

Welding procedure trails and operator qualification trials shall be carried out under site conditions using the plant to be used on the Site.

17.8.10 Accuracy of Assembly

Steelwork shall be assembled on blocks and wedges accurately to line, level and camber as shown on the Drawings.

17.8.11 Misfits

Misfits of holes shall be corrected by means of parallel barrel drifts and parallel shank reamers having diameters equal to the full diameters of the bolts.

If any errors in fabrication are found, which cannot be corrected by light reaming, the circumstances shall be reported to the Construction Supervisor and his approval shall be sought for the proposed method of correction. Heavy drifting which would distort the metal around the bolt holes are prohibited.

17.9 MEASUREMENT AND PAYMENT

The items for ‘Structural Steelwork, supply, fabricate, shop paint and deliver to the site’ and ‘Erect’ shall be measured for payment as the weight of steel permanently remaining in the structure. The unit will normally be the tonne.

Seismic restraints shall be measured by number of complete units galvanised and supplied to site. Installation is covered under Clause 19.8 of this Specification.

This item shall include all bolts, nuts, nuts and washers other than hold down bolts where they are measured separately, but exclude bearings which shall be measured separately.

The Billed Rates shall include full compensation for all materials, plant, tools, labour, equipment and steelwork, including the erection and removal of all falsework; all sealing operations; protective coatings; mastic fillers where necessary; and all other incidental scheduled items, all as specified in the Contract Documents and as directed by the Construction Supervisor.

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GROUP 16

PROTECTION OF STEELWORK

18.1 SHOP PAINTING

18.1.1 Surface Preparation

After dismantling subsequent to satisfactory trial assembly, all grease, oil and foreign matter shall be removed from the surfaces of all steelwork by washing with solvent in conformity with the requirements of AS 1627.1. The surface steelwork, excepting as otherwise provided, shall be prepared as specified of Class 3 surface preparation in accordance with AS 1672.4. Other methods of surface preparation may be approved by the Construction Supervisor, however, if so approved they shall be carried out in accordance with the relevant Australian Standard

18.1.2 Priming

A prime coat as specified in Clause 18.9 shall be applied to all steelwork surfaces, except those specified in Clause 18.1.3, within three (3) hours of abrasive blast cleaning. Should any steelwork surface become contaminated by oil, grease, dirt, dust or water prior to application of the Prime Coat, it shall be prepared in accordance with Clause 18.1.1. The Prime Coat shall be applied in an enclosed workshop.

18.1.3 Surfaces Not To Be Primed.

(a) Unless a primer with approved friction grip properties is used, surfaces to be brought into contact in friction-grip joints shall not be primed. Such surfaces shall in any case not receive top coats of paint.

(b) Surfaces of steel to be in contact with, or embedded in concrete shall not be painted.

(c) Surfaces to which bearings are to be bonded shall not be painted.

(d) Such surface as described in (a), (b), (c) above shall be treated by an approved process in order that they may be protected from excessive deterioration during transport and/or storage before erection. Prior to or during erection these surfaces shall be prepared in the manner prescribed in the appropriate section of the Specification.

(e) Galvanised surfaces of seismic restraints, impact angles and movement joint cover plates shall not be painted.

18.2 GALVANISING

Items of steelwork indicated on the Drawings shall be hot dip galvanised in accordance with AS/NZS 4680.

The Construction Supervisor may order any test of the coating to be carried out in accordance with AS/NZS 4680 at the Contractor's cost.

Where galvanised bolts or fasteners are indicated on the Drawings, they shall conform to AS 1214.

18.2.1 Painting in Lieu of Galvanising

In the event of painting in lieu of galvanising being approved by the Construction Supervisor, the paint system shall comply with that specified in the Clause 18.9.2 of this Specification.

18.3 FIELD PAINTING OF STEELWORK

18.3.1 Preparation

Surfaces that will be in contact with concrete shall not be painted. Existing concrete work shall be protected from paint splashes and drips during painting of adjacent steelwork. Any paint on concrete shall be cleaned off to the satisfaction of the Construction Supervisor.

All field joints and any damage occurring to the shop coat(s) during construction shall be made good prior to field painting being commenced.

Bolts, nuts, washers and other fasteners shall be treated with an etch primer with dry film thickness of 75 microns minimum..

18.3.2 Painting

The protective system to be applied to all exposed surfaces shall be as specified in Clause 16.9. All products shall be applied strictly in accordance with the manufacturer's instructions and recommendations.

18.3.3 Application of Paint.

Surfaces to be painted shall be thoroughly dry and free from oil, grease and dust or other deleterious substances.

Paint shall not be applied in wet, or dusty weather or in other unsuitable weather conditions unless precautions, approved by the Construction Supervisor, are taken to exclude the effects of such weather from the work.

The paint (including sprayed paint if directed by the Construction Supervisor) shall be vigorously brushed into the surface around rivet and bolt heads, nuts and washers, and into all corners, joints of plates etc., and crevices and then lightly and evenly smoothed out. Any recesses which could contain or entrap water or debris, or through which water might be able to percolate, shall be filled with thick paint or, if so directed by the Construction Supervisor, with a waterproofing compound before completion of the final coating.

As soon as the first coat has dried, and cured if necessary, an extra stripe of paint in a contrasting shade shall be applied by brush to all edges, corners, crevices, exposed parts of bolts and welds.

Each completed coat shall be substantially free from tracks etc., and shall have a uniform and even appearance.

Damage to either the top coat or the primer shall be repaired with materials compatible with the original coatings as approved by the Construction Supervisor.

18.4 TRANSPORT AND STORAGE OF PAINT

Paint shall be stores in sealed containers at a temperature between 4^0C and 33^0C. Any special transport and storage conditions recommended by the paint manufacturers shall be observed.

Paint which has not been used within its “shelf life” or within 12 months from the date of manufacture, whichever is the lesser, shall be replaced. At the end of each working day, paint from painter’s kettles and the like shall be returned to the store and kept in sealed containers which are not less than 90 per cent full.

18.5 STORAGE OF STEEL AND FABRICATED STEELWORK

The Contractor shall take all necessary precautions to minimise exposure of steel, awaiting fabrication, to chemical pollution.

Fabricated steelwork stored awaiting delivery to site or erection shall be kept clear of the ground and shall be laid or stacked so as to prevent water or dirt accumulating on or against the surfaces.

Packing shall be placed between layers of stacked steelwork. Where a cover is provided it shall be sufficiently ventilated to keep condensation to a minimum.

18.6 REPAIRS TO DAMAGED SURFACES

Areas of paint which have been damaged shall be cleaned back to bare metal and the edges of the damaged paint bevelled. The damaged areas and the existing paint within 50 mm of the affected part shall be coated as noted for ‘Touch Up’ in Clause 18.9.2 (e) of this Specification. Each coating of paint shall overlap the existing paint by at least 50 mm.

18.7 WELDED JOINTS

Unless otherwise described on the drawings or in the Specifications, weld and surfaces affected by welding shall receive the same protection which is applied to the parent surfaces.

18.8 SURFACE PREPARATION AND PAINTING OF COMPLETED JOINTS

Where the interfaces of 8.8/TF bolted joints (bolting category as per AS 5100.6 Table 12.5.1) are bare steel, the surfaces of the parent and joint material shall be prepared together with exposed parts of bolts, nuts, washers, load indicating devices and welds, and painted as specified within ten(10) days of the joints having been made and accepted by the Construction Supervisor.

18.9 PROTECTIVE SYSTEMS FOR STEELWORK

18.9.1 General

The protective system to be adopted for the various components of the steelwork shall be as noted in this Clause and detailed on the Drawings.

18.9.2 Painted Surfaces

(a) Paint

The paint shall be an Epoxy Micaceous Iron Oxide Two Pack Epoxy, unless otherwise approved by the Construction Supervisor. The finished colour shall be mid-grey.

Paint including primers and thinners used in the painting of steelwork to be incorporated in the Works shall be supplied by one single manufacturer only.

Except as provided in this Clause, paint supplied shall be either approved under the Australian Paint Approval Scheme (APAS) or manufactured by an APAS Recognised Manufacturing Unit and accepted by the Construction Supervisor as suitable for the specified purpose or for use in the conditions that the steelwork is to be installed.

For acceptance of a paint by the Construction Supervisor, the following information shall be provided for the Construction Supervisor's consideration, at least 20 working days prior to placing orders for supply of the paint:

(i) Name of the manufacturer;

(ii) Evidence that the manufacturer is an APAS Recognised Manufacturing Unit;

(iii) Which specifications of the APAS 2900 series, if any, the paints comply with;

(iv) Details of any previous use of the paint on steelwork installed in conditions similar to those in which the painted steelworks is to be installed; and

(v) Manufacturer's data sheets showing the suitability of the paint for use in the specified conditions.

Paint that does not comply with the above provisions of this Clause will be considered by the Construction Supervisor for approval only if the Contractor provides all information required by the Construction Supervisor for his consideration and which will include, as a minimum, the information in paragraphs (i), (iv) and (v) above. Without limiting the generality of this requirement, the Construction Supervisor may require test panels to be prepared and subjected to any appropriate test detailed in any part of AS/NZS 1580.0.

The Construction Supervisor has absolute discretion to accept or reject a paint not approved under APAS.

(b) Thinners

For each of the paint products to be applied, only the specific thinners recommended by the paint manufacturer for the thinning of paint shall be used.

(c) Fillers

Only a two-part solventless epoxy putty shall be used to fill crevices and gaps between steel members.

(d) Surface Preparation

All steelwork	Abrasive blast clean Class 2 ½ to AS 1627.4
Touch Up	Power tool clean Class 3 to AS 1627.2 or spot blass Class 2 ½ to AS 1627.4

(e) Application

The coating shall be a primer followed by two top coats, all applied in strict accordance with the manufacturer's recommendations provided that the dry film thickness shall be not less than 75 microns for the primer and 100 microns for each top coat.

(f) Touch UP

Repairs and touch up shall be carried out using identical materials to the primer and top coats.

18.9.3 Seismic Restraints

All seismic restraint steelwork shall be hot dipped galvanised.

Where seismic restraint components are to be buried but not cast in concrete they shall be protected as follows, or by using a similar alternative approved by the Construction Supervisor.

(i) Denso MP primer applied at a rate of 0.2 to 0.5 kg per square metre,

(ii) Denso Mastic filling around all bolts, turnbuckles, welds and other irregularities to improve contours for subsequent tape wrapping,

(iii) Denso Tape wrapped to give 55% overlap,

(iv) Denso MP/HD Overwrap Tape wrapped to give 55% overlap, and

(v) Secure ends with Denso Hi-tack Tape.

18.9.4 Piles

Steel piling, where required, shall be coated with Dimet ‘Tarset Standard’ applied with airless or high pressure atomising spray equipment to achieve a minimum dry film thickness of 400 micron in no more than two coats in one day.

Thinning of paint shall be carried out by the Contractor under the supervision of the Construction Supervisor or by the paint manufacturer.

18.10 PROTECTIVE COATING TO PILES

Where shown on the Drawings, piles shall have a protective system, as detailed in Clause 18.9.4, applied to the area noted. The surface of this area shall be prepared in accordance with Sub-Clause 18.1.1 and the coating applied strictly in accordance with the manufacturer’s instructions and recommendations, and as specified in Sub-Clause 18.9.4

The Contractor shall make good any damage to the protective coating resulting from pile driving or other construction activities, or any shortfall to the protective coating shown on the Drawings, to the satisfaction of the Construction Supervisor. The remedial work shall be suitable for the location of the damage to provide the same protection as the specified coating and shall be carried out in strict accordance with the manufacturer’s or supplier’s written instruction for the type of repair to be carried out. The cost of any remedial work shall be deemed to be included in the Billed Rate for ‘Protective Coating on Steel Piles’.

18.11 MEASUREMENT AND PAYMENT

18.11.1 Structural and General Steelwork

The unit of measurement for ‘Protection of Steelwork’ shall be square metre, and the measurement for this work shall include only the area of steelwork which has been painted. The Billed Rate for this work shall include for all labour, plant, materials and other associated costs for the supply and application of the coating.

Preparation, priming and other forms of protective coatings shall not be included in the ‘Protection of Steelwork’ item but shall be included in the Billed Rates for supply of the relevant steelworks.

18.11.2 Piles

Protective coating to piles shall be measured in square metres of surface shown on the Drawings or otherwise directed to be coated, and the Billed rate shall include for all labour, plant, materials and other associated costs necessary for preparation, supply and application of the protective coating.

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GROUP 19

MISCELLANEOUS BRIDGEWORKS ITEMS

19.1 PROPRIETARY PRODUCTS

Where proprietary products are specified by name on the Drawings it implies a standard and is in no way intended to preclude the use of an alternative approved by the Construction Supervisor. The product shall be used in accordance with the manufacturer's instructions. Where such instructions are in conflict with the Drawings or Specification the Contractor shall draw the Construction Supervisor's attention to the inconsistency and await the Construction Supervisor's direction.

19.2 BEARINGS

19.2.1 General

The Contractor shall supply and fit all bearings in the positions and to the details shown on the Drawings. Bearings shall be set when the ambient temperature is approximately equal to the mean temperature shown on the Drawings or advised by the Construction Supervisor.

19.2.2 Elastomeric Bearing Pads

The elastomer shall comprise natural rubber and other materials compounded and cured to give the properties specified in AS 5100.4 with IRHD 60 ± 5.

Pads and strips shall be vulcanised in a mould under pressure and shall not be extruded or cut from sheet.

Tolerances on the width and length of the bearings shall be 0 to + 3 mm and on the thickness 0 to + 2 mm, provided the bearing surfaces shall be plane and parallel to one another within a tolerance of 0.75 mm.

Unless otherwise shown on the Drawings all bearings shall be bonded with approved epoxy resin adhesive to the upper surfaces.

The Contractor shall submit test certificates to the Construction Supervisor giving physical properties and mechanical properties for each bearing. All bearings shall be indelibly marked with appropriate bearing type number and a unique number for correlation to test certificates.

The following procedure shall be used for the installation of the elastomeric bearings at abutments and piers unless otherwise detailed in the drawings or an alternative procedure is approved by the Construction Supervisor.

(a) Bond the bearing to the underside of the girders using an approved epoxy resin adhesive.

(b) Erect the girders and bracing on steel packs true to line and level. Tighten up holding down bolts.

(c) Firmly pack under the bearing with cement-sand mortar taking care to ensure that all voids are completely filled. The mortar shall extend beyond the bearing by a distance at least equal to the mortar thickness. It shall then be battered off at approximately 1 to 1.

(d) Grout up the holding down bolts using, unless otherwise stated in the Drawings, cement-sand grout taking care to ensure that the bolt pockets are completely filled.

(e) After seven days or other period directed by the Construction Supervisor, remove the steel packs.

19.2.3 Other Bearings

Sliding, rocker and/or roller bearings shall be accurately aligned, levelled in approved cement-sand grout and anchored to the abutments and/or piers with holding down bolts as shown on the Drawings and to the satisfaction of the Construction Supervisor.

19.3 DECK JOINTS, SEALANTS AND VOID FORMERS

19.3.1 Impact Angles

Where shown on the Drawings the concrete edges at deck level shall be protected by steel angle sections, bent, if necessary, to conform with the profile of the wearing surface, and rigidly fixed to the superstructure as shown.

Care shall be taken in placing concrete adjacent to the protection angles to ensure that it is sound, without air pockets and is properly worked into corners and/or below the outstanding legs of the angles.

If indicated on the Drawings, impact angles shall be hot dipped galvanised in accordance with Clause 18.2 of this specification. Galvanizing shall satisfy any test ordered in accordance with AS/NZS 4680.

19.3.2 Performed Neoprene Jointing

Performed neoprene compression joint seals shall be installed to the width and details given in the Drawings. The brand of the jointing shall be approved by the Construction Supervisor. The jointing shall be installed according to the manufacturer’s recommendations. Alternative jointing to that detailed on the Drawings may be used if approved by the Construction Supervisor.

Compression seals shall be installed in one continuous length. The lubricant-adhesive shall be compatible with the bridge joint and shall be resistant to oxidisation and fuel oils.

19.3.3 Other joints, Sealants and Void Formers

Other joints, sealants and void formers shall be installed as detailed on the Drawings and in accordance with the manufacturer's instructions.

19.3.4 Waterstops

Waterstops shall be of the centre bulb or valve type and manufactured from polyvinyl chloride. In addition, waterstops shall be provided with reinforced eyelets or a suitable fixing strip along each edge. Water stops shall be adequately fixed to the reinforcement to maintain correct positioning during concreting. Prior to installation, waterstops shall be cut and spliced at all changes in direction. Site splicing shall be carried out strictly in accordance with the manufacturer's instructions and recommendations.

19.3.5 Joint Filler

Joint filler to movement joints and to seismic restraints shall be compressible closed cell polyethylene foam joint filler. The brand and type of the jointing shall be approved by the Construction Supervisor. The stress to compress the joint filler to 50 percent of its original thickness shall be not less than 0.1 MPa and not greater than 0.3MPa. The Contractor shall submit test certificates detailing the compressive stress/strain relationship for the joint filler.

19.3.6 Joint Sealant

Joint sealant to trafficked surfaces shall be a hot poured coal tar based sealant acceptable to the Construction Supervisor. Sealant shall be applied strictly in accordance with the Manufacturer's instructions and recommendations. The pouring temperature of the sealant shall not exceed the manufacturer's recommended safe heating temperature. Where primer is required or recommended by the sealant manufacturer the primer shall be applied in accordance with the manufacturer's recommendations. Prior to the application of all sealant, adjacent concrete surfaces shall be masked.

19.4 SCUPPERS

Drainage openings or scuppers shall be constructed in the positions and to the details shown on the Drawings. Outlets shall be arranged so as not to stain exposed surfaces with water discharged.

UPVC pipes for scuppers shall be un-plasticised polyvinyl chloride pipes conforming to the requirements of AS/NZS 1260.

19.5 EPOXY MORTAR

Epoxy mortar shall not be used unless specified on the Drawings or approved by the Construction Supervisor. The epoxy binder shall be Epirez 133 General Purpose Epoxy Mortar Binder or
approved equivalent, used as recommended by the manufacturer.

The sand shall be a hard, sharp, siliceous material free of all organic material. It shall be oven fried and delivered to the Site in sealed waterproof containers so that moisture content is not more than 0.4% by weight when the sand is used on site. Grading shall comply with the following sieve analysis to within ± 5% of the following proportions:

AS 1152 Sieve Size	Percentage Passing, By Mass
1.18 mm	100
0.600 mm	10
0.300 mm	0.2
0.150 mm	0

The binder shall be added to the sand in the proportion of 1 part of binder to 5 parts of sand. The proportion may be changed to 1:4 or 1:3 if the mix is not sufficiently workable. Zircon stone may be incorporated with the sand if necessary to improve its grading.

Safety precautions recommended by the manufacturers of the epoxy binder shall be followed.

19.6 EPOXY ADHESIVE

Epoxy adhesive unless where specified on the Drawings or authorised by the Construction Supervisor shall be Episet 8242 Structural epoxy adhesive or approved equivalent applied in accordance with the manufacturer's recommendations. Surfaces to be bonded shall be roughened or etched as ordered by the Construction Supervisor and shall be cleaned with acetone prior to application of the adhesive.

19.7 MEASUREMENT AND PAYMENT

Scuppers shall be measured as the number furnished in place

Movement joints shall be measured by number, the joint type number being stated, and shall be deemed to include all costs associated with the construction of the joint not otherwise covered as a separate item in the Bill of Quantities.

The supply and installation of elastomeric bearing pads shall be measured by the number and bearings strips by the length in metres of each width strip.

Supply and installation on UPVC tubing for handrail post and bridge guard rail post holding down bolts shall be measured by number.

Payment shall include full compensation for all materials, testing, labour, plant and all other incidentals necessary to supply and /or install the items in accordance with the Contract.

19.8 SEISMIC RESTRAINTS

The measurement and payment of seismic restraints, timber packers, rubber and elastomeric pads, bolts, ancillary steelwork and the like indicated on the Drawings shall be by number.

Payment shall include full compensation for the supply of all materials, (with the exception hot dip galvanised steelwork listed separately), testing, labour, plant and incidentals necessary to install the items in accordance with the Specifications. Separate payment will not be made for forming pockets and subsequent grouting.

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GROUP 20

RIVER TRAINING AND BANK PROTECTION

20.1 GABIONS AND RENO MATTRESSES

20.1.1 General

The requirements as set out in this Clause 20.1 for Gabions shall also apply to Reno mattresses unless otherwise specified.

The gabions shall be flexible PVC coated and galvanised wire boxes fabricated of wire mesh of the type and size, and selvedged as specified below. Each gabion shall be divided by diaphragms into cells whose length shall not be greater than the width of the gabion plus 100 millimetres, except in the case of 1.5 metre long by 1 metre wide gabions which have no diaphragm, 2.5 metre long by 1 metre wide gabions which shall have one central diaphragm, and Reno mattresses where the diaphragms shall have a maximum spacing of 600 mm.

Unless otherwise stated Gabions shall be flexible, woven, PVC coated galvanised wire mesh boxes of dimensions as shown on the Drawings or directed by the Construction Supervisor, as supplied by Maccaferri Australia, or an approved equivalent.

20.1.2 Wire

All wire used in fabrication of the gabions and in the wiring operations during construction shall be low tensile wire to AS 2423 having a tensile strength of not less than 350 MPa.

Unless stated otherwise on the Drawings, the wire used shall have a diameter as follows:

- For gabions 2.7 mm
- For mattresses less than 350 thick 2.0 mm
- For mattresses with thickness 350 to 500mm 2.4 mm
- Selvedge wire 3.0 mm
- Binding and connecting wire 2.2 mm

The wire shall be galbanised as noted in Clause 20.1.3.

In all cases the above dimensions are, if the galvanised wire is to be coated, the dimensions of the wire core.

The wire shall be PVE coated in accordance with Clause 20.1.4,

20.1.3 Galvanising

All wire used in the fabrication of the gabions and in the wiring operations during construction shall be galvanised to AS/NZS 4534 Class W10Z or W10Z5A.

20.1.4 PVC Coating

All wire used in the fabrication of the gabions and in the wiring operations during construction shall, after galvanising, have extruded on to it a coating of polyvinyl chloride, otherwise referred to as 'PVC'. The coating shall be grey or green in colour, shall have an average thickness of 0.55 mm and nowhere be less than 0.40 mm in thickness and shall be capable of resisting deleterious effects of natural weather exposure and immersion in salt water. The PVC coatings shall comply with the test methods and specifications listed in AS 2423 Appendix E, Table E1.

20.1.5 Mesh

The mesh shall be hexagonal woven mesh wherein the joints are formed by twisting each pair of wires through two full turns. The wire used is to be as specified in Clause 20.1.2 of this Specification.

The undisturbed size of the mesh shall be nominal 60 mm by 100 mm. The tightness of the twisted joins shall be such that a force of not less than 1.75 kN pulling on one wire is required to separate it from the other, provided each wire and the applied force are all in the same plane.

The wire mesh shall have the elasticity sufficient to permit elongation of the mesh equivalent to the minimum of 10% of the length of the section of mesh under test without reducing the diameter or tensile strength of individual wire strands to values less than those for a similar wire 0.3 mm smaller in diameter

20.1.6 Selvedges

All edges of the gabions, diaphragms and end-panels, except as stated in Clause 20.1.7 of this Specification, shall be selvedged with a continuous wire of which the core diameter is 3.0 mm. Where the selvedge is not woven integrally with the mesh but has to be fastened to the cut ends of the mesh, it shall be attached by binding the cut ends of the mesh about it so that a force of not less than 8.5 kN applied in the same plane as the mesh, at a point on the selvedge of a mesh sample of length one (1) metre is require to separate it from the mesh.

20.1.7 Diaphragms

The diaphragms and end-panels shall be selvedged on the top and vertical sides only. The end panel shall be attached by twisting the cut ends of the mesh wires at the bottom of the panel about the selvedge on the base of the gabions. Similarly, the diaphragms shall be attached by twisting the cut ends of the mesh to the twisted joins of the mesh of the gabions. In each case the force required to separate the panels from the base shall not be less than that required to break the mess over the same length.

20.1.8 Binding and Connecting Wire

Sufficient binding and connecting wire shall be supplied with the gabions to perform all the wiring operations to be carried out in the construction of the gabion work as stated in Sub-Clause 20.1.11 to 20.1.13 below. The diameter of wire shall be 2.2 millimetres.

20.1.9 Filling Material

Filling material shall consist of hard, durable stone of minimum dimension 100 mm and maximum dimension 250 mm and shall be tightly packed to give minimum of voids. The top layer of material shall consist of selected smaller stone with dimensions between 100 mm and 150 mm.

20.1.10 Tolerances

A tolerance on the diameters of all wire of ± 2 ½ % shall be permitted. The length of the gabions is subject to a tolerance of ± 3 % and the width of gabions to a tolerance of ± 25 mm. All other gabion dimensions are subject to a tolerance of ± 3 % of the sizes stated in these Specification or on the Drawings

20.1.11 Fabrication

The gabions shall be unfolded on the ground and stretched to the maximum extent possible while ensuring that all creases are in the correct positions for forming the box. Any cutting required shall be carried out so that the cut ends of wire are a minimum of 50 mm from the twisted joins. After stretching and cutting as required, the side and end panels shall be lifted so that the tops of all sides are level. Any loose ends of wire protruding above a \level plane at the top or from the corners shall be bent down into the box. Corners shall be fastened securely and the box shaped to commencing any binding

The binding wire shall be securely fastened to the top of a corner by lacing between two meshes at the corner and twisting the binding wire through three half turns. The wire shall then be laced around the two vertical selvedges, when applicable, and through each mesh in turn in a continuous lacing action to the bottom corner by the three half turns to an adjacent wire.

The diaphragm panels shall then be placed in position and secured to the gabion sided in the same manner as the corners. The empty box shall then be firmly seated on a prepared area in its final position and laced to the adjoining corners or sides of gabions previously placed along all adjoining corners and tops. If additional binding of the gabions is required this shall be shown on the Drawings or directed by the Construction Supervisor.

20.1.12 Placement

The placement of the gabion boxes shall be carried out in an orderly manner so that a face of uncompleted work is maintained.

At least two rows of empty boxes shall be wired together at the face of uncompleted work prior to filling the box closes to the completed work. Prior to filling any box one end or side of the box shall be secured to completed works or to stakes driven into the ground at the corners or in any other approved manner and the opposite end, side or corner shall be stretched with crowbars and secured top to bottom in an approved manner.

20.1.13 Filling

When boxes used are one (1) metre high or more they shall be cross tensioned in each compartment at third points in the height by wires of the same diameter as the binding wire securely tied by two turns around the mesh or selvedge wire and three turns around itself. The boxes shall be filled to between 25 and 50 mm above their tops. The lids shall be stretched tight over the filling with a crow bar or similar and wired done in a continuous lacing process in the same manner as that specified for corners. Each edge may be laced with a separate length of binding.

20.1.14 Measurement

The Billed Rate for Gabions shall include for all work specified including excavation, filling, compacting and trimming necessary to construct the gabions to the lines and levels specified. Measurement of the quality in cubic metres for which payment will be made shall be based on the nominal external dimensions of the gabion baskets and Reno mattresses which have been constructed in accordance with the Contract.

20.2 BANK PROTECTION

Bank protection works shall, unless otherwise shown on the Drawings or directed by the Construction Supervisor, be carried out with gabions and Reno mattresses as detailed in Clause 20.1. The gabions and Reno mattresses shall not be placed until the bank has been trimmed and compacted to the satisfaction of the Construction Supervisor.

The Contractor is to note that the works shown on the Drawings are simply an indication of type of construction and extent of works. The actual detailed layout will be decided on site by the Construction Supervisor.

20.3 RIVER TRAINING

River training works shall be constructed as shown on the Drawings except that the detailed layout will be decided on site by the Construction Supervisor.

The front line of gabion works is intended to break the force of the river and cause deposition. Unless otherwise directed by the Construction Supervisor they shall be placed at a level with their tops approximately 600 mm above the river’s normal flow level.

Chain mesh fences shall be placed generally to the lines and detail as shown on the Drawings, or as directed by the Construction Supervisor. They are intended to act as a debris trap. Adequate numbers of plant/tree cuttings shall be planted to provide long term protection; these shall be placed to the direction of the Construction Supervisor. The cuttings shall be of a type known to grow strongly, with heavy root growth, in moist ground conditions, in the area in which the works are being carried out.

Where there is a requirement for provision of piles as part of the protection requirements details will be shown on the Drawings and the piles shall be installed to the satisfaction of the Construction Supervisor.

20.4 CONSTRUCTION OF LEVEES, PLATFORMS FOR RIVER TRAINING WORKS AND THE REALIGNMNET OF CHANNELS

Levees and platforms for river training works shall be constructed as shown on the Drawings or as directed by the Construction Supervisor. Before work commences, a survey shall be carried out to permit measurement. Realignment of channels and reshaping of river channels adjacent to bridges shall be carried out as directed by the Construction Supervisor.

20.5 MEASUREMENT AND PAYMENT

Re alignment of channels and re-shaping of river channels adjacent to bridges shall be measured in a manner approved by the Construction Supervisor to enable the quantity to be calculated in cubic metres (m^3).

The unit of measurement for the construction of levees and platforms for river training works shall be the cubic metre (m^3).

Gabions and Reno mattresses shall be measured as detailed in Clause 20.1.

The unit of measurement for fences shall be the linear metre and shall include the star pickets and wire ropes.

The unit of measurement for wire aprons shall be the square metre (m^2).

The unit of measurement for piles shall be number of given length and shall include the supply of piles, the provision of plant and pitching and driving the piles.

The unit of measurement for tripods of cuttings shall be number.

Measurement of Timber Retard walls shall be as per the items shown in the Bill of Quantities. No other payment will be made for construction of the walls as detailed on the Drawings.

20.6 GEOTEXTILE FABRIC

20.6.1 Properties

Geotextile fabric shall be a composite synthetic non-woven material which has been bonded into a homogeneous sheet from a continuous filament and needle punched. The fabric shall be resistant to degeneration caused by exposure to sunlight.

Geotextiles shall be stabilised against ultraviolet radiation such that when tested in accordance with AS 3706.11, they shall have retained strength of at least 50% after 672 hours of test exposure.

Unless otherwise noted on the Drawings, the geotextile fabric shall comply with the following:

	Property	Test Method	Requirement
a	Elongation	AS 3706.4	$\geq$ 30%
b	Grab strength	AS 2001.2.3.2 Method B	> 900
c	Tearing strength	AS 3706.3	> 350
d	G Rating	See Note	> 2,000
e	Flow rate Q_{100}	AS 3706.9	> 50 $l/m^2/s$
f	Permitivity	AS 3706.9	$\geq$ 0.5 s^{-1}
g	EOS O_{95}	AS 3706.7	< 0.12 mm
h	Mass	AS 3706.1	> 200 g/m^2

Note G Rateing = geo-textile strength rating = $(L \times h_{50})^{1/2}$

where L = burst strength determined in accordance with AS 3706.4 and

h_{50} = drop cone puncture resistance determined in accordance with AS 3706.5

20.6.2 Installation

Unless otherwise directed by the Construction Supervisor, geotextile fabric shall be placed directly on the surfaces behind or under rip rap, stone beaching, retaining walls, drainage backfill, gabions and Reno mattresses, and in any other location where shown on the Drawings or as directed by the Construction Supervisor. Overlay of the fabric shall take place as soon as possible after placement of the fabric. The fabric shall be joined by overlapping with a minimum overlap of 300 mm above water level and 900 mm below water level.

The Contractor shall exercise all care and employ only those construction techniques which will ensure that the geotextile fabric is not pierced or damaged during the entire construction period.

20.6.3 Measurement and Payment

The unit of measurement for geotextile fabric shall be in square metres of area shown for coverage on the Drawings or as directed by the Construction Supervisor. No extra payment shall be made for overlaps. Payment shall be made at the rate entered in the Bill of Quantities. This rate shall cover the supply and installation of the geotextile fabric, inclusive of wastage and overlapping, and includes all plant, labour and materials necessary to carry out the work.

20.7 ROCK RIP RAP

20.7.1 General

Rock rip rap bank protection shall be placed as shown in the Drawings or as required by the Construction Supervisor.

Rock for rip rap protection shall have a weight a specific gravity of 2.65 minimum unless shown otherwise on the Drawings or approved by the Construction Supervisor and shall comprise of hard, durable, crushed, quarried or natural stone. The rock shall be free of weak laminations and cleavages with a crushing strength of at least 25 Mpa

Rock shall not be single sized, but be a well graded mixture designed to ensure that all the interstices between the large rocks are filled with rocks of progressively smaller sizes. It shall range in diameter from 100 to 800 mm with at least 50% being in the 150 to 600 mm range.

The rock shall be predominantly angular in shape with not more than 25% of rock, distributed through the size gradation, having a length more than twice the breadth or thickness. No rock shall have a length exceeding 2.5 times its breadth or thickness.

20.7.2 Preparation of Slopes

Slopes shall be allowed the full thickness of the specified rip rap, and filter material. Slopes shall not be steeper than the slope specified in the Drawings. Where the slopes cannot be excavated to undisturbed material, the underlying material shall be compacted in accordance with Group 4 of this Specification. A footing trench shall be excavated along the toe of the slope where detailed in the Drawings.

20.7.3 Filter Fabric

When required by the Drawings, filter fabric as specified in Clause 20.6 shall be placed immediately prior to rock rip rap.

Rock rip rap shall be placed such that the laps in the filter cloth are maintained at all times.

20.7.4 Placing Rip Rap

Rip rap may be placed by hand or by machine and shall be placed to provide minimum of voids. Stone may be placed by dumping and spreading in layers by bulldozers or other equipment, provided that dumping and spreading operations do not cause rip rap to fracture such that the completed rip rap does not meet the requirements of Clause 20.7.1

20.8 CONCRETE ARMOURING (PRECAST CONCRETE UNITS)

20.8.1 General

Precast concrete armouring units shall be manufactured and placed as detailed on the Drawings

20.8.2 Preparation of Slopes and Base

Slopes and base shall be prepared as specified in Clause 20.7.2 and as shown on the Drawings

20.8.3 Placing Units

Precast concrete units shall be carefully placed as detailed on the drawings.

20.9 MEASUREMENT AND PAYMENT FOR RIP RAP AND CONCRETE ARMOURING

The Billed Rate for Rock Rip Rap and Concrete Armouring shall include for all work specified including supply and placement of materials, collection transportation and placement of rip rap and other filling, excavation, filling compaction and trimming necessary to construct the rock rip rap and concrete armouring to the lines and level specified.

Measurement of the quantity of rock rip rap should be in cubic metres supplied and placed.

Measurement of the quantity of concrete armouring shall be the number of units supplied and placed.

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GROUP 21

DAYWORKS

21.1 LABOUR

The item in the Bill of Quantities for the provision of Labour employed on Dayworks shall include for the cost of the actual hours worked by leading hands and workmen at the direction of the Construction Supervisor. The leading hands and workmen shall be paid at the basic rate of pay, together with such plus rates for skill only as specified by the Labour Act or the Employment Act of Vanuatu, or other appropriate wage- fixing body current at the time the work is carried out.

The basic rates shall be increased for overtime, where applicable, in accordance with the Registered Award. Overtime shall only be worked on the written instruction of the Construction Supervisor.

The percentage added by the Contractor to the costs as detailed above for overheads and profit shall include for:

(i) All charges of every description in accordance with the Labour Act or the Employment Act

(ii) Annual and Public Holiday pay

(iii) Long Service Leave

(iv) Use and maintenance of all small tools, plant and appliances not provided for under Clause 21.1

(v) Protective Clothing

(vi) Profit

(vii) Incentive and bonus payments

(viii) Supervision

The Construction Supervisor reserves the right to inspect time sheets of the Contractor's employees to verify Dayworks labour charges.

21.2 MATERIALS

The item in the Bill of Quantities for the provision of material expended on Dayworks shall include for the net price paid by the Contractor for materials delivered to the Site.

These net costs must be substantiated by Supplier's invoices.

The percentage added by the Contractor to the costs for overheads and profit shall include for:

(i) the cost of unloading at the Site,

(ii) taking into store,

(iii) storing as may be required,

(iv) profit, and

(v) the cost of transporting materials paid for by Dayworks to Site when it is not possible for the supplier to do so.

21.3 PLANT HIRE

21.3.1 General

In this Clause 19.3, the terms ‘Plant’, ‘Constructional Plant’ and the like shall mean ’Contractor’s Equipment’ as defined in Conditions of Contract.

The Contractor shall furnish and deliver Constructional Plant for hire, together with all supplies and repairs incidental to and necessary for the operation thereof in accordance with the provisions of the Contract.

21.3.2 Inspection Prior to Acceptance

All Constructional Plant offered for hire shall be made available for inspection by the Construction Supervisor when required. All items offered shall be subject to approval by the Construction Supervisor prior to acceptance. If the Construction Supervisor requires that various alterations or repairs be carried out on the items prior to their commencing work on the Site, any acceptance subsequently issued shall be subject to these alterations and repairs being satisfactorily completed.

If the Contractor proposes to use new plant, he shall furnish to the Construction Supervisor full details of the plant to be purchased and the plant shall be approved for use subject to it conforming with details submitted.

21.3.3 Operators

The Contractor at his own cost and expense shall provide an approved operator for all plant items to be furnished. Such operators shall be the servant of the Contractor, paid and accommodated by the Contractor, and under his supervision and control and may be removed or replaced by the Contractor at his discretion and the Contractor shall be solely responsible for any damage, loss or injury caused by any act or omission of such operator.

The actions and control of the operator shall also be subject to any provisions stated in the Contract.

21.3.4 Maintenance of Plant.

The Constructional Plant to be furnished under this Contract shall be in first class mechanical condition so as to produce satisfactory results. The Contractor shall keep all plant in good and substantial repair and shall carry out at his own cost all repairs and maintenance required. Damage to the plant, from whatever cause, shall be the sole responsibility of the Contractor.

Whatever the proper or possible output of any plant item which is being hired is reduced due to need for repairs and adjustments, such repairs or adjustments shall be made at the first available interval between working days or shifts; provided however that if such need for repairs or adjustments results in unsatisfactory output, and therefore, in the opinion of the Construction Supervisor, further operation of the plant will cause increased costs of the work, the Construction Supervisor shall have the right to suspend operations of the plant until the necessary repairs and adjustments are made.

The Contractor shall, at his own cost and expense, have available at all times a serviceman or mechanic together with the necessary wrenches, tools, etc. to maintain the equipment in proper working order. The Contractor shall also have available on the Site or within reasonable proximity, sufficient spare parts to enable normal maintenance repairs to be carried out.

The Contractor shall provide the workshop and tool facilities, labour and supplies necessary to satisfactorily carry out maintenance and repairs to the plant.

21.3.5 Fuel, Oil and Grease

The Contractor shall, at his own cost and expense, furnish all fuel, oil, grease and supplies necessary for the operation, servicing and maintenance of the Constructional Plant and shall be responsible for the storage of such items.

21.3.6 Safety of the Plant

The Contractor shall be responsible for the safety of the plant and of any accessories or tools or temporary works provided for the maintenance, servicing or operation of the plant.

21.3.7 Use of the Plant

Subject to the provisions of the Contract, the Construction Supervisor shall have the right to decide what plant, in what locality and on what days and for what hours during the continuance of the Contract, the Contractor’s plant will be required. During the Contract period the Constructional Plant shall be made available for inspection by the Construction Supervisor as and when required.

21.3.8 Transport of Plant to and from the Site.

In the event of plant brought to the Site on the written instructions of the Construction Supervisor and used only for Dayworks, the cost of transport to and from the Site will be paid to the Contractor net. The Contractor will not be paid for the hire of the plant during the time it is being transported to and from the Site.

21.3.9 Assessment of Hours of Hire.

The Contractor shall be paid for the actual hours worked by each item of plant in accordance with the Contract, valued at the scheduled rates and subject to the following:

(i) Payment shall not be made, in respect of any one item of plant, for more than eight hours in any one day unless the Construction Supervisor has requested in writing that such additional hours be worked

(ii) Payment shall not be made for hours worked which have not been directed by the Construction Supervisor to be worked.

(iii) Payment shall not be made for time when the plant was unserviceable or broken down or when the Construction Supervisor has suspended the hire of the plant as provided for in Sub-Clause 19.3.4 above. In this respect, when one item of plant which forms a group for a construction task, becomes unserviceable or is suspended, and the task cannot efficiently be carried out in the absence of this item of plant, the Construction Supervisor shall have the right to suspend the hire on the remaining items in the unit until all necessary items are reinstated to a satisfactory condition.

(iv) Payment shall be made for the time consumed in making emergency minor repairs and adjustment necessary to keep the plant items properly operating provided however, that such accumulated delay time in any one day does not exceed one tenth of the established working time for that calendar day and provided also that the Contractor has complied with all other requirements of the Specification with regard to the maintenance of the plant.

(v) The Construction Supervisor shall have the right to deduct from the number of hours to be certified for payment, such hours as he determines that the plant was not gainfully employed in carrying out the Works due to failure of the operator to maintain normal production. The Construction Supervisor shall provide the Contractor with details of the number of hours so deducted in respect of each item of plant and the reason why the hours have been deducted.

(vi) Payment shall not be made for time during which the plant is not able to work due to adverse weather conditions.

(vii) The Contractor will be paid for time spent by plant travelling within the Site provided that the Contractor’s transport proposals are approved by the Construction Supervisor and provided also that Sub-Clause 21.3.9 (viii) does not apply.

(viii) Payment shall not be made for time during which plant, which is not able to be self-propelled to its working location, is being loaded onto or carried by a truck or float, however the cost of the transport as is provided shall be paid for at the rate tendered for the number of hours which the transport item actually spent loading, hauling and unloading the plant but not including time spent in positioning and returning the transport item.

21.3.10 Evidence of Hours Worked

Further to the requirements of Clause 52.4 of the Conditions of Contract, the Contractor shall prepare dockets showing the number of hours worked by each plant item in accordance with the Contract. These dockets shall be signed at the end of each day's work by the Contractor and the Construction Supervisor and such signature shall indicate that the dockets area true record of the number of hours worked during the day. Should the Construction Supervisor dispute any figures shown on the dockets he shall, prior to signing, note the figures that are in dispute and advise the Contractor, in writing, of the hours he considers are correct and such dispute shall be dealt with as provided for in the Contract.