MINISTRY OF PUBLIC WORKS
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TRANSPORT

MAINSTREAMING APPROPRIATE LOCAL ROAD STANDARDS AND SPECIFICATIONS AND DEVELOPING A STRATEGY FOR THE MPWT RESEARCH CAPACITY

SEACAP 3

Low Volume Rural Road Standards and Specifications: Part II

Pavement Options and Technical Specifications

UNPUBLISHED PROJECT REPORT

MAINSTREAMING APPROPRIATE LOCAL ROAD STANDARDS AND SPECIFICATIONS AND DEVELOPING A STRATEGY FOR THE MPWT RESEARCH CAPACITY
SEACAP 3

Lao Low Volume Rural Road Standards and Specifications: Part II

Pavement Options and Technical Specifications

Prepared for: Project Record:	**SEACAP 03. Mainstreaming Appropriate Local Road Standards and Developing a Strategy for the MPWT Research Capacity**
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ABBREVIATIONS & ACRONYMS

AADT	Average Annual Daily Traffic
ADT	Average Daily Traffic
ASEAN	Association of South East Asian Nations
CBR	California Bearing Ratio
CNCTP	Cambodia National Community of Transport Practitioners
CRC	Community Road Committees
CSA	Crushed Stone Aggregate
CSIR	Council for Scientific and Industrial Research (South Africa)
DBM	Dry Bound Macadam
DBST	Double Bituminous Surface Treatment
DCP	Dynamic Cone Penetrometer
DfID	Department for International Development
DoR	Department of Roads
EADT	Equivalent Average Daily Traffic
EDCs	Economically emerging and Developing Countries
ENS	Engineered Natural Surface
esa	equivalent standard axles
FHWA	Federal Highways Association (US)
FM	Fines Modulus
FWD	Falling Weight Deflectometer
GMSARN	Greater Mekong Sub-region Academic and Research Network
GoL	Government of Lao PDR
gTKP	global Transport Knowledge Partnership
GVW	Gross Vehicle Weight
GWC	Gravel Wearing Course
HDM4	Highway Development and Management Model
HQ	Headquarters
HRD	Human Resource Development
IFG	International Focus Group
IFRTD	International Forum for Rural Transport Development
ILO	International Labour Organisation
IRI	International Roughness Index
km	kilometre
LCS	Low Cost Surfacing
LRD	Local Roads Division (DoR)
LVRR	Low Volume Rural Road
m	metre(s)
MCTPC	Ministry of Communication, Transport, Post and Construction (now MPWT)
MERLIN	**M**achine for **E**valuating **R**oughness using **L**ow-cost **IN**strumentation
mm	millimetre(s)
MoU	Memorandum of Understanding
MPa	Mega Pascals
MPWT	Ministry of Public Works and Transportation (formerly MCTPC)
NGPES	National Growth and Poverty Eradication Strategy

NUOL	National University of Lao
OCTPC	Office of Communication Transport Posts and Construction (District Level)
OPWT	Office of public works and transport (at district level – formerly OCTPC)
ORN	Overseas Road Note
PAD	Personnel and Administration Division (MPWT)
PCU	Passenger Car Unit
Pen Mac	Penetration Macadam
PIARC	World Road Association
PTD	Planning and Technical Division (DoR)
QA	Quality Assurance
Ref.	Reference
RRGAP	Rural Road Gravel Assessment Programme (Vietnam)
RRSR	Rural Road Surfacing Research (Vietnam)
RRST	Rural Road Surfacing Trials (Vietnam)
RT1	Rural Transport 1st Project, Vietnam
RT2	Rural Transport 2nd Project, Vietnam
RT3	Rural Transport 3rd Project, Vietnam
SBST	Single Bituminous Surface Treatment
SCC	SEACAP Coordinating Committee
SEACAP	South East Asia Community Access Programme
SIDA	Swedish International Developments Cooperation Agency
SOE	State Owned Enterprise
T	Tonne
TRL	Transport Research Laboratory
UK	United Kingdom
UNOPS	United Nations Office for Project Services
VN	Vietnam
VOCs	Vehicle Operating Costs
VPD	Vehicles per day
WBM	Water Bound Macadam
WLAC	Whole Life Asset Costs
WLC	Whole Life Costs

1 Introduction

1.1 Background

This second Low Volume Rural Roads document is concerned with the design of appropriate pavement and surfacing options and related technical specifications and follows on from Part I: LVRR Classification and Geometric Standards.

Part I presented the general background to the overall Standards and Specification documentation and this may be summarised as follows:

- Reducing transport costs through rural road improvement generates significant reductions in poverty and this is an important component of the National Growth and Poverty Eradication Strategy (NGPES).
- It is estimated that approximately 11,000 km of rural roads will have to be rehabilitated and approximately 10,000 km of new rural roads constructed to develop the local road network.
- It is necessary that the rural roads are designed, constructed and maintained to appropriate standards.
- Significant successful research has been undertaken by DfID and other organisations on identifying appropriate Low Volume Rural Road (LVRR) solutions.

Undertaking research and developing likely solutions is not nearly enough; there has to be a framework within which they can be mainstreamed. Suitable LVRR Standards are therefore seen as essential to provide the context and control framework within which local resource-based pavement options may be assessed and selected for appropriate use in Lao.

1.2 Technical context

Key general issues that govern the technical context for the LVRR pavement design and technical specifications may be summarised as follows:

- The road designs in this Standard are appropriate for one traffic lane and are intended for the construction, rehabilitation or improvement of roads to all-weather standard to provide all-year access to villages and communities.
- In developing the recommendations provided in this document, good road engineering principles have been adhered to and careful consideration has been given to the safety of pedestrian, non-vehicular traffic, and light 2 or 3-wheeled motorized traffic on LVRRs.
- The road Specifications covered by this document are suitable for routes with traffic that will include vehicles up to medium sized commercial vehicles and loadings that will normally not exceed 4.5Tonnes on a single axle. This categorisation has been identified as appropriate for a substantial portion of the rural road network in consideration of current and future economic conditions and traffic demand, and pragmatic management of the road network with the limited resources available.
- The roads covered by this document are not suitable for the passage of heavy commercial vehicles because of the loading they will place on the pavement structure, and importantly the total road widths are inadequate for regular passages of these vehicles, bearing in mind both their width and length.
- Where a sealed pavement is proposed it has an assumed minimum pavement design life of 12 years. Design life decisions usually involve a combination of economic and policy considerations and rural road pavement design life typically varies between 10 and 15 years.

During this design life, periodic maintenance seals may be required to preserve the structural asset on some types of pavement.

- The recommended road designs and specifications are compatible with an overall Environmentally Optimised Design (EOD) strategy ranging from individual Spot Improvements through to overall road link construction or upgrade.

- The designs and specifications are compatible with key road environment factors within Lao, such as climate, materials resources, hydrology and soaked subgrade strength as well as taking into account the reported road construction and maintenance regimes.

1.3 Document content

This document is based around the presentation of tables relating to the selection and design of appropriate LVRR pavements and surfacings (Chapter 2). These Tables are backed by sections on the principles involved together with the key technical assumptions, constraints and recommendations (Chapter 3). Drainage issues are covered in Chapter 4. The related Technical Specifications are contained separately in two Appendices:

A: LVRR Road Pavements and Surfacings and

B: Road Drainage.

1.4 Document use

This document is intended for use in conjunction with two companion LVRR documents:

- Lao LVRR Standards and Specifications Part: I: Classification and Geometric Standards, - containing the definition of the traffic limits to Lao LVRRs and the related geometric standards.
- Lao LVRR Standards and Specifications Part III: Guidelines on the Application of LVRR Standards and Specifications – containing advice on the application of Parts I and II within an Environmentally Optimised Design strategy ranging from Spot Improvement to the construction or upgrade of whole road links.

Other documents dealing with issues such as structures (bridges, culverts, retaining walls) and maintenance may at some future date be incorporated into the LVRR suite of Standards.

An important aspect of the NGPES is the increased decentralisation of rural road management to Community Road Committees (CRCs) at ‘kum ban’ (village cluster) or village level. For this reason this document is primarily aimed at the design, construction and supervision of LVRRs by district authorities (OPWTs). It is recognised that the Technical Specifications will also be used mainly by small to medium contractors, most of whom will have limited experience in road building procedures other than those associated with unsealed gravel wearing course construction.

It is intended that all rural roads falling within the Low Volume envelope, whether funded by Donors, NGOs or GoL should be designed and constructed following these Standards.

2 LVRR Pavement and Surfacing Options

2.1 Introduction

The LVRR principles require that as much use as possible should be made of locally available materials and the least use of more expensive high quality pavement materials, particularly where these have to be hauled long distances. This requirement has been met by using the thinnest roadbase and sub-base that is possible with reasonable risk considerations and making up the required total protection of the subgrade by using a capping layer. The capping layer uses a material quality that is significantly lower than the sub-base requirement. It is expected that capping layer materials will be available either close to the project site or at sources to be used for upper pavement materials. There is often waste of the lower quality materials encountered in the process of extracting the higher specification materials suitable for pavement uses.

2.2 Pavement types and thickness

The pavement types and the thickness required for each layer are given in Table 1 for unsealed roads; in Table 2 for sealed roads and in Table 3 for concrete roads.

Table 1, Pavement Thicknesses Required: Unsealed Pavements

Traffic Group A			Traffic Group B		
Subgrade Soaked CBR%	**Pavement Layer**	**Layer Thickness D (mm)**	**Subgrade Soaked CBR%**	**Pavement Layer**	**Layer Thickness D (mm)**
2-3.9	Wearing Course	200	2-3.9	Wearing Course	200
	Capping Layer	250		Capping Layer	300
4-6.9	Wearing Course	200	4-5.9	Wearing Course	200
	Capping Layer	100		Capping Layer	150
>7	Wearing Course	200	6-7.9	Wearing Course	200
	Capping Layer			Capping Layer	100
			>8	Wearing Course	200
				Capping Layer	0

Note:
Layer thicknesses D in the above table are composed of a minimum structural thickness element (d^1) plus an additional thickness (d^2) needed to compensate for gravel loss between maintenance regravelling operations, so that $D=d^1+d^2$.

In this case the d^2 element has been taken as a constant 100mm to allow a general 3-4 year regravelling cycle although the actual period will vary according to road-specific characteristics. This issue is discussed further in Part III of the LVRR Standards and Specifications.

Table 2, Pavement Thicknesses Required: Sealed Pavements

Subgrade Soaked CBR%	Pavement Layer	Traffic Group A Layer Thickness (mm)	Traffic Group B Layer Thickness (mm)
2-3.9	Surface	Seal	Seal
	Base	100	100
	Sub-Base	100	150
	Capping Layer	200	275
4-6.9	Surface	Seal	Seal
	Base	100	100
	Sub-Base	100	150
	Capping Layer	100	175
7-10.9	Surface	Seal	Seal
	Base	100	100
	Sub-Base	100	150
	Capping Layer	0	100
>11	Surface	Seal	Seal
	Base	100	100
	Sub-Base	100	150
	Capping Layer	0	0

Table 3, Pavement Thicknesses Required: Concrete Pavements

Subgrade Soaked CBR%	Pavement Layer	Traffic Group A Layer Thickness(mm)	Traffic Group B Layer Thickness(mm)
2-6.9	Surface (concrete)	150	150
	Sub-Base	150	150
>7	Surface(concrete)	150	150
	Sub-Base	100	100

The following are some key points regarding the application of these Tables:

1. The required quality for natural materials within Tables 1 to 3 may vary, as shown in Table 4
2. The subgrade condition may be determined by laboratory testing, or assessed from DCP site measurements towards the end of the wet season.

3. The required thickness of the GWC is based on consideration of the annual gravel loss that is expected; the minimum GWC cover to the subgrade or capping layer that is required (100mm), and the period that is expected between initial construction and initial regravelling.
4. It follows that for the range of conditions experienced in Laos, for a gravel surfaced LVRR it will be necessary to carry out periodic maintenance regravelling on a number of occasions through the design life of the road. Relevant maintenance issues are outlined in Part III of the LVRR Standards and Specifications.
5. Quoted CBR strengths are for the 4-day soaked condition.
6. Material strengths are the minimum requirements and there are likely to be occasions where it is sensible to use the nearest available materials even though these exceed the minimum requirements.
7. Technical specifications for the relevant pavement and surfacing options are included in Appendix A.

Table 4, Material Quality Required

Pavement layer	Traffic Group A		Traffic Group B	
	Unsealed GWC CBR%	Sealed Flexible CBR%	Unsealed GWC CBR%	Sealed Flexible CBR%
Base/GWC	25	50	25	80
Sub-Base	NA	25	NA	25
Capping	10	10	10	10
For **concrete roads** the requirements for pavement layer materials in all subgrade categories are:				
Concrete, minimum 28-day cube strength:			20 MPa	
Sub-base CBR			25%	

The matrix of pavement types and thicknesses is contained within two principal Traffic Groups which have been defined as follows:

Traffic Group A: An AADT of all 4-wheeled vehicles of less than 150, and a cumulative traffic loading of less than 10,000esa's; likely to comprise mostly small trucks of the Kolao-type vehicles.

Traffic Group B: an AADT of all 4-wheeled vehicles of less than 150, and a cumulative traffic loading of greater than 10,000esa's and less than 100,000esa's; likely to comprise a mix of small and medium trucks all with an axle loading of less than 4.5T; for example Kolao, Isuzu and Gaz 66 vehicle types.

In practical terms, the designer simply has to determine whether:-

i) Traffic currently exceeds an AADT of 150, or is expected to within the design life or the road will be used regularly by any numbers of heavy trucks – if so, MPWT standard designs and Specifications should be used.

ii) Traffic currently is less than AADT of 150, and is expected to remain so within the road design life and a substantial number of medium trucks (e.g. Gaz 66) will regularly use the road – if so, the proposed MPWT LVRR designs and Specifications should be used for **Traffic Group B**.

iii) Traffic currently is less than AADT of 150, and is expected to remain so within the road design life and the largest vehicles are expected to be light trucks of the Kolao-type – if so, the proposed MPWT LVRR designs and Specifications will be used for **Traffic Group A**.

The risks of this approach are acceptable if the future traffic is monitored so that if traffic increases beyond the design parameters, then arrangements can be made to upgrade the pavement in a timely way.

2.3 Pavement and surfacing matrix

Table 5 presents an LVRR matrix for an initial list of five pavement and surfacing options based on the data contained in Tables 1 to 3:

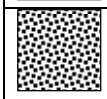
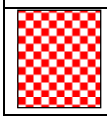
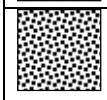
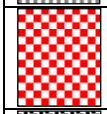
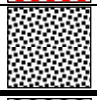
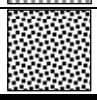
Unsealed: Gravel Wearing Course

Flexible: Sealed Gravel; Sealed Armoured Gravel; or Sealed Macadam

Rigid: Non Reinforced Concrete

Further options may be added to this list as results and recommendations become available from relevant rural road trials in Vietnam and Cambodia as well as those in Lao. In particular, options for improving the quality of locally available materials by lime or cement stabilisation techniques are likely to be of significant importance.

Table 5, Initial Pavement and Surfacing Matrix

		Layer	Layer Materials	Comments on Selection and Use
Unsealed Gravel		GWC	2@100mm gravel III	Standard Lao procedure understood by local small contractors. Sustainability is totally dependant upon effective and funded routine and periodic maintenance systems being in place. Limitations on use further discussed in Part III.
		Capping	As per Table 1	
Sealed Natural Gravel		Seal	DBST or Double Otta Seal	An option currently favoured in Lao in peri-urban situations. Anecdotal evidence indicates a poor performance record. Option is a high risk if gravel III is used in both layers even for very low volumes of traffic with no trucks. With gravel II in the upper layer this option is suitable for Traffic Group A, but not Group B. It is a possible Spot solution in low traffic situations.
		Base/Sub-base	1@100mm gravel II 1@100mm gravel III.	
		Capping	As per Table 2	
Sealed Armoured Gravel		Seal	DBST or Double Otta Seal	This is a valid option for an upgrade for existing gravel roads or spot solution for an overall unsealed gravel road. High risk option if there is any danger of axle loading over 4.5T.
		Armour	70mm CSA	
		Base/Sub-base	2@100mm gravel III	
		Capping	As per Table 2	
Sealed Macadam		Seal	DBST or Double Otta Seal	A standard sealed road procedure appropriate for areas where suitable good quality gravel or crushed stone is available in economic quantities. Dry-bound requires the use of both static and vibrating compaction machinery; the latter may not be readily available for small contractors. Wet-bound is not appropriate over moisture-susceptible subgrades
		Base	100mm Macadam	
		Sub-base	100mm Macadam	
		Capping	As per Table 2	
Non Reinforced Concrete		Concrete surface	150mm non-reinforced concrete	High cost option suitable for high rainfall, steep gradient and flood prone area spot improvement. Minimal maintenance if properly constructed and cured. Procedures generally well understood by local small contractors.
		Sub-base	100mm Gravel III	

Notes:
Gravel quality is the minimum required in each layer
Gravel I: Soaked CBR 80%
Gravel II Soaked CBR 50%
Gravel III Soaked CBR 25%

3 Key Technical Issues

3.1 Surfacing materials

3.1.1 Gravel wearing course

Gravel roads are difficult to design in a pavement engineering sense because the wearing course is a wasting resource. Moreover, the material requirements can be conflicting. They should contain sufficient plastic fines to bind the aggregates in the mix together in drier weather and prevent ravelling, corrugations and excessive dust, but the quantity of plastic fines should not be excessive such that too much strength is lost in wetter weather.

The gravel wearing course provides the vitally important means of protecting the capping layer as well as the subgrade. It should be apparent to the road designer that the wearing course cannot be permitted to erode to such an extent that the passability of the road will be lost, and with it accessibility and the purpose of the road. In the LVRR specifications the gravel wearing course specifications in the current LRDM have been largely retained, but the existing CBR requirement of 20% (15% for 15 commercial vehicles per day) has been increased to a CBR of 25%. This remains a very low specification in terms of those required for sealed pavements and materials of this quality should not be sealed directly without being improved to roadbase requirements.

3.1.2 Sealed surfacings

Either a double surface dressing (DBST) which uses crushed aggregates or a double Ottaseal which uses graded aggregates may be used for the sealed flexible paving options. The choice will depend upon the availability and cost of suitable aggregates. When constructed as a double layer either will provide a durable impermeable seal for the road for about 8 (DBST) to 12 years (Otta seal). It is expected that the DBST will require a maintenance re-seal after about 8 years to restore its effectiveness and impermeability. Both of these surfacing types are quite flexible and tend to follow any minor movements in the road without cracking for most of their design life if constructed properly. With the design life of 12 years, both of these sealed surfaces could be expected to be overlaid with a treatment such as thin penetration macadam to restore any deformation and seal properties at the end of the anticipated 12 year design period. This would provide a further extension to the life of the road.

Although asphalt concrete is most likely to be excluded on a cost basis, it is also excluded on technical grounds because it is not expected to be sufficiently flexible and therefore may tend to crack on the types of sub-bases and bases being specified for LVRR. For similar reasons asphalt concrete should not be used as a strengthening overlay on these LVRR designs.

3.1.3 Concrete surfacing

The concrete surface for the rigid pavement option is the surfacing of the road. It must be well constructed with sufficient crossfall for drainage and with sufficient skidding resistance to provide safe passage. The surface should be provided with a texture by forming shallow ridges at right angles to the direction of the road to aid skidding resistance.

3.2 Pavement construction materials

3.2.1 Roadbase

Generally a CBR 80% is required for the roadbase material, but if material of this quality is not available then CBR 50% can be used for Traffic Group A. A CBR lower than 50 is not advisable in the roadbase of sealed roads because there would be a serious risk of shear failure of the roadbase. An exception is possible where there are no small, medium or heavy trucks in the traffic mix. as indicated in Table 4.

A material with a CBR of 25% and meeting the other requirements of a Gravel Wearing Course may be used provided that an armouring layer of graded crushed stone with a nominal maximum particle size greater than 25mm and less than 38mm is laid and compacted on top of the GWC. The top of the GWC should be sufficiently scarified to allow the graded stone to substantially penetrate and key into the GWC. The engineer should target an initial compacted thickness of 70mm for the armouring layer.

To obtain the desired strengths and characteristics from available natural materials it is expected that the quality of natural gravels can be improved by screening and re-blending components of the material, and or the addition of crushed aggregates.

Although not as yet included within the LVRR design options, it is envisaged that in the future lime or cement-stabilised materials will provide strong and relatively impervious layers resistant to rainfall and erosion, both in the pavement and across the shoulder. Experience indicates that repairs and maintenance can be undertaken readily at a local level using these stabilised materials.

3.2.2 Sub-base

The sub-base is an important load spreading layer in the completed pavement. It enables traffic stresses to be reduced to acceptable levels in the subgrade, it acts as a working platform for the construction of the upper pavement layers and it acts as a separation layer between subgrade and roadbase. Under special circumstances it may also act as a filter or as a drainage layer. In wet climatic conditions the most stringent requirements are dictated by the need to support construction traffic and paving equipment. In these circumstances the sub-base material needs to be more tightly specified than in dry climatic conditions. The selection of sub-base materials will therefore depend on the design function of the layer and the anticipated moisture regime, both in service and at construction.

The minimum sub-base strength requirement for LVRR roads is a soaked strength of CBR of 25%.

For the Lao conditions, sand sub-bases and sand cushions are not recommended under a concrete slab. If the joint seals between slabs leak, the sand is prone to saturation and erosion and pumping under traffic causing voids to form under the slab, resulting in loss of support and subsequent cracking of the slab.

3.2.3 Capping layer

In a similar way to the sub-base, the capping layer provides a construction platform over weaker soils and is an essential layer in protecting the subgrade from excessive stresses. A soaked CBR of 10 % is required for the capping layer except where the subgrade soils are very weak. Particular care is required in placing and compacting material on very weak subgrades, of CBR 2 or 3 per cent.

It is strongly recommended that a capping layer is used as shown in Table 1 and 2. However, if suitable material cannot be obtained, the sub-base (or gravel wearing course) thickness must be increased by 65% of the thickness of the capping layer shown in the Tables, rounded to the nearest 25mm.

3.2.4 Shoulders

Shoulders are an essential element of the structural design of a road, providing lateral support for the pavement layers, as well as providing the space for vehicles to pass and hence will be intermittently trafficked. To simplify pavement design engineers usually specify that the shoulders are constructed of the same material to the full width of the road. Thus the shoulders will have the same permeability as the pavement.

However, it will generally be too expensive to construct them to the full width using wholly crushed materials. In addition shoulder materials that are not slightly plastic will tend to ravel and lack sufficient cohesion to withstand the abrasive action of traffic and hence may need to be stabilised in some way.

In circumstances where extending the roadbase is not possible the shoulder material should be selected using the same principles as for a gravel-surfaced road or a sub-base to carry construction traffic. Thus the material should be strong enough to carry occasional vehicles and should be as cohesive as possible without being too weak when wet. The material will normally be of sub-base quality and the soaked CBR value at the specified density should exceed 25 per cent.

It is also very desirable if at least the outer edge of the shoulder is able to support the growth of grasses which help to bind the surface and prevent erosion.

It should be recognized that unsurfaced shoulders often require considerable maintenance if satisfactory performance is to be guaranteed.

4 Drainage

4.1 General

Rainfall and storm rainfall intensities are very high in Lao compared to many other countries with similar LVRR basic access requirements. Much of the country receives rainfall above 2000mm per annum over a 7.5 month wet season, and storm intensities of 150mm per hour are indicated in the Lao Road Design Manual for a 5 or 10 minute storm with a return period of two years.

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. 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 rainwater quickly and the top of the subgrade or improved subgrade must be raised above the level of the local water table to prevent it being soaked by ground water.

A good road drainage system, which is properly maintained, is vital to the successful operation of a road and the road designs described in this standard are based on the assumption that the side drains and culverts associated with the road are properly designed and function correctly.

Drainage within the pavement layers themselves is an essential element of structural design because the strength of the subgrade used for design purposes depends on the moisture content during the most likely adverse conditions. It is impossible to guarantee that road surfaces will remain waterproof throughout their lives, hence it is important to ensure that water is able to drain away quickly from within the pavement layers.

4.1.1 Pavement cross-section

The width of the carriageway and the overall geometric design of the road are dealt with in Part I of these standards.

Suitable values of camber or crossfall for sealed and gravel surfaced roads are:-

- Gravel roads should be constructed to 6% crossfall and maintained at between 4 and 6% through a programme of regular routine maintenance by manual re-shaping or motor/towed grading,
- Bitumen sealed roads should be constructed to a crossfall of 4%,
- Concrete slab pavements may be constructed to a crossfall of 1 – 2 % to facilitate screeding and compaction of the concrete.

It is important that each of the pavement layers and the subgrade are given at least the same crossfall as any layer immediately above.

4.1.2 Drainage of layers

Provided the crossfalls indicated above are adhered to and the bituminous surfacing and the shoulders are properly maintained, rainwater falling on the road will be shed steadily over the shoulders. When permeable roadbase materials are used, particular attention must be given to the drainage of this layer. Ideally, the roadbase and sub-base should extend right across the shoulders to the drainage ditches, this has however significant cost implications.

If it is too costly to extend the roadbase across the shoulder, the sub-base should be extended to the shoulder and consist of a material that is able to carry water away to the side ditches by providing a continuous drainage layer of pervious material.

The 'trench' type (or boxed-in) cross-sections in which the pavement layers are confined between continuous impervious shoulders should not be used. If this type of design is unavoidable, drainage grips of graded granular free draining material, 300mm wide and extending from under the base and for the full depth of the sub-base layer under the shoulder are recommended every 5 metres.

In circumstances where the subgrade itself is permeable and can drain freely it is preferable that vertical drainage is not impeded. This is achieved by ensuring that each layer of the pavement is more permeable than the layer above. In these circumstances, the additional drainage layer through the shoulders is not required.

4.1.3 Shoulder drainage

Crossfall on the finished shoulders against sealed or concrete pavements should be steeper than the adjacent paving; between 3 and 5%.

4.2 External drainage

The four main functions of the external drainage system:

- To convey rainwater 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.

Both in the design and in maintenance of drainage, it is important to interfere as little as possible with the natural flow of water. Culverts on natural water-courses should follow the existing alignment as closely as practicable and re-alignment (often 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 turnouts where side drains cannot be discharged to existing watercourses. In sidelong 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.

Suitable designs for LVRR side ditches and cut of drains are given in the Lao Road Design Manual. These are summarised in Appendix B to this document. Designs and specifications for culverts, drifts and bridges will be contained in separate LVRR Standards and Specification documents. Currently, guidance on these topics may be obtained from the following documents:

TRL Ltd, 1997, Principles of Low Cost Road Engineering in Mountainous Regions

TRL Ltd, 2000, Overseas Road Note 9, A Design Manual for Small Bridges.

5 Acknowledgements

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MAINSTREAMING APPROPRIATE LOCAL ROAD STANDARDS AND SPECIFICATIONS AND DEVELOPING A STRATEGY FOR THE MPWT RESEARCH CAPACITY
SEACAP 3

Low Volume Rural Road Standards and Specification: Part II

Appendix A

LVRR Pavement Specifications

INTRODUCTION

The following sections contain general pavement layer specifications covering the options included to date in the current SEACAP 3 LVRR Standards and Specification documents.

It is appreciated that individual LVRR construction contracts may require either a particular contract style or be compatible with specific technical requirements, in which cases they can be adopted or amended as required.

It is expected that additional specifications will be included in this LVRR list as further information becomes available from ongoing LVRR trial programmes.

LOW VOLUME RURAL ROAD SPECIFICATIONS
STANDARD PARAGRAPHS

S.01 TRIAL SECTIONS

1) Prior to the commencement of the sub-base, base or wearing course laying operations, the Contractor shall construct trial lengths as directed by the Engineer. The materials used in the trials shall be those approved for use in the relevant layers and the equipment used shall be that which the Contractor intends to use for the work proper.

2) The objective of these trials is to determine the adequacy of the Contractor's equipment, the loose depth measurements necessary to result in the specified compacted layer depths, the field moisture content, and the relationship between the number of compaction passes and the resulting density of the material.

3) Each trial length shall be 100 m long, and the Engineer may order up to 10 such lengths. The trial lengths will be incorporated in the Works.

4) The Engineer may direct that from the compaction trials results the control of the constructed gravel course compaction may be by 'method specification', i.e. a minimum number of passes of the approved roller. The Engineer may at any time elect to revert to 'end product' testing as the basis of compaction approval.

S.02 MATERIALS

1) This document provides target specifications for natural materials that should be used in the construction of pavement layers. In the event that appropriate material cannot be reasonably obtained then the Contractor may submit alternative materials to the Engineer for approval. This approval may involve adjustments to the pavement design. Under no circumstances may the Contractor use non-specification materials without the prior approval of the Engineer.

S.03 PREPARATIONS

1) The Contractor shall establish sufficient setting out 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-worked and sufficient new material added to attain the correct shape.

2) The surface on which material is to be placed shall be shaped, compacted, smooth, hard, uniform and meeting the requirements of these Specifications, with all irregularities having been bladed out and rolled down, and approved by the Engineer prior to the placing of base material.

S.04 MATERIAL SAMPLING AND TESTING

1) The Engineer shall exercise control over quality of the materials incorporated and works performed through quality control tests carried out to the frequencies defined by the Engineer. The frequencies are the minimum, and the Engineer shall have the authority to have these tests at more frequent intervals where quality of a material or work is in doubt.

2) Materials from each source should be submitted to the Engineer for approval in advance of the commencement of work. Where testing facilities are not conveniently available, the Contractor shall submit samples to the Engineer for approval.

3) Visual inspections will be made to check compliance with the drawings and specifications. Shallow inspection pits shall be excavated through the completed roadbase on centre line and 0.5 metres from each edge of the roadbase every 0.5 km and to be properly reinstated, all as directed by the Engineer. Component layer thickness tolerances to be -5 mm to +15 mm.

S.05 Mode of Payments

1) 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.

GRAVEL SUB-BASE, ROADBASE & WEARING COURSE: LVRR-1

1.01 GENERAL

1 Scope

1) This work shall consist of furnishing, placing, compacting, shaping and finishing one or more layers of natural gravel material or a mix of gravel and natural or crushed sand/gravel/stone and water on a prepared and approved surface in accordance with the Specification, in conformity with the lines, grades, thickness and typical cross sections shown on the Drawings or established by the Engineer.

1.02 MATERIALS

1 General

2) The material shall consist of graded gravel material or a mix of gravel material and natural river sand/gravel or crushed stone/gravel. The gravel and the sand/gravel/stone shall be materials from selected and accepted sources and be suitable for mixing, as required, to comply with these Specifications.

3) All material shall be free from topsoil, organic matter, shale or other deleterious matter and shall be of such quality that it will bind readily to form a firm, stable pavement layer or surface.

4) The constituent materials shall be screened and mixed if necessary to achieve the Specification requirements. The proportions of the different materials to produce the final properties of the gravel material shall be established by testing and full scale field trials.

5) Placed gravel will be according to the requirements of surfacing gravel or for incorporation in a structural pavement as specified.

2 Grading Requirements

1) The materials shall have the following grading characteristics when tested in conformity with AASHTO T88:

AASHTO Sieve		**Gravel Material (Type I/II/III)**
(mm)	**Designation**	**Percentage Passing (by weight)**
50		100
37.5		90 - 100
25		75 - 95
9.5		50 - 85
4.75	No. 4	35 - 75
2.0	No.10	25 -60
0.425	No.40	15 - 40
0.075	No.200	5 - 30

2) The grading is based on aggregates of uniform specific gravity, and the percentage passing the various sieves are subject to adjustment by the Engineer when aggregates of varying specific gravities are used.

3. Other Requirements

1) Gravel material shall have the following characteristics when compacted on the road:

Description	Test Method		Requirements
- Liquid Limit	AASHTO T 89	Gravel I/II	< 35%
		Gravel III	< 45%
- Plasticity Index	AASHTO T 90	Gravel I/II	5-15%
		Gravel III	5-20%
- CBR (4 days soaked) (95% modified AASHTO)	AASHTO T 193	Gravel I	min. 80%
		Gravel II	min. 50%
		Gravel III	min. 25%

4 Acceptance

1) Samples for determination of CBR values shall be obtained from uncompacted layers on the road for testing. Samples for Atterberg Limits and grading shall be taken from compacted layers.

2) Final acceptance of the material by the Engineer will be based on the gravel as placed on the road.

1.03 EQUIPMENT

1 General

1) The type and condition of the grading, watering and compaction equipment shall be approved by the Engineer.

2) The number of required passes of the compaction equipment shall be confirmed by correlation with achieved strength and density in trial sections at the beginning of site operations.

1.04 COMPACTION TRIALS

1) The Contractor shall not proceed with gravel laying until the methods and procedures established in the compaction trials (as described in Specification LVRR-S.01) have been approved by the Engineer.

1.05 CONSTRUCTION REQUIREMENTS

1 Spreading

1) The surface on which gravel material is to be placed shall be well compacted, smooth, hard and uniform, with all irregularities having been bladed out and rolled down, meeting the

requirements of these Specifications and approved by the Engineer prior to the placing of gravel course material.

2) The quantity of the different materials to be used in any mix (mechanical stabilisation) shall be determined by tests undertaken by the Contractor as approved by the Engineer.

3) The gravel course materials shall be delivered to the roadway and shall be placed, mixed and spread on the prepared surface in a uniform layer or layers not exceeding 200mm and not less than 60mm in compacted thickness.

4) The materials shall be handled so as to avoid segregation. Segregated materials shall be remixed until uniform. No "skin-patching" shall be permitted.

5) No hauling or placement of material will be permitted when, in the opinion of the Engineer, the weather or road conditions are such that the hauling operations will cause cutting or rutting of the surface or cause contamination of the gravel material.

6) Spreading shall be done by either by hand or by approved graders which distribute the material to the required width and loose thickness. If a grader is operated causing segregation or leaves ridges or other objectionable marks on the surface which cannot be eliminated easily or prevented by adjustment of the grader operation, the use of such a grader or grader operator shall be discontinued.

2 Compaction

1) The moisture content of the gravel material shall be adjusted prior to compaction, by watering with approved sprinkler trucks or by using approved labour based procedures or by drying out to that appropriate to obtain the specified density for the gravel course with the Contractor's equipment. The gravel course shall be compacted to the following standards

- Gravel Wearing Course: 98% MDD Modified AASHTO
- Road-base: 98% MDD Modified AASHTO
- Sub-base: 95% MDD Modified AASHTO
- Shoulder: 95% MDD Modified AASHTO

2) All field tests results are to be equal to or above the specified value for acceptance of the sample represented by the field tests. Sites for in situ density testing shall be selected on an essentially random basis unless otherwise directed by the Engineer.

3) The gravel materials shall be compacted by means of approved compaction equipment progressing gradually from the outside towards the centre of the road with each succeeding pass uniformly overlapping the previous pass. Rolling shall continue until the entire thickness of each layer is thoroughly, uniformly compacted to the specified density, smooth surface and free from ruts or ridges. Filling outside the finished gravel course width may be necessary in order to achieve the required compaction for the full finished gravel course width.

4) Any areas inaccessible to normal compaction equipment shall be compacted by means of mechanical tampers until satisfactory compaction is obtained.

5) The Contractor shall plan the work and handle the various operations so that the least quantity of water will be lost as evaporation from uncompacted surfaces. If the Contractor delays placing of succeeding layers of material to the extent that additional water must be applied, the application of such water and required mixing shall be at the Contractor's own costs.

6) If the material is laid and compacted in more than one layer of the gravel course, the Contractor shall plan and coordinate the work in such a manner that the previously placed and compacted layers be allowed ample time for drying and development of sufficient stability

before vehicles hauling materials for the succeeding layers, or other heavy equipment, are permitted on the lower layers.

7) Each layer of gravel shall be completely compacted and approved by the Engineer prior to the delivery of materials for a succeeding layer.

8) Prior to placing the succeeding layers of material, the top of the under laying layer shall be made sufficiently moist to ensure bond between the layers.

9) Additional water shall be applied at such times as directed by the Engineer. The Engineer shall have full authority to require the suspension of all other work on pavement construction to ensure the proper maintenance of previously compacted material.

10) Edges and side slopes shall be bladed or otherwise trimmed to conform to the lines and dimensions shown on the drawings to present straight, neat and workmanlike lines and slopes as free of loose materials, as practicable.

1.06 TOLERANCES

1) The variation of the surface of finished gravel course from any two points of contact with a 3-m straight-edge shall in no case exceed 10 mm when placed on or parallel to the centreline or 10 mm when placed perpendicular to the centreline of the roadway.

2) Finished gravel surfaces shall not vary by more than 10 mm (wearing course 20 mm) above or 10 mm below the required elevation.

3) All humps and depressions and thickness deficiencies exceeding the specified tolerances shall be corrected by removing the defective work or by adding new material as directed by the Engineer.

1.07 CORRECTIVE MEASURES OF DEFICIENCIES AND IMPERFECTIONS

1) If, after the gravel course is compacted, any areas fail to meet the specified grading and Atterberg Limit requirements and the density and CBR requirements or are above or below proper grade and true elevations, such areas shall be loosened and after having had additional materials added or been reconstructed, as described herein as required, be reshaped and recompacted to meet the specification requirements.

1.08 MAINTENANCE

1) Following construction, the compacted gravel course shall be maintained by the Contractor at his own costs until it is sealed or covered by subsequent pavement layers or handed over at the end of the contract maintenance period. The Contractor shall blade, broom and otherwise maintain the gravel course, keeping it free from ravelling and other defects, Water shall be applied at such times as directed by the Engineer.

2) The contractor shall ensure that proper drainage of the pavement and shoulder courses and adjacent ditches are maintained at all times during the contract period.

1.09 METHOD OF MEASUREMENTS

1) Gravel material shall be measured by the cubic metre (m^3) as placed and compacted to the required density on the approved subgrade, or other layer, according to the theoretical dimensions shown on the Drawings or as otherwise specified by the Engineer.

2) No measurement for over-depth shall be made even when such over-depth of material is permitted to remain in place by the Engineer, Unauthorized over-depth of gravel layers shall be at the Contractor's own expense.

3) No separate measurement or payment will be made for filling outside the finished gravel wearing course dimensions or for trimming.

1.10 BASIS OF PAYMENTS

1) Following Pay Items may be included in the Bills of Quantities:

Pay Item No.	Description	Pay Unit
1-1	Gravel I	m^3
1-2	Gravel II	m^3
1-3	Gravel III	m^3

DRY-BOUND / WATER-BOUND MACADAM SUB-BASE AND BASE: LVVR-2

2.01 DESCRIPTION OF WORK

1 Scope

1) The work comprises providing, laying and compacting dry-bound or water-bound macadam layers to lines, levels and dimensions as shown on the Engineering Drawings and as directed by the Engineer. Dry-bound macadam (DBM) consists of a layer of broken or crushed stones of size up to 50mm, with finer, cohesionless material laid on top and vibrated into the voids, with minimal use of water. Water-bound macadam (WBM) is essentially similar but water is used to slush the fines into the voids

2.02 MATERIALS

1 General

1) Each layer of DBM or WBM shall consist of a crushed or broken stone layer and a separate application of Blinding Fines.

2 Aggregate

1) This shall be machine crushed or manually broken fresh material that may include, quarried rock, natural granular material such as rocks, gravel or boulders. The material shall be single sized, separated by screening. After crushing/breaking, the material shall be angular in shape meeting the following requirements:

   Flakiness Index <35%

   Water absorption shall not exceed 2%.

   Los Angeles Abrasion (LAA) < 35% or as directed by the Engineer

2) The crushed/broken stone materials shall conform to one of the following grading limits:

Test Sieve (mm)	Percentage by mass passing	
	M1	M2
75	100	-
50	85 – 100	100
37.5	35 – 70	85 – 100
28	0 – 15	0 – 40
20	0 – 10	0 – 5

3) The grading of M2 corresponds with a nominal 37.5mm single-sized aggregate and is appropriate for use with mechanically crushed aggregate. M1 is a broader nominal 50mm specification that can be used for manually-broken stone but if screens are available, M2, is preferred.

3 Blinding fines

1) These should be clean, non-plastic, angular, well graded, crushed stone or natural sand passing the 5.0mm sieve.

2) Fineness Modulus of sand fraction shall not be less than 1.80 and shall be free from deleterious materials.

2.03 EQUIPMENT

1 General

1) The type and condition of the compaction equipment shall be approved by the Engineer and the number of passes confirmed by correlation with achieved strength and density in trial sections at the beginning of operations.

2.04 CONSTRUCTION REQUIREMENTS

1 General

3) Prior to laying the DBM or WBM, the Contractor shall correct any deformations, ruts, soft spots or other defects in the formation or sub-base to the satisfaction of the Engineer whose approval shall be obtained before dry-bound macadam works commence. All drainage works necessary to keep the road formation and pavement layers free of standing water should be completed.

4) The DBM or WBM shall, on completion of compaction, be well closed, free from movement under the compaction plant and free from compaction planes, ridges, cracks or loose material. All extraneous matter, loose, segregated or otherwise defective areas shall be removed and made good with new material to the full thickness of the layer.

5) The target in-situ strength and density of the compacted dry-bound macadam layers shall be not less than CBR 25% for sub-base (95% Modified AASHTO) and either CBR 50% or 80% for base (at 98% Modified AASHTO) , depending on the design requirements.

2 Dry-Bound Macadam

1) The DBM process involves laying single-sized crushed/broken stone of either 37.5 mm or 50mm nominal size in a series of layers to achieve the design thickness. The compacted thickness of each layer should not exceed twice the nominal stone size. Each layer of coarse aggregate shall be placed, raked and shaped and then compacted into an interlocked condition with an approved static roller (or vibrating roller with vibration switched off).

2) The approved well graded fine aggregate, passing the 5.0mm sieve, shall then be spread onto the surface, and rolled into the voids with a vibrating roller to produce a dense layer. Compaction shall be carried out in a series of continuous operations covering the full width and length of the layer concerned.

3) Any loose material remaining is brushed off and final compaction carried out. The sequence is then repeated until the design thickness is achieved.

4) The blinding fines may need to be lightly watered 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 subgrade do not become saturated. The compacted thickness of each layer should not exceed twice the maximum size of the stone.

2 Water-bound Macadam

1) The WBM process involves laying single-sized crushed/broken stone of either 37.5 mm or 50mm nominal size in a series of layers to achieve the design thickness. The compacted thickness of each layer should not exceed twice the nominal stone size. Each layer of coarse

aggregate shall be placed, raked and shaped and then compacted into an interlocked condition with an approved static roller (or vibrating roller with vibration switched off).

2) The approved well graded fine aggregate, passing the 5.0mm sieve, shall then be spread onto the surface, and washed into the voids to produce a dense layer. Compaction shall be carried out in a series of continuous operations covering the full width and length of the layer concerned.

3) Any loose material remaining is brushed off and final compaction carried out. The sequence is then repeated until the design thickness is achieved.

4) The compacted thickness of each layer should not exceed twice the maximum size of the stone.

2.05 TOLERANCES

1) Component layer thickness tolerances to be -5 mm to +15 mm.

2.06 CORRECTIVE MEASURES OF DEFICIENCIES AND IMPERFECTIONS

1) If, after the DBM or WBM layer is compacted, any areas fail to meet the specified grading and the density and strength requirements or are above or below proper grade and true elevations, such areas shall be loosened and after having had additional materials added or been reconstructed, as described herein as required, be reshaped and recompacted to meet the specification requirements.

2.07 MAINTENANCE

1 General

1) Following construction, the compacted base shall be maintained by the Contractor at his own costs until such time as the bituminous prime coat or other surface is applied. The Contractor shall blade, broom and otherwise maintain the base, keeping it free from ravelling, and other defects Water shall be applied at such times as directed by the Engineer.

2) The contractor shall ensure that proper drainage of the pavement and shoulder courses and adjacent ditches are maintained at all times during the contract period.

2.08 METHOD OF MEASUREMENTS

1 General

The unit of measurement shall be cubic metres (m^3) of placed and compacted material. The quantity for which payment shall be made shall be the product of the instructed average width, thickness and the measured length along the centre line of the road.

The rates shall include the supply, placing, spreading, shaping and compaction as specified and shown on the Drawings.

2 Over depth and /Over width

1) No measurement for over-depth shall be made even when such overdepth of material is permitted to remain in place by the Engineer. Unauthorized overdepth of base shall be at the Contractor's own costs, and shall not form a request for additional compensation.

2) No separate measurement or payment will be made for filling outside the specified base dimension, or for trimming.

2.10 BASIS OF PAYMENTS

1) Following Pay Items may be included in the Bill of Quantities:

Pay Item No.	Description	Pay Unit
2	Dry-bound/water-bound macadam	
2-1	Dry-bound macadam base	m^3
2-2	Water-bound macadam base	m^3
2-3	Dry-bound macadam sub-base	m^3
2-4	Water-bound macadam sub-base	m^3

2) Aggregate base course will not be paid for complete in-place until the subsequent surfacing is constructed thereon. However, the Engineer may authorize payment of 85 percent of the quantity of base course on current estimates of volumes in advance of the succeeding operations, provided it has been completed in accordance with these Specifications and is properly maintained to the acceptance of the Engineer pending the placing of the surfacing.

CRUSHED STONE AGGREGATE (CSA) ARMOURING: LVRR 3

3.01 GENERAL

1. Scope

1) This work shall consist of furnishing, placing, compacting, shaping and finishing a layer of graded crushed stone aggregate (CSA) armouring over an existing gravel layer. The purpose of the armouring is to improve the bearing capacity of the gravel layer to receive a seal treatment for an upgrade of a Low Volume Rural Road.

2) The armouring consists of one layer of crushed stone and water placed on an existing prepared, scarified and approved gravel surface in accordance with Specification LVRR-1, in conformity with the lines, grades, thickness and typical cross sections shown on the Drawings or established by the Engineer.

3) The preparation of the existing gravel layer, including any addition of material, shall be carried out in accordance with, and measured separately under LVRR-1.

4) A surface seal would normally be applied to the roadbase as a separate Specification item.

3.02 MATERIALS

1 Aggregate Armouring Layer

1) This is a fresh, graded material that may include, crushed quarried rock, natural granular material such as rocks, gravel or boulders. The materials shall be separated by screening and then recombined to produce the required particle distribution if necessary. After crushing, it shall comply with the requirements of the MPWT Standard Technical Specifications, Part 2, Section 3.22 Aggregate Base, Clause 3.22.02.

3.03 EQUIPMENT

1) The type and condition of the watering and compaction equipment shall be approved by the Engineer.

2) The number of required passes of the compaction equipment shall be confirmed by correlation with achieved strength and density in trial sections at the beginning of site operations. (See section S.01)

3.04 CONSTRUCTION REQUIREMENTS

1. Preparation

1) The preparation of the existing gravel layer, including any addition of material, shall be carried out to achieve the thicknesses, levels and cross falls as shown on the drawing or as directed by the Engineer. The prepared compacted gravel surface shall be scarified to ensure an intimate bond between the gravel and armouring.

2. Spreading of Aggregate

1) The aggregate shall be spread uniformly upon the prepared gravel layer in quantities such as to comply with the specified final compacted thickness. Any segregation of the dumped material shall be reworked by labourers with hand tools. The surface of the aggregate shall be carefully finished with the aid of templates and levelling of all high or low spots by removing or adding aggregates as may be the case.

3. Compaction

1) Immediately following the spreading of aggregate, it is to be first rolled dry with the aid of an approved vibratory roller. The rolling shall begin from edges with roller running forward and backward, parallel to the centre line of the road until the layer has been firmly compacted. Rolling shall continue until the material matrix is thoroughly keyed and stone creeping ahead of the roller in no longer visible. Light sprinkling of water may be required to assist compaction. The rolled surface shall be checked transversely and longitudinally with templates and if the irregularities exceed 12 mm from the required plane, the surface should be loosened and aggregate added or removed before rolling again. In no case shall the use of screenings be permitted to make up depressions.

2) After the dry rolling, the surface shall be copiously sprinkled with water, swept and rolled with the approved vibratory roller. Hand brooms shall be used to sweep the wet screenings into voids and distribute them evenly. The sprinkling, sweeping, and rolling operations shall be continued, with additional screenings applied if necessary, until the coarse aggregate has been thoroughly keyed, well bonded and firmly set in its full depth and a grout of screening and water is seen squeezing out ahead of the roller.

3) Care shall be taken to see that the roadbase, sub-base or subgrade does not get damaged due to the addition of excessive water during construction.

5. Curing of the CSA Armouring:

1) After final compaction of the roadbase, the road shall be allowed to dry overnight. Next morning hungry spots shall be filled with screening materials as directed by the Engineer, lightly sprinkling water if necessary and rolled. No traffic shall be allowed on the road until the CSA Armouring has set.

3.05 TOLERANCES

1) The variation of the surface of finished CSA Armouring from any two points of contact with a 3-m straight-edge shall in no case exceed 10 mm when placed on or parallel to the centreline or 10 mm when placed perpendicular to the centreline of the roadway.

2) Finished CSA Armouring course shall not vary by more than 10 mm above or 10 mm below the required elevation.

3) All humps and depressions and thickness deficiencies exceeding the specified tolerances shall be corrected by removing the defective work or by adding new material as directed by the Engineer.

3.06 CORRECTIVE MEASURES OF DEFICIENCIES AND IMPERFECTIONS

1) If, after the CSA Armouring is compacted, any areas fail to meet the specified grading; plasticity; density or strength requirements or are above or below proper grade and true elevations, shall be loosened and after having had additional materials added or been reconstructed, as described herein as required, be reshaped and recompacted to meet the specification requirements.

3.07 MAINTENANCE OF CSA ARMOURING

1) Following construction, the CSA Armouring layer shall be maintained by the Contractor at his own costs until it is covered with a seal coat.. The Contractor shall blade, broom and otherwise maintain the course, keeping it free from ravelling and other defects, Water shall be applied at such times as directed by the Engineer.

3.08 METHOD OF MEASUREMENTS

1) CSA Armouring shall be measured by the cubic metre (m3) as placed and compacted to the required density on the approved gravel layer, according to the theoretical dimensions shown on the Drawings or as otherwise specified by the Engineer.
2) The rates shall include the supply, placing, spreading, shaping, watering and compaction as specified and shown on the Drawings. The rates also include for the scarifying of the existing gravel surface, but not the other preparation costs relating to the addition of materials or shaping of the gravel surface; measured separately.
3) No measurement for overdepth shall be made even when such overdepth of material is permitted to remain in place by the Engineer,.
4) No separate measurement or payment will be made for filling outside the finished CSA Armouring course dimensions or for trimming.

3.09 BASIS OF PAYMENTS

1. Mode of Payments

1) Payment for all work required by this Section 3 will be made at the unit rate entered for Item No. 3-1 in the Bill of Quantities.

2. Pay Items

1) Following Pay Items may be included in the Bills of Quantities:

Pay item No	Description	Pay Unit
3.1	Armoured Crushed Stone Aggregate	
3.1-1	Crushed stone armoured Roadbase	m^3

DOUBLE BITUMINOUS SURFACE TREATMENT (DBST): LVRR-4

4.01 DESCRIPTION OF WORK

1 Scope

1) The work covered by this section consists of the application of a double bituminous surface treatment (DBST) course consisting of the application of two hot bituminous seal coats each followed by aggregate cover material placed and rolled into the seal. The DBST is applied to a previously constructed and approved primed surface, all in accordance with the appropriate Specifications and in conformity with the lines and typical cross sections shown on the Drawings, or as directed by the Engineer.

4.02 MATERIALS

1 Bitumen Seal Coats

1) Bitumen materials used in these surface treatments shall be one of the types and grades listed in the following table:

Item No	Description	Type of Material	Requirements
1.		Penetration Graded Bitumen	AASHTO M 20
1.1	AC 85-100	Grade 85-100	
2		Cut Back Bitumen	AASHTO M 18
2.1	RC - 250	Rapid Curing	
2.2	RC - 800	Rapid Curing	
2.3	RC - 300	Rapid Curing	

2) The type of seal coat material to be used is indicated on the Drawings, or as directed by the Engineer.

3) Alternative types of bituminous materials maybe used, where the Contractor can prove its satisfactory use on similar projects and demonstrate its performance to the Engineer's approval.

4) The use of bitumen emulsion is covered by a separate specification.

5) The bitumen material shall show no separation prior to use.

6) Each consignment brought to the Site shall be accompanied by the manufacturer's certificate and a test report stating the shipment number, date of shipment, net weight, and the results of the tests specified.

7) Certificates and samples for each consignment of bitumen materials shall be submitted to the Engineer at least 28 days before the Contractor intents to use the bitumen materials.

8) No bitumen material, other than that represented by certificates, test results and samples submitted to the Engineer, shall be used.

2 Aggregate Cover Material

1) Aggregates shall be screened, crushed rock, crushed stone or crushed gravel of uniform quality.
2) The cover material shall be clean, tough, hard, durable, basically cubical in shape, and free from visible stone dust and dirt and other harmful, deleterious or objectionable matters such as clay, silt, organic matter, and from excess of flat and elongated pieces, and be dry.
3) When crushed stone or crushed gravel is used, not less than 90 percent by weight of the particles retained on 4.75 mm sieve shall have at least one fractured face.
4) Aggregates shall be of such a nature that when thoroughly coated with bitumen material proposed for the work, the coating will not be removed upon contact with water.
5) The cover aggregate shall meet the following physical requirements:

Description	Test Method	Requirement
Los Angeles Abrasion	AASHTO T 96	Max. 35% by weight
Soundness of Aggregate	AASHTO T 104	Maximum
Sodium Sulphate		10% loss by weight
Magnesium Sulphate		12% loss by weight
Bitumen Affinity		Good
Water Absorption		Not greater than 1% by weight

6) The deleterious substances in cover aggregates shall meet the following requirements:

Item No	Description	Test Method Requirements
1.	Soft Fragments	Maximum 2% by weight
2	Clay Lumps	Not accepted
3.	Flakiness	Maximum 30 % by weight

7) If satisfactory tests and service records of the aggregates are not available, the Engineer may require that other tests shall be carried out to determine the acceptability for surface treatment.
8) Sources of aggregate cover materials shall be selected by the Contractor and be subject to the acceptance of the Engineer.
9) Acceptance of source shall not mean approval of materials from that source.
10) Use of aggregates for surface treatment is subject to testing in conformity with these Specifications and approval by the Engineer.
11) The cover aggregate shall meet the following grading requirements:

AASHTO Sieve (mm)	Percentage Passing (by weight)					
	Type 1		Type 2		Type 3	
	First Course (14/10 mm nom size)	Second Course (10/6 mm nom. size)	First Course (16/13 mm nom. Size)	Second Course (10/6 mm nom. size	First Course (19/16 mm nom size)	Second Course (14/10 mm nom. size)
25.0			100	100	100	100
19.0	100	100	100	100	55-85	100
16.0	100	100				
12.5	85-100	100	30-50	90-100	0-15	90-100
9.5	10-30	85-100				
6.3		10-30				
4.75	0-5	0-5	5-20	30-60	0-2	10-30
2.00	0-4	0-4	0-2	0-4		0-3

12) The grading to be used is indicated on the Drawings, or as directed by the Engineer.

3. Additives

1) Bitumen additives shall be used, if and when directed by the Engineer. Prior approval must be obtained from the Engineer regarding the type of additive to be used.

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4.03 EQUIPMENT

1 General

1) Equipment for surface treatment shall include approved bitumen heating equipment, cleaning equipment, pressure bitumen distributors, chipping cover spreader and drag brooms, as required, and rollers for compacting.

2 Equipment for Seal Coat Materials

1) The equipment for heating and spreading bitumen materials shall meet the requirements of Section 4.04.

3 Equipment for Aggregate Cover Materials.

1) Equipment for spreading aggregate cover material shall be self propelled or towed mechanical spreader accepted by the Engineer. Approved and tested labour based methods may also be used at the discretion of the Engineer.

2) The equipment and procedures shall be capable of distributing readily the cover aggregate to predetermined, controlled and uniform rate, over variable width and at adjustable rates, as necessary.

3 Rollers

1) The rollers for seating the aggregate firmly into the bitumen seal coat without crushing the particles shall be self propelled pneumatic tyred rollers, supplemented by accepted steel wheel roller.

4.04 CONSTRUCTION REQUIREMENTS – FIRST SEAL

1 Application of Seal Coat

1) Seal coat shall be applied by means of a bitumen distributor in a uniform, continuous spread over the section to be treated and within the temperature range specified. The quantity of material per square metre shall be within the limits hereinafter specified or determined based on trial lengths and as directed by the Engineer.

2) A strip of building paper, at least 1 m wide and with a length equal to that of the spray bar of the distributor plus 0.30 m, shall be used at the beginning of each spread. When the cut-off is not positive, the use of paper may be required by the Engineer at the end of each spread. The paper shall be removed and disposed of in an accepted manner.

3) The distributor shall be moving forward at proper application speed at the time the spray bar is opened. Any skipped areas or deficiencies shall be corrected in an accepted manner. Junctions of spreads shall be carefully made to ensure a smooth riding surface.

4) An application procedure utilising a hand-lance in association with appropriate bitumen heating equipment may be approved at the discretion of the Engineer.

5) The length of spread of seal coat shall not be in excess of that which aggregate cover material can immediately cover and compaction started and be completed before the bitumen seal coat has set.

6) The width of spread of seal coat shall not be more than 150 mm wider than the width covered by the aggregate cover material from the spreading device.

7) Under no circumstances shall operations proceed in such manner that seal coat is allowed to cool or otherwise impair retention of the cover coat.

8) The distributor shall be so designed that, when not spreading, it does not drip.

9) Distribution of the seal coat shall be so regulated and with sufficient material left in the distributor at the end of each application so that there is a uniform distribution of material. In no case shall the distributor be allowed to expel air, thereby causing uneven coverage.

10) The angle of the spray nozzles and the height of the spray bar shall be so adjusted and frequently checked that uniform distribution is obtained. When the rising of the spray bar as the load is reduced becomes excessive and contributes to dripping and streaking of the seal coat, the frame of the distributor shall be blocked or snubbed to the axle of the truck to maintain a constant height of the spray bar above the road surface.

11) The distribution shall cease immediately upon any clogging or interference of any nozzle. Corrective measures shall be taken before distribution is resumed.

12) The seal coat distribution operation shall usually not be more than 300 linear metres ahead of the spreading and compacting of the aggregate, unless sufficient cover aggregate spreaders and rollers are available to complete the cover aggregate spreading and compaction before the seal coat has set.

2 Application of Cover Material

1) Immediately, and at latest within one to two minutes when using penetration graded bitumen, and within two to four minutes when using rapid curing cutback bitumen the application of

the seal coat, the cover materials shall be spread with an approved aggregate spreading procedure in quantities directed by the Engineer and within the limits specified herein, or determined based on trial lengths, and immediately followed by compacting rollers.

2) Spreading shall be accomplished in such a manner that the tyres of any trucks or aggregate spreader at no time come in contact with uncovered seal coat.

3) The aggregate shall be clean, dry and conforming to the grading requirements, when spread.

4) The moisture content in the aggregate when spread shall be insignificant, including the water absorption of the aggregate at the time of delivery to the job site.

5) Starting, stopping or turning any piece of equipment which results in displacement of the cover material or damage to the seal coat shall be prohibited.

6) The spreading procedure shall be such that as the aggregate is placed complete coverage is obtained. No brooming, or blading of the cover materials shall be permitted prior to initial rolling. Any rearrangement of the cover materials shall be done by manual methods. Overlapping applications of cover materials shall be avoided. Spillage shall be removed from the surface. Before rolling commences, the seal coat shall be uniformly covered.

3 Rates of Application

1) Seal Coat: The rate of application of seal coat shall be such rate as is specified by the Engineer, following the construction of the trial lengths.

2) Cover Aggregate: The rate of application of cover material shall be such coverage as is specified by the Engineer, following the construction of the trial lengths.

3) The Engineer may by Variation Order alter the rates of application whenever he deems it necessary or desirable

4 First Manipulation

1) After the aggregates have been rearranged as may be necessary to provide uniform and complete coverage, it shall be thoroughly embedded in the seal coat by rolling in the manner described below, immediately and completed within a few minutes after application of the cover material.

2) The initial rolling shall be by pneumatic-tyred rollers, A sufficient number of such rollers shall be available so that one complete coverage is completed within less than 10 minutes after the material is applied for penetration graded bitumen, and within less than 15 minutes for rapid curing cut back bitumen.

3) Steel-wheeled rolling shall begin immediately after the start of the initial rolling and shall continue until two complete coverages are obtained.

4) The finishing rolling shall be by pneumatic-tyred rollers until aggregates are roughly embedded in the seal coat.

5) The sequence of rolling with the pneumatic-tyred and steel-wheeled rollers may be varied by the Engineer.

6) All rollers shall be self-propelled and shall be operated on each coverage so that each succeeding trip of the roller will overlap slightly the coverage of the preceding trip. Steel-wheeled rollers shall be operated at a maximum speed of 4 km/hour and pneumatic-tyred rollers at a maximum speed of 8 km/hour. The weight of rollers shall be varied, as directed by the Engineer, to obtain the most satisfactory embedment of the cover material without undue crushing of the aggregate.

7) Rolling shall be longitudinal and shall generally be commenced at the outer edges and progress towards the road centre, but from the lower edge to the upper edge on superelevated sections. The speed of the rollers or the rolling sequence shall be so controlled that it is unnecessary for one roller to turn out to permit another roller to pass. Turning of rollers on the surface is prohibited.

8) Pneumatic-tyred rollers may be substituted for steel-wheeled rollers when, in the opinion of the Engineer, the cover materials furnished is subject to crushing under the steel-wheeled rollers. When pneumatic-tyred rollers are substituted for steel-wheeled rollers the number of passes of rolling specified shall be increased to the acceptance of the Engineer.

9) When necessary, or directed by the Engineer, additional cover materials shall be added and the additional materials shall receive additional rolling.

10) Drag brooms or light blades shall not be used to shift the cover materials until the first manipulation has been completed and the seal coat has cooled and set sufficiently to hold the cover materials.

5 Second Manipulation

1) The second manipulation shall be carried out on the day after the first manipulation, when satisfactory weather conditions permits, or as soon thereafter as conditions do permit.

2) The second manipulation shall consist of blading and dragging the loose aggregate to spread it uniformly over the surface, and rolling the surface with a pneumatic-tyred roller. The manipulation shall cover the entire previous day's work.

3) A suitable light blade and drag broom shall be operated immediately ahead of the roller to keep all of the loose aggregates uniformly spread over the bituminous surface during rolling. The blading and dragging shall be conducted so as not to displace embedded material.

4) The rolling in the second manipulation shall constitute at least two complete passes with a pneumatic-tyred roller.

5) The second manipulation may be omitted, when the results of the first manipulation is accepted by the Engineer and he so permits.

6 Maintenance of the Completed Work

1) When directed by the Engineer, the Contractor shall make good defective areas by further applications of seal coat and/or cover material, and further manipulation as described above, at his own costs.

2) After all other work has been completed the excess loose cover material along the edges of the surface shall be broomed and bladed off the shoulder to provide a definite and distinct line along the edge of the sealed surface.

4.05 CONSTRUCTION REQUIREMENTS – SECOND SEAL

1 Application of Seal Coat

1) The second seal coat shall not be applied until 28 days after the application of the first seal coat.

2) Immediately prior to application, the surface of the first seal shall be cleaned in an accepted manner of all dust and loose cover material. Care shall be taken that no embedded material is dislodged.

3) The application of the second seal coat shall conform to the requirements specified for the first seal coat.

2 Application of Cover Material

1) The application of cover material shall conform to the requirements specified for the first seal.

3 Rates of Application

4) Seal Coat: The rate of application of seal coat shall be such rate as is specified by the Engineer, following the construction of the trial lengths.

5) Cover Aggregate: The rate of application of cover material shall be such coverage as is specified by the Engineer, following the construction of the trial lengths.

6) The Engineer may by Variation Order alter the rates of application whenever he deems it necessary or desirable

4 Further Manipulation

1) The first manipulation of the second seal shall comply with the requirements specified for the first manipulation of the first seal.

2) The second manipulation of the second seal shall comply with the requirements specified for the second manipulation of the first seal, but the rolling shall be by steel-wheeled rollers, if not otherwise directed by the Engineer.

3) The third manipulation shall be carried out on the day following the second manipulation, if satisfactory weather condition permits, or as soon thereafter as weather conditions do permit.

4) The third manipulation shall be as specified for the second manipulation.

5) The third manipulation may be omitted, when the results of the second manipulation is accepted by the Engineer and he so permits.

5 Maintenance of Completed Work

1) The second course shall be maintained in the manner specified for the first course.

4.06 MEASUREMENTS OF APPLICATION RATES

1 General

1) The rate of application of seal coats and cover aggregates shall be measured during the field trials and during construction.

2) The measurement shall be made by passing trays, pans, plates or sheet of appropriate sizes at appropriate intervals to receive the seal coat or cover aggregate during the application operation.

3) During construction following the measurements shall be of application on first and second course separately.

Item No	Description	Requirements
1.	Seal Coat	
1.1	Collecting Tray or Plate	
1.1.1	Size	0.4 m^2 (not necessary square)
1.1.2	Numbers	At least 6 for each 300 m or less
1.1.3	Location	To be placed at variable distances and sideways of travel track of the seal coat material distribution
2	Cover Aggregate	
2.1	Collecting Tray or Plate	
2.1.1	Size	0.4 m^2 (not necessary square)
2.1.2	Numbers	At least 3 for each 300 m or less
2.1.2	Location	To be placed at variable distances and sideways of travel track of the cover aggregate spreader

4) The locations where trays or plats have been placed shall be manually covered by seal coat before spreading cover aggregate and similar covered by cover aggregate before compaction rolling is started and with in the time limits stated above.

4.07 OTHER REQUIREMENTS

1 Weather and Temperature Limitations

1) Surface treatment operations shall be carried out only when the surface is dry, when the atmospheric temperature is above +15 deg C, and when the weather is not foggy or rainy. The above requirements may be waived, but only when so directed by the Engineer.

2 Protection of Adjacent Structures

1) When bituminous materials are being applied, the surface of all structures, guard rails, kerbs and gutters, and other roadway appurtenances shall be protected in an approve manner to prevent them from being splattered with bituminous materials or marred by equipment operations.

2) In the event that any appurtenances become splattered or marred, the Contractor shall at his own costs remove all traces of bituminous materials, and repair all damage, and leave the appurtenances in an approved condition.

3 Working Periods

1) Surface treatment operations shall be so conducted that all manipulation work specified can be completed and under favourable weather conditions before sunset, as determined by the Engineer.

4 Traffic Control

1) Traffic shall be prevented from running on the courses until the manipulation work has been competed, unless otherwise permitted by the Engineer.

2) Once the manipulation work has been completed, or the Engineer so directed or agreed traffic shall be directed over the courses. The contractor shall post signs restricting the speed of traffic to 20 km/hour for such periods as the Engineer directs.

5. Tidy up

1) After a period of trafficking approved by the Engineer, excess chippings will be swept from the surface and shoulders and removed.

4.08 CORRECTIVE MEASURES OF DEFIENCIES AND IMPERFECTIONS

1 General

1) The Contractor shall undertake corrective measures to rectify any imperfections in the surface treatment work using manual or equipment methods as described above, at his own cost. .

2 Corrective Measures

1) In the cases where the Contractor fails to meet the requirements of these Specifications and/or areas have been damaged due to not adhering to these Specifications, as determined by the Engineer, the Engineer will instruct the Contractor to apply an additional course of seal and cover aggregate, as a measure of rectification.

2) In such a case the Contractor shall carry out the additional corrective measures at his own costs.

4.09 METHOD OF MEASUREMENTS

1 General

1) Bitumen seal coat shall be measured by the litre computed by multiplying the areas to be measured as shown on the Drawings and any other areas directed by the Engineer, by the appropriate rate or rates of application measured according to Clause 4.06 within the rates directed by the Engineer, corrected to +15 deg. C completed, maintained and approved by the Engineer.

2) Cover material shall be measured by the cubic metre (m^3), computed by multiplying the areas to be treated as shown on the Drawings and any other areas directed by the Engineer, by the appropriate rate or rates of application measured according to Clause 4.06 within the rates directed by the Engineer, complete maintained and approved by the Engineer.

3) No measurement or payment will be made for areas treated outside the limits specified, nor will any measurement or payment be made for material in excess of the rates of application directed by the Engineer.

4.10 BASIS OF PAYMENTS

1 Mode of Payments

1) All work required by this Section will be paid for at the unit prices for Items, when entered in to the Bill of Quantities.

2 Payment Items

1) Following Pay Items may be included in the Bill of Quantities:

Pay Item No	Description	Pay Unit
4.1	DBST SURFACE TREATMENT	
4.1-1	Bitumen Seal Coat	
4.1-1.1	Penetration Graded Bitumen	Litre
4.1-1.2	Rapid Curing Cut-Back Bitumen	Litre
4.1.2	Cover Aggregate	
4.1-2.1	Nominal size 10/6 mm	m^3
4.1-2.2	Nominal size 14/10 mm	m^3
4.1-2.3	Nominal size 16/13 mm	m^3
4.1-2.4	Nominal size 19/16 mm	m^3

OTTA SEALS: LVRR-5

5.01 DESCRIPTION OF WORK

1 Scope

1) The work covered by this section consists of the application of Single Otta Seal (SOS) or Double Otta Seal (DOS) course consisting of the application of a bituminous seal coat of relatively soft bitumen followed by aggregate cover material place and rolled into the seal. The SOS or DOS is applied to a previously constructed and approved primed surface, all in accordance with these Specifications and in conformity with the lines and typical cross sections shown on the Drawings, or as directed by the Engineer.

5.02 MATERIALS

1 Bitumen Seal Coat

1) Bitumen materials used in surface treatments shall be one of the types and grades listed in the following table:

Item No	Description	Type of Material	Requirements
1.		Penetration Graded Bitumen	AASHTO M 20
1.1	AC 150/200	Grade 150-200	
2		Cut Back Bitumen	AASHTO M 18
2.1	MC- 3000	Medium Curing	
2.2	MC - 800	Medium Curing	

2) The type of seal coat material to be used is indicated on the Drawings, or as directed by the Engineer.

3) The bitumen material shall consist of cut back bitumen binder. It shall be free from water, show no separation prior to use, and shall conform to all the re requirements for Grade MC-3000 medium-curing cutback bitumen as specified in AASHTO M81. 150/200 penetration grade bitumen or MC 3000 cutback grade bitumen shall be used in warm weather. In cold weather, when night temperatures are likely to fall below 10^{o}C, MC 800 cutback grade bitumen may be used or alternatively 150/200 penetration grade bitumen may be cutback with power paraffin to the appropriate viscosity range as directed by the Engineer

4) Alternative types of bituminous materials maybe used, where the Contractor can prove its satisfactory use on similar projects and demonstrate its performance to the Engineer's approval.

5) Each consignment brought to the Site shall be accompanied by the manufacturer's certificate and a test report stating the shipment number, date of shipment, net weight, and the results of the tests specified.

6) Certificates and samples for each consignment of bitumen materials shall be submitted to the Engineer at least 28 days before the Contractor intents to use the bitumen materials.

7) No bitumen material, other than that represented by certificates, test results and samples submitted to the Engineer, shall be used.

2 Aggregate Cover Material

1) Aggregates shall be screened natural gravel, crushed rock, crushed stone or crushed gravel of uniform quality.

2) The cover material requirements are less stringent than for DBST chippings and should have a gradation in particle sizes. Aggregates shall be hard, durable, and rounded or cubical in shape. Some cut faces in gravel material will be beneficial. As-dug gravels should be screened to remove oversized material and excessive fines. Aggregates must be free from harmful, deleterious or objectionable material such as, organic matter, and from excess of flat and elongated pieces, and be dry.

3) The preferred maximum particle size is 16mm, but 19mm can be accepted in the first seal where a double seal is to be constructed.

4) The amount of fines (<0.075mm) shall not exceed 10%.

5) Aggregates shall be of such a nature that when thoroughly coated with bitumen material proposed for the work, the coating will not be removed upon contact with water.

6) The cover aggregate shall meet the following grading requirements

AASHTO Sieve (mm)	Overall requirement	Preferred Open Grading AADT <100	Preferred Medium Grading AADT :100 – 1,000
	% passing	% passing	% passing
25	100	100-	100
19	100	100	100
16	80 - 100	80 - 100	84 - 100
13.2	52 – 100	52 - 82	68 - 94
9.5	36 - 98	36 - 58	44 - 73
6.7	20 - 80	20 - 40	29 - 54
4.7	10 - 70	10 - 30	19 - 42
2.0	0 - 48	0 - 8	3 - 18
1.18	0 - 38	0 - 5	1 - 14
0.425	0 - 25	0 - 2	0 - 6
0.075	0 - 10	0 - 1	0 - 2

7) The cover aggregate shall meet the following physical requirements

Test	Requirement
Los Angeles Abrasion	Max 35%
Sodium Sulphate Soundness	Max 10%
Magnesium Sulphate Soundness	Max 12%
Flakiness Index	Max 30%
Wet and dry strength ratio	Min 60%
Water Absorption	Max 1%

8) If satisfactory tests and service records of the aggregates are not available, the Engineer may require that other tests shall be carried out to determine the acceptability for surface treatment.

9) The grading to be used is indicated on the Drawings, or as directed by the Engineer.

10) Sources of aggregate cover materials shall be selected by the Contractor and be subject for the acceptance of the Engineer.

11) Acceptance of source shall not mean approval of materials from that source.

12) Use of aggregates for surface treatment is subject to testing in conformity with these Specifications and approval by the Engineer.

3 Additives

1) Bitumen additives shall be used, if and when directed by the Engineer. Prior approval must be obtained from the Engineer regarding the type of additive to be used.

5.03 EQUIPMENT

1 General

1) Equipment for otta seals shall include bitumen heating equipment, cleaning equipment, self propelled pressure bitumen distributors, chipping cover spreader and drag brooms, as required, and rollers for compacting.

1 Equipment for Seal Coat Materials

1) The equipment for heating and spreading bitumen materials shall meet the requirements of Section 5.05.

2 Equipment for Aggregate Cover Materials.

1) Equipment for spreading aggregate cover material shall be self propelled or towed mechanical spreader accepted by the Engineer. Labour based methods may also be approved at the discretion of the Engineer

2) The procedure shall be capable to distribute readily the cover aggregate to predetermined, controlled and uniform rate, over variable width and at adjustable rates, as necessary.

3 Rollers

1) The rollers for seating the aggregate firmly into the bitumen seal coat without crushing the particles shall be self propelled approved 10-12t steel wheel rollers.

5.04 CONSTRUCTION REQUIREMENTS

1 Application of Seal Coat

1) Seal coat shall be applied by means of a bitumen distributor in a uniform, continuous spread over the section to be treated and within the temperature range specified. The quantity of material per square metre shall be within the limits hereinafter specified or determined based on trial lengths and as directed by the Engineer.

2) A strip of building paper, at least 1 m wide and with a length equal to that of the spray bar of the distributor plus 0.30 m, shall be used at the beginning of each spread. When the cut-off is not positive, the use of paper may be required by the Engineer at the end of each spread. The paper shall be removed and disposed of in an accepted manner.

3) The distributor shall be moving forward at proper application speed at the time the spray bar is opened. Any skipped areas or deficiencies shall be corrected in an accepted manner. Junctions of spreads shall be carefully made to ensure a smooth riding surface.

4) Heating and spraying temperatures shall be in accordance with the following table;

	Heating and spraying temperatures(°C)		
Materials	Min	Max	Recommended
Road grade bitumen 150/200	150	175	165
Cut-back bitumen			
MC-800	110	135	125
MC-3000	135	155	145

5) The length of spread of seal coat shall not be in excess of that which aggregate cover material can immediately cover and compaction be started and be completed before the bitumen seal coat has set.

6) The width of spread of seal coat shall not be more than 150 mm wider than the width covered by the aggregate cover material from the spreading device.

7) Under no circumstances shall operations proceed in such manner that seal coat is allowed to cool or otherwise impair retention of the cover coat.

8) The distributors shall be so designed that, when not spreading, it does not drip.

9) Distribution of the seal coat shall be so regulated and with sufficient material left in the distributor at the end of each application so that there is a uniform distribution of material. In no case shall the distributor be allowed to expel air, thereby causing uneven coverage.

10) The angle of the spray nozzles and the height of the spray bar shall be so adjusted and frequently checked that uniform distribution is obtained. When the raise of the spray bar as the load is reduced is excessive and contributes to dripping and streaking of the seal coat, the frame of the distributor shall be blocked or snubbed to the axle of the truck to maintain a constant height of the spray bar above the road surface.

11) The distribution shall cease immediately upon any clogging or interference of any nozzle. Corrective measures shall be taken before distribution is resumed.

12) The seal coat distribution operation shall usually not be more than 300 linear meter ahead of the spreading and compacting of the aggregate, unless sufficient cover aggregate spreaders and rollers are available to complete the cover aggregate spreading and compaction before the seal coat has set.

2 Application of Cover Material

1) Immediately, and latest within one to two minutes when using penetration graded bitumen , and within two to four minutes when using rapid curing cutback bitumen following the application of the seal coat, the cover materials shall be spread with an approved aggregate spreader in quantities directed by the Engineer and within the limits specified herein, or determined based on trial lengths, and immediately followed by compacting rollers.

2) Spreading shall be accomplished in such a manner that the tyres of the trucks or aggregate spreader at no time come in contact with uncovered seal coat.

3) The aggregate shall be dry and conforming to the grading requirements, when spread.

4) The moisture content in the aggregate when spread shall be insignificant, including the water absorption of the aggregate at the time of delivery to the job site..

5) Starting, stopping or turning any piece of equipment which results in displacement of the cover material or damage to the seal coat shall be prohibited.

6) The spreading equipment shall be of such width and arrangements that as the aggregate is placed, complete coverage is obtained. No brooming, or blading of the cover materials shall be permitted prior to initial rolling. Any rearrangement of the cover materials shall be done by manual methods. Overlapping applications of cover materials shall be avoided. Spillage shall be removed from the surface. Before rolling commences, the seal coat shall be uniformly covered.

7) The seal surface shall receive not less than 20 passes of a 10-12t heavy tandem steel roller. During the following 2 days, the entire sealed area, including the shoulders, shall receive a further minimum of 15 passes daily, unless otherwise approved by the Engineer.

8) The Engineer may direct even trafficking of the surfaced area and channeling of the traffic may be required for certain periods and traffic cones or similar may be required.

9) The road should be opened to traffic immediately after the sealing operations are completed, but a maximum speed limit of 50km/h should be enforced during the initial 2-3weeks after construction.

10) Aggregate that has been dislodged by traffic during the immediate post construction period shall be broomed back into the exposed areas during the first 2-3weeks, as directed by the Engineer.

11) After 2-3 weeks of trafficking the excess aggregate shall be swept off the road surface and the speed limitations can be lifted, unless otherwise directed by the Engineer. If natural gravel is used with a fairly high content of fines, the period may be extended to 6 weeks or as directed by the Engineer.

12) A team shall be retained on site to deal with areas of bleeding if required. The team will be required during the normal construction period as well as during the first hot season following the completion of sealing operations.

13) A minimum period of 8-12 weeks should normally elapse between construction of the subsequent layers of the surfacing, and during that period the road should receive as much heavy trafficking as possible, unless otherwise directed by the Engineer.

3 Rates of Application

1) Seal Coat: The rate of application of seal coat shall be such rate as is specified by the Engineer, following the construction of the trial lengths. They are likely to be according to the table below:

	Hot bitumen spray rates for un-primed base course (l/m^2)	
Type of Otta seal	Open grading	Medium grading
Single Otta seal with sand seal	1.6	1.7
Single Otta seal without sand seal	1.7	1.8
Double Otta seal 1st layer	1.6	1.7
Double Otta seal 2nd layer	1.5	1.6

2) On a primed roadbase the spray rate shall be reduced by 0.2 l/sqm in the first layer.

3) Penetration bitumen 150/200, MC-3000 or softer may be used. Power paraffin may be used as a cutter to obtain the required viscosity range as directed by the Engineer. Penetration bitumen 80/100 or softer shall not be allowed to use unless cut back by the use of both a softener and power paraffin.

4) The binder for the otta seal shall be according to the following table:

	Type of bitumen	
ADT at the time of construction	Open grading	Medium grading
100-1000	150/200 pen.grade	150/200 pen.grade in cold weather
<100	150/200 pen.grade	MC-3000

5) Cover Aggregate: The rate of application of cover material shall be such coverage as is specified by the Engineer, following the construction of the trial lengths. They are likely to be according to the table below:

	Aggregate spread rates (m^3./m^2)	
Type of otta seal	Open grading	Medium grading
Single otta seal	0.013 – 0.016	0.013 – 0.016

5.05 OTHER REQUIREMENTS

1 Weather and Temperature Limitations

1) Otta seal operations shall be carried on only when the surface is dry, when the atmospheric temperature is above + 15 deg C, and when the weather is not foggy or rainy. The above requirements may be waived, but only when so directed by the Engineer.

2 Protection of Adjacent Structures

1) When bituminous materials are being applied, the surface of all structures, guard rails, kerbs and gutters, and other roadway appurtenances shall be protected in an approved manner to prevent them from being splattered with bituminous material or marred by equipment operations.

2) In the event that any appurtenances become splattered or marred, the Contractor shall at his own expense, remove all traces of bituminous materials, and repair all damage, and leave the appurtenances in an approved condition.

3 Working Periods

1) Otta seal operations shall be so conducted that all work specified can be completed before sunset and under favourable weather conditions as determined by the Engineer.

4 Traffic Control

1) Traffic shall be prevented from running on the constructed otta seal until the rolling work has been completed, unless otherwise ordered or permitted by the Engineer.

2) Once the otta seal construction work has been completed or the Engineer so orders, traffic shall be directed over the courses. The Contractor shall post signs restricting the speed of traffic to 20 km/hour for such periods as the Engineer directs.

5. Tidy up

1) After a period of trafficking approved by the Engineer, excess aggregates will be swept from the surface and shoulders and removed.

5.06 CORRECTIVE MEASURES OF DEFIENCIES AND IMPERFECTIONS

1 General

1) The Contractor shall undertake corrective measures to rectify any imperfections in the otta seal work using manual or equipment methods as described above, at his own cost..

2 Corrective Measures

1) In the cases where the Contractor fails to meet the requirements of these Specifications and/or areas have been damaged due to not adhering to these Specifications, as determined by the Engineer, the Engineer will instruct the Contractor to apply an additional course of seal and cover aggregate, as a measure of rectification.

2) In such a case the Contractor shall carry out the additional corrective measures at his own costs.

5.07 METHOD OF MEASUREMENTS

1 General

1) Bitumen seal coat shall be measured by the litre computed by multiplying the areas to be measured as shown on the Drawings and any other areas directed by the Engineer, by the appropriate rate or rates of application measured according to Clause 5.04 within the rates directed by the Engineer, corrected to +15 deg. C completed, maintained and approved by the Engineer.

2) Cover material shall be measured by the cubic metre, computed by multiplying the areas to be treated as shown on the Drawings and any other areas directed by the Engineer, by the appropriate rate or rates of application measured according to Clause 5.04 within the rates directed by the Engineer, complete maintained and approved by the Engineer.

3) No measurement or payment will be made for areas treated outside the limits specified, nor will any measurement or payment be made for material in excess of the rates of application directed by the Engineer.

5.08 BASIS OF PAYMENTS

1 Mode of Payments

1) All work required by this Section will be paid for at the unit prices for Items, when entered in to the Bill of Quantities.

2 Payment Items

1) Following Pay Items may be included in the Bill of Quantities:

Pay Item No	Description	Pay Unit
5.1	OTTA SEALS	
5.1-1	Bitumen Seal Coat	
5.1-1.1	150/200Penetration Graded Bitumen	Litre
5.1-1.2	MC-3000 Cut-Back viscosity Bitumen	Litre
5.1-1.3	MC-800 Cut-Back viscosity Bitumen	Litre
5.1-2	Cover Aggregate	
5.1-2.1	Aggregate for single otta seal	m^3
5.1-2.2	Aggregate for double otta seal	m^3

NON-REINFORCED CONCRETE PAVEMENT: LVRR-6

6.01 DESCRIPTION OF WORK

1 Scope

1) Non-reinforced cement concrete is a form of rigid pavement designed to spread the applied load due to traffic through a slab effect. It is therefore ideal for construction on weak subgrades, and on routes liable to seasonal flooding. The normal basic materials in the typical non-reinforced pavement slab are Portland cement, load transfer devices (between slabs), and joint sealing materials. The pavement requires minimal routine maintenance for the shoulders and occasional re-filling of the slab expansion joints with bitumen.

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6.02 MATERIALS

1 Concrete

1) Concrete shall be Grade 200 and have a minimum compressive strength of 20Mpa (28 days) with a guidance mix water/cement ratio of 0.45.

2) Concrete mix proportions should be calculated to suit the available materials in order to meet the required compressive strength and slump requirements The use of low water-cement ratios (e.g. <0.45), higher cement contents, plasticiser and high early-strength cement is beneficial in minimising the risk of cracks.

3) Concrete shall otherwise be constructed to the requirements of current Lao Standards.

2 Concrete Aggregate

1) Concrete aggregates shall conform to the current Lao Standards applicable to crushed stone aggregate.

2) No uncrushed rounded coarse natural aggregate shall be permitted.

3 Load Transfer Dowels

1) Load transfer dowels shall be provided at each joint between slabs. They shall be made with 14 mm diameter mild steel reinforcing bars, 500mm in length.

2) The steel shall comply with current Lao Standards related to concrete reinforcement.

6.03 CONSTRUCTION METHODS

1 General

1) NRC pavement shall be constructed on a previously prepared sub-base that has been examined and accepted by the Engineer.

2 Joints

1) Partial depth Contraction joints of 10mm width are to be provided at 5m intervals in the pavement, to relieve tensile stresses. Full depth Expansion joints of 10mm width are to be provided at 250m intervals.

2) All joints are to be filled and sealed with a mixture of sand and bitumen, with a reservoir of bitumen provided at the top of each joint. All joints are to be provided with load transfer steel dowels.

3) 14mm diameter mild steel reinforcing bars of 500mm length are to be placed at 250mm centres at all expansion and contraction joints.

4) At expansion joints the dowel bar should be anchored into the concrete at one end and the other end coated with bitumen and fitted into a PVC sleeve. The PVC tube is to be omitted at contraction joints.

5) 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 Engineer.

6) Longitudinal joints should have a load transferring dowel and sealing arrangement similar to that of transverse contraction joints. In low volume roads it may be permissible to use profiled formwork to produce a "tongue in groove" load transferring arrangement for longitudinal joints in place of dowels.

3 Concrete

1) All concrete shall be mixed on site in small capacity batch mixers complying with the appropriate Lao Standards. Mixers with a capacity less than one bag of cement shall not be used and no mixer shall be charged in excess of its rated capacity.

2) Cement shall be fresh and stored in a clean dry location.

3) Aggregates shall be stored separately in a clean area. Proportions of aggregates shall be measured using weighing apparatus or batching boxes.

4) Water should be fresh not brackish (total salt content <5,000mg/litre) and not contaminated by industrial or other waste. Water proportions shall be determined using containers of known volume.

5) All formwork shall be well secured and free from defects or gaps, and able to resist the tamping forces. The top edge of the formwork shall be within ± 2mm of the required finished road levels.

6) Prior to placing the concrete, all formwork shall be thoroughly inspected and passed by the Supervising Engineer's Representative. All wood chips, dust, sand, construction debris and any other deleterious material shall be removed from the formwork and sand bedding layer prior to placing the concrete. All formwork shall be wetted to ensure it is damp when the concrete is poured. Care should be taken during this operation such that pools of excess water do not form in the base of the formwork.

7) Once the concrete had been placed uniformly within the forms, compaction shall be carried out using a mechanical poker vibrator. 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.

8) No concrete shall be compacted after initial setting has commenced. All concrete shall be compacted until no air bubbles appear on the surface of the fresh concrete. Care shall be taken not to touch the formwork with the vibrator since this would result in concrete having begun initial setting being exposed to re-vibration.

9) After placement and compaction, the camber shall be shaped in the fresh concrete to lines and levels detailed in the Engineering Drawings. In order to improve the skid-resistance of the surface and to minimise the vehicles' breaking distance, transverse grooves shall be etched in the fresh concrete surface utilising an appropriate rake.

10) The concrete shall be cured by spreading sand or sacking over the surface of the pavement and repeatedly wetting the materials for a period of at least 7 days. The Engineer may direct a longer curing period depending on local circumstances.

11) 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.

12) Concrete shall not be mixed or poured when ambient shade temperatures are less than 4 degrees Celsius or more than 38 degrees Celsius.

6.04 CONSTRUCTION EQUIPMENT

The following equipment, apparatus and special hand tools shall be used:

- Formwork
- Concrete mixer of at least 250 litre capacity
- Batching boxes or weighing apparatus
- Wheelbarrows
- Vibrating poker powered by electricity or portable generator
- Tamping screed
- Portable sun protection canopy if casting in direct sunlight if ambient shade temperatures are above 25 degrees Celsius
- Grooving rake

6.05 MEASUREMENT

1) The unit of measurement shall be cubic metres (m^3) of constructed non-reinforced concrete. 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.

2) 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.

6.06 BASIS OF PAYMENT

1) The rates shall include the supply, placing, spreading, shaping, watering and compaction as specified and shown on the Drawings.

2) Pay Item shall be:

CLAUSE	DESCRIPTION	UNIT OF MEASUREMENT
6.1	Non-Reinforced Concrete	m^3

MAINSTREAMING APPROPRIATE LOCAL ROAD STANDARDS AND SPECIFICATIONS AND DEVELOPING A STRATEGY FOR THE MPWT RESEARCH CAPACITY
SEACAP 3

Lao Low Volume Rural Road Standards and Specification: Part II

Appendix B

LVRR Drainage Details

SIDE DITCHES AND CUT-OFF DRAINS

1 General

The following sections on the Specifications for LVRR external drainage have been adopted from the current Lao Road Design Manual (LRDM). Appropriate figures are cross-referenced to that document for use in LVRR construction.

The recommended types of side ditches and cut-off ditches are shown in Figure B1 and listed in Table B.1 which gives guidelines regarding the choice of each particular type. These guidelines are based upon general economic and aesthetic considerations. However, the type of side ditch selected must be checked to ensure that it will carry the expected flow without running so deep as to wet the road pavement nor so fast as to cause scour.

Due to their location, cut-off ditches are usually difficult to maintain and should therefore, whenever possible, be constructed as "natural permanent depressions" with as gentle side slopes as possible.

2 Expected flow in side ditches.

The Road Design Manual Part IV, Hydraulic Design, covers the discharge capacity of side ditches as well as the determination of culvert sizes for discharging water crossing the road.

The side ditches must be designed to carry the storm-water run-off originating from the carriageway, shoulder, drain and cut slope. Where cut-off ditches are not provided, any run-off from beyond the cut slope must also be included. The expected flow, or run-off, should be estimated using the formula:

$$Q = 0.278\ C.I.A.$$

where:

- Q is the expected flow (m^3/s)
- C is the run-off coeffcient (suggested value 0.9 for pavement, shoulder, drain and cut slope)
- I is the intensity of rainfall (mm/h) for a 5 minute storm with a return period of 2 years (determined in accordance with an approved method)
- A is the area drained (km^2)

3 Capacity of Side Ditches

The capacity of a side ditch should be estimated using the Manning Strickler formula (metric):

$$Q = K.A.R^{2/3}.S^{1/2}\ A.\ V$$

or $V = K.R^{2/3}.S^{½}$

where:

Q is the capacity (m^3/s)

A is the cross-sectional area of water (m^2)

V is the velocity of flow (m/s)

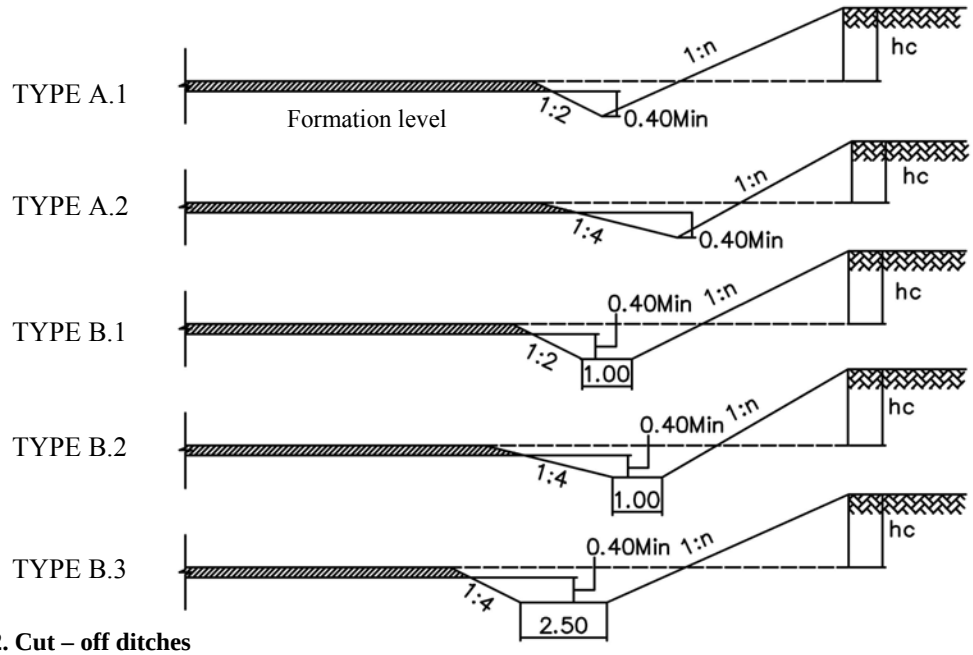
K is the Roughness Coefficient

R is the hydraulic radius, A/P where P is the wetted perimeter

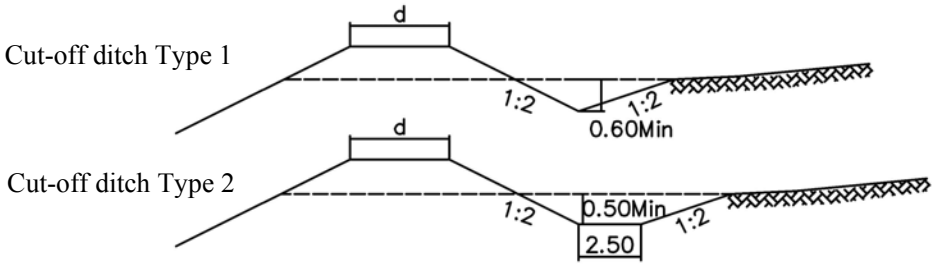
S is the longitudinal slope of flow in metres per metre (H/L)

Figure B1: Side Ditches and Cut-off Ditches

1. Side ditches



2. Cut – off ditches



- Table relating to design of side ditches and cut - off ditches

Height of Cut hc	Slope (1:n) of cutting in Earth (1)	Distance ,d, between edge of cutting and cut-off ditch
hc < 1.00	1 : 3	d = 1.0
1.00 < hc ≤ 3.00	1 : 2	d = 4.0
hc > 3.00	1 : 1.5(2)	d ≥ 5.0

(1) In rock the slope 1:n will vary from 1 : 0.33 to 1 : 0.10
(2) If earth not stable at 1:1.5 the slope maybe decreased to 1 : 2
If natural slope steeper than 1:1.5 then the natural slope may be used as the cut slope
(3) The slopes in to the ditch should be as indicated or flatter

Table B1: Guidelines for the Selection of Side Ditch and Cut-off Ditch Types

Side-ditch Type	To be used under the following condition	Remarks
Al	Hilly to mountainous terrain with heavy earthwork.	Back slope to be varied according to stability of cut material. Slope should be stable and enable vegetation to establish.
A2	Rolling terrain with mode- rate earth work. Hilly to mountainous terrain where flatter ditch than Al is required due to capacity and/or velocity limitations.	As for Al
B1	Hilly to mountainous terrain where flatter ditch than Al is required due to capacity and/or velocity limitations.	As for Al, width may be increased if fill material is required
B2	Rolling terrain with mode-rate earthwork where a flatter ditch than A2 is required due to capacity and/or velocity limitation.	As for B1
B3	Flat terrain with little earthwork. Rolling terrain with moderate earthwork where a flatter ditch than B2 is required to capacity and/or velocity limitation.	As for B2
Cut-off ditch Type	To be used under the following conditions	Remarks
1	Moderate catchment area and little chance of siltation.	
2	Large catchment area and in areas liable to silting and/or damage to the ditch profile by pedestrians, cattle etc.	

Limiting values for the velocity of flow (v) to prevent scour, together with the corresponding Roughness Coefficients, are given in Table B.2 for the different types of ditch material which will normally be encountered.

Table B.2, Allowable Velocity in Ditches and Corresponding Roughness Coefficients

Ditch Material	Maximum Allowable velocity(m/s)	Roughness Coefficient
Sand, loam, fine gravel, volcanic ash	0.6*	45
Stiff clay	1.1*	50
Coarse gravel	1.5	40
Conglomerate, hard shale, soft rock.	2.0	25
Hard rock	3.0	25
Masonry	3.0	40
Concrete	3.0	60

* In areas where good grass cover is guaranteed, these values may be increased up to a maximum of 1.5 m/s; in such cases a Roughness Coefficient of 30 should be used. Where grass cover is expected but not guaranteed a maximum velocity of 1.1 m/s should be used with a Roughness Coefficient of 30.

4 Scour Protection.

It is important to note that a side ditch will only perform as designed if the design cross-section is maintained, i.e. excessive scour must be prevented. In practice, due to local inconsistencies in roughness and surface level, no side drain in any but the hardest of materials will be immune from scour. Thus, for long lengths of side ditch at gradients in excess of 4-5%, scour checks should be considered.