



Manual Pavement Labour-Based Technology for Rural Road Works



**Don Bosco Foundation
Training Center in Comoro**



**Don Bosco Foundation
Training Centre in Comoro**

Training Manual

**Construction of Rural Road Pavements
Utilizing Labour-Based Technology**

Part 1: Rigid Pavements

Part 2: Flexible Pavements

Copyright © ILO & Don Bosco Timor-Leste, First published 2015

Short excerpts from may be reproduced without authorization, on condition that the source is indicated. For rights of reproduction or translation, application should be made to ILO & Don Bosco in Timor-Leste. Organisations and institutions may make copies in accordance with the license issued to them for this purpose

Manual, Pavement for Labour-based Road Construction

Timor-Leste, ILO & Don Bosco 2015

ISBN: 978-92-2-130857-7

Visit our website: www.donbosco.tl

Introduction

This Manual comprises two parts; Part 1 one covers *Rigid Pavements* and Part 2 covers *Flexible Bituminous pavements* and has been prepared for the training and accreditation of small scale domestic contractors and their staff in the construction of specific types of rigid and flexible pavements suitable for rural road construction in Timor Leste through the use of Labour-Based Technology.

The associated classroom and practical training for Company Directors, engineers, technicians and supervisors prepares successful graduates from this training to be able to establish themselves as pavement contractors in both the public and private sectors; such is the current and anticipated on-going demand for pavement construction, reconstruction and maintenance in Timor Leste.

The training provided in this course is also intended to provide trainees with the basic skills essential for not only the construction of rigid and flexible pavements for rural roads but also to prepare them to be able to understand and eventually undertake similar work of a higher specification and scaled-up in larger contracts where larger equipment units may be necessary for the delivery of the work.

This Manual incorporates international best practices and draws on the extensive work of the International Labour Organization (ILO) and the work of the UK Government Department for International Development (DFID) and the World Bank (WB) in Asia and Africa under their SEACAP and AFCAP research projects as well as contemporary practices in New Zealand.

The types of rigid pavements covered by this manual include hand-packed cobblestone (CSP), plum concrete (PCP) and more contemporary un-reinforced (plain) concrete pavements (UCP). The types of flexible bituminous pavements covered include Latasir¹ or LB Hotmix (HMP), Coldmix (CMP), Penetration macadam (PMP) and Double Bitumen Emulsion Seal Treatment) (ESP).

This selection of these various pavement types optimizes the use of local rock and stone materials for road pavement construction, is generally very cost effective in terms of life-cycle costing and with ready access to local materials further improves their prospects of sustainability.

Acknowledgements

This manual has been prepared by John Howse and Mike Shone of Fraser Thomas Ltd, Consulting Engineers, New Zealand with funding support from the New Zealand Ministry of Foreign Affairs and Trade and has been subject to a peer review within Timor Leste by engineers working in the rural roads sector.

The valuable support and local technical advice of the Ministry of Public Works, the EU funded ERA technical team of Don Bosco and the International Labour Organization; the only accredited roads training programme in Timor Leste as well as the Australian Aid funded R4D project; the lead rural roads project of the Ministry of Works in Timor Leste, is gratefully acknowledged.

¹ Latasir is an Indonesian engineering expression derived from; Lapisan (layer), tipis (thin), aspal (asphalt) and pasir (sand).

Training Manual

Construction of Rural Road Pavements Utilizing Labour-Based Technology

Part 1. Rigid Pavements

Rigid Pavements

Table of Contents

1.	Glossary of Technical Terms for Rigid Pavements	1
2.	Introduction to Rigid Pavements	2
3.	Occupational Safety and Health (OSH) in the Construction of Rigid Pavement Roads.	3
3.1.	Safety Measures.....	3
3.2.	Drinking Water	3
3.3.	Safety Gear and Equipment	3
3.4.	First Aid	4
4.	Cobblestone Surfacing	5
4.1.	Materials	5
4.2.	Work Method.....	6
4.3.	Quality Control for Construction of Stone Surface	8
4.4.	Technical Resources and Reference Materials for Stone Paved Roads.	10
5.	Construction of Plum Concrete Surface.....	11
5.1.	Material.....	11
5.2.	Work Method.....	12
5.3.	Quality Control for Construction of Plum Concrete Surface.....	14
6.	Construction of Un-reinforced Concrete (UPC) Pavements	17
6.1.	Alternative Concrete Pavement Options	17
6.2.	Concrete Materials.....	19
6.3.	Work Method.....	20
6.4.	Quality Control for Un-reinforced Concrete Pavement Construction	23
6.5.	Technical Resources and Reference Material for Un-reinforced Concrete Pavements:	25

Worksheets

Item: Construction of Rural Road Cobblestone Pavement.....	26
Item: Construction of Rural Road Plum Concrete Pavement	30
Item: Construction of Rural Road Un-Reinforced Concrete Pavement	34

Rigid Pavements

1. Glossary of Technical Terms for Rigid Pavements

Blinding Course

A layer of lean concrete, usually 5 to 10 cm thick, placed on soil to seal it and provide a clean and level working surface to build a road or any other structure. A blinding course can also comprise the application of fine material e.g. sand, to fill voids in the surface of a pavement or as a base for concrete slabs.

Cobble Stone (Dressed stone)

Cubic pieces of stone larger than setts, usually shaped by hand in blocks of at least 25cm and built into a road surface layer or used as surface protection.

Concrete

A construction material composed of cement, (most commonly Ordinary Portland Cement (OPC)), aggregate (generally a coarse aggregate such as gravel or crushed stone plus a fine aggregate such as sand), water, and sometimes incorporates chemical admixtures to improve performance or workability.

Curing

The process of protecting freshly laid/placed concrete to prevent excessive evaporation which results in loss of strength or cracking.

Filler

Mineral matter composed of particles smaller than 0.075mm.

Hand Packed Stone

A layer of large, angular broken stones laid by hand with smaller stones or gravel rammed into the spaces between stones to form a road surface layer. These can be rectangular or irregular shaped provided they conform with the surface profile design requirements.

Local Resources

These can be human resources, local government, private, NGO, and community institutions, local entrepreneurs such as contractors, consultants, entrepreneurs, artisans, local labour (skilled and unskilled), locally made or fabricated hand tools or intermediate equipment, local materials such as locally produced aggregates, timber and other materials or inputs.

Low Volume Road

Roads carrying up to about 300 motor vehicles per day and intended to carry less than about 1 million equivalent standard axles over their design life.

Plum Concrete

A mixture of coarse and fine stone aggregate bound with cement and water constructed over a base of rock “plums” comprising no more than 50% of the total volume of the works.

Sett (Pavé)

A small piece of hard stone trimmed by hand to a size of about 10cm cube used as a paving unit, but not usually as a full depth pavement.

2. Introduction to Rigid Pavements

This Manual covers three types of Rigid Pavement and in some respects follows the evolution of Roman road methods to more contemporary rigid pavement construction:

- Cobblestone pavements (**CSPs**),
- Plum Concrete pavements(**PCPs**) and
- Un-reinforced Concrete pavements (**UCPs**)



Surviving Roman Cobblestone and Plum concrete roads in the United Kingdom

The Romans were certainly famous for their roads and many Roman roads have stood the test of time, some 2000 years after they were made. Full depth stone pavements as well as surfacing methods using stone paving techniques even incorporating traditional designs in the surfacing have been further developed in Europe and to this day the Portuguese are recognized internationally in this particular expertise. Additionally of course the Romans used Labour-Based Technology; the very same technology they used to build impressive bridges and aqueducts still standing today.

Pre-requisite sound sub-grade and good drainage. No rigid pavement can achieve its design requirements without it being built on a sound subgrade or sub-base with satisfactory drainage. This applies equally to cobblestone pavements, plum concrete and un-reinforced concrete pavements. The preparation of subgrade and drainage systems and associated quality control and testing of the finished work is addressed in the LBT Training Manuals for the Rehabilitation of Rural Road Works and must be strictly adhered to.

3. Occupational Safety and Health (OSH) in the Construction of Rigid Pavement Roads.

This section addresses the essential provision of general safety and health measures for all workers on construction and quarrying sites for the construction of rigid pavement of stone and concrete.

3.1. Safety Measures

-  Carry out a safety briefing for all workers before works begin. Make sure work is organized so that each worker has enough space to carry out his or her task without endangering other workers. Make sure that all workers are aware of the need for protective clothing including footwear, eye-protection and gloves for certain construction and quarrying activities.
-  Place warning signs or cones at each end of the work area. The warning signs should be placed 50-100 m away from the working areas. The text on the warning signs should read: "KUIDADU" or "HALAI NENEIK". Where necessary speed regulating devices such as "Road bumps or rumble strips" shall be installed at each end of the work site. The worksite shall either be clear and safe or have warning lights on at night and protection around the site works.
-  All equipment operators must be trained in the use of their equipment (trucks, rollers, concrete mixers, quarrying and construction hand-tools). Equipment must be maintained in good condition and workers must be aware of that safety covers should be used over moving parts on machinery.
-  Other than authorised workers, No persons, especially children, are allowed to enter in the work area.
-  The contractor shall not allow the use of alcohol or drugs on the works site or in the site camp.
-  The Contractor shall maintain a diary recording the details of any worker accidents on site and shall report these to the supervising engineer on the day of any accident.

3.2. Drinking Water

Clean drinking water must be available within 50 metres of all work sites and at least 2 litres should be available per worker per day. Consideration should also be given to flexible working hours to avoid working in the hottest time of the day.

3.3. Safety Gear and Equipment

All workers and operators must be instructed on all potential dangers or hazards of all work activities and be aware of what precautions must be taken to avoid any accidents on site. All workers and operators shall be provided with appropriate safety gear in sufficient numbers. All workers must be instructed how and when to use safety gear and all safety gear shall be replaced when unusable or lost: The Contractor shall provide the following safety gear:

-  Safety jackets in bright "fluro" colours for all supervisors and workers working on a road that has frequent traffic
-  Closed shoes and gloves for all workers for general road works. Note that cotton gloves need to be replaced regularly and are generally inadequate for quarrying and rock placement work.
-  Gum boots and good quality gloves when mixing and carrying concrete.
-  Dust masks and eye protection when working with rock and dusty aggregate fines. Note that dust masks must be replaced regularly and dusty sites should be regularly watered
-  A working chemical fire-extinguisher shall be mounted on the site office exterior wall for easy access in an emergency.

3.4. First Aid

A first aid box must be provided on each site and must be regularly checked and restocked. Work supervisors must be aware of the procedure to provide first aid and transport an injured worker to a health post or hospital in the event of a serious injury.

4. Cobblestone Surfacing

The stone surface option is used for rural road construction where there is ready availability of rock material and is suitable for medium to high traffic densities or where sections of the road have steep longitudinal gradients. Stone surfacing may also provide appropriate surface treatments for road sections through rural villages and communities as well as market places. The stone surface can be produced using the natural shape of the stone and placing it by hand in its tightest possible positions by minimizing the size of the joints. The joint will then be filled by smaller stone and fine material. The stone surface can also be produced by cutting stone into cubic or rectangular shapes in order to ensure that they are placed in a tight pattern. Cutting (or dressing) stones in this way means the final surface will be smoother than the stone using only its natural shape.



In both options the stones are laid on a prepared road sub base with a blinding layer of sand cushion about 5 cm between the stones and the road sub-base layers. The sand cushion accommodates irregularities in the stones allowing the stones to be assembled with a smooth and level riding surface. The sand cushion layer also acts as a drainage layer for any water entering between the stones and therefore requires regular outlets. The stone surface is then covered by a layer of fine gravel filling gaps between the stones and providing a smoother riding surface for traffic. The stone surface option can also be used as road base course layer for bituminous surfacing.

4.1. Materials

Material for constructing the stone surface consists of coarse sand, stone and gravel. The minimum required characteristic of the material are described below:

Stones

The stone to be used for the pavement must be clean, hard, durable, solid and free from soft material or loose pieces. Cracked and hollow stones must not be used. Stones should be cubic or rectangular in shape. The stone should not be able to be cracked under the impact of compaction equipment. Round shape stone or river stones are not recommended for this purpose. The size of the stones may vary depending on the functions of the stones or as otherwise specified in the drawings. Recommended size and shape of the stones to use for the stone surface are:



- ✚ Stone for surface should be 15 cm x 25 cm, with the smallest acceptable size 10 cm x 15 cm. Stones should be cubic or rectangular shaped. Stone from a quarry should be dressed or shaped to the required shape when delivered to site.
- ✚ Stones for edge kerbs should ideally be 20 cm x 30 cm with the smallest acceptable size 15 cm x 25 cm. The kerbstones should be cubic or rectangular shaped. Kerbstones from a quarry should be dressed to shape when delivered. The kerb stone is crucial for holding the other stones in place.



Small stones for filling the gaps should be 2 cm x 3 cm and 3 cm x 5 cm.

Sand

Sand for the stone surface is used to accommodate any irregularities in the shape of the stones allowing the stones to be assembled with a smooth and level riding surface. The sand is also used as a drainage medium for any water entering between the stones. The sand should be coarse sand either from river or mountain sand and must be clean, free of leaves, grass, compost, clay lumps, or dust etc. Drainage outlets from the stone bedding must be provided at regular 5 to 10 m intervals.

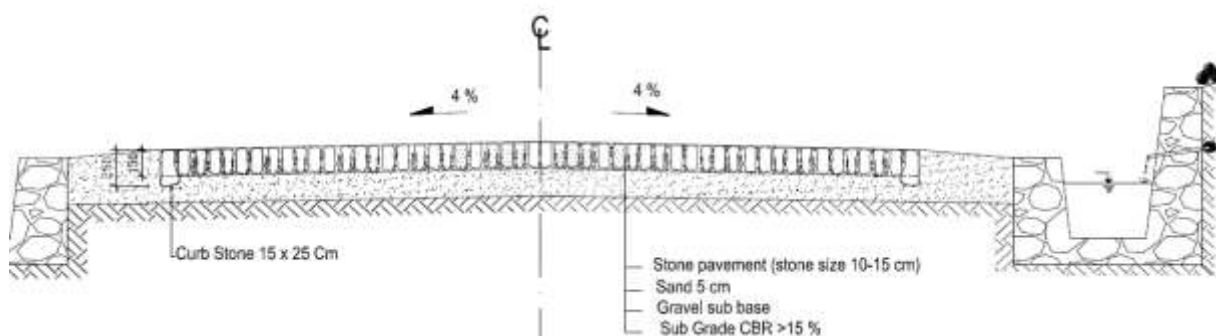
Gravel

Gravel is used to fill gaps between stones to restrain the stones' movement when under traffic load. The gravel also acts to provide a smooth running surface in the final layer. The gravel is laid over the stone surface and will fill the gaps. The gravel for this purpose can be mountain gravel or river gravel and should be well graded. The maximum size of the gravel however should not be greater than 50 mm and must be clean, free of leaves, grass, compost, clay lumps etc.

4.2. Work Method

Step 1. Setting Out

Set out the road cross section by setting center line peg and pegs at edge of the carriageway. The cross section should be set for every 5 m interval. Mark the finished level of the stone surface at the center line and transfer with the design cross-fall to edge pegs. The cross-fall from the center line to the edge pegs should be 4-5%.

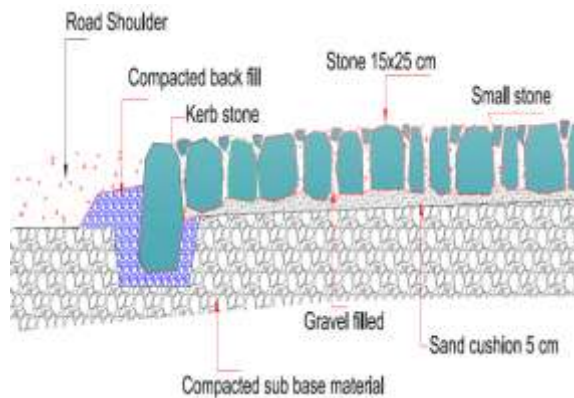


Excavate foundation for Kerbstones. The foundation should be excavated along all road edges. The width of the foundation should be 25-30 cm and depth should be 15-20 cm. Bed level of the foundation of both edges should be checked using a line level to ensure they are at the same level.

Position Kerbstones in the excavated foundation in vertical position by keeping top level of the stone as set in the peg. The kerbstones should then be placed as tightly as possible. Back fill the kerbstones with gravel and provide compaction by hand rammer. Repeat the same process of placing kerbstones along the other edge of the road.

Step 2. Blinding Course

Prepare the road sub-base by shaping the sub-base to level and ensuring 4-5% camber. Compact the prepared sub-base then place and spread the blinding course layer of coarse sand of 5 cm thickness.

**Step 3. Placing of Stones**

Ensure the string line is tightened at the marked levels and connected from edge pegs to centre line pegs. Place the stones on the spread sand as close together as possible. Where some stones are slightly wedge-shape it is necessary to place the wider end down onto the sand layer. The stones should be placed starting from the outside edge and then working towards the centre line of the road. Ensure the top level of the stones is at the level set by the string line. Where-ever the top level of the stone is higher than the set string line; such stones should be hammered down into the sand to level. After the large stones are placed it is important to use small stones to tighten the larger stones by inserting the small stones into gaps between the large stones. The laying of the stone surface requires skilled labour to achieve good workmanship.

Step 4. Surface Gravelling and Compaction

To avoid movement of the stone, a thin layer of sand is spread over the stone surface and washed into the voids by water.



In order to make the stone surface water-tight and to provide a smoother surface for vehicles, the stone paving should then be covered by a thin layer (5 cm) of selected gravel. The selected gravel should contain mixture sand and coarse aggregate of grading not larger than 50 mm with a small portion of clay. The selected gravel is spread on the stone surface. Some portions of the gravel will then be filled the stones gaps to further strengthen the stability of the stones and other gravel will remain on the surface.

After spreading the selected gravel, final compaction will be carried out, by 2-3 passes using a

3-5 tonnes roller. Vibration during the compaction should not be used. The compaction will level the height of the stones providing smoother surface on the carriage way. The compaction should be carried out from road edge towards the centre-line of the road.

Step 5. Constructing Road Shoulders

Road shoulders shall be filled by using mountain gravel or laterite. Before filling, the existing shoulder should be watered. The shoulders are filled and shaped to the same level as the kerbstones. The filled material is spread to form a slope of 7-8% away from the road. Compaction is then carried out by vibrating pedestrian roller or plate compactor/vibrating tamper.



Step 6. Constructing Filter Drains

Filter drains are constructed to drain water from the stone surface beds. The filter drains are provided at interval 5 - 10 m for both side of road shoulder. The filter drains should be constructed at the time of filling road shoulders by excavating the drain across the road shoulders in rectangular shapes of 20-30 cm wide with the invert (bottom level) of the drain the same as bottom level of the kerbstone and sloping slightly away from the road. The excavated rectangular box is then filled with broken stone and surfacing should be the same material as that of the road shoulders. Compaction can then be commenced at the time of compacting for road shoulders.

Step 7. Slope Protection

The road shoulders and slopes should be protected from erosion by planting grass and turfing. The roots of the grass can help to retain the soil and stabilise the slopes and shoulders by preventing the surface soil from being washed away. Where necessary bio-engineering work methods shall be engaged as required (Refer to separate LBT Slope Protection Manual).

4.3. Quality Control for Construction of Stone Surface

The construction of a cobblestone pavement includes the selection and testing of materials, preparation and placement of stone. Quality control and tests for these works include checking the suitability of the materials. Some of these tests can be carried out in the field but certain tests should be carried out in a laboratory as required by the contract.

Description/ Work Activity	Test/Check Method	When	Tools
Material Stone Surface			
Gravel and sand	✓ Check the quality of the gravel and sands meets the specified requirements.	Written Certification before delivery on site	NA
Stone for surface kerbstone	✓ Check the Hardness, shape, strength, durability of the stone and kerbstones against the specified requirements ✓ The quality control of stone used should be the same as for stone masonry work	Written Certification before delivery on site	Measuring tape and Steel hand-pick

	✓ Randomly carry out visual checks on the size and shape of stone be used.		
Construction of Stone Surface			
Placing kerbstone	✓ Check pegs and string line are used at edges of the carriage way at 5 m intervals ✓ Check width and depth of the foundation for placing kerbstone according to the drawings ✓ Check the kerbstones are placed vertically and as close to each other as is possible.	During the carrying out of the kerbstone activity	Measuring tape
Placing stone surface	✓ Visually check sub base layer is compacted, cleaned and levelled ✓ Check thickness of sand bedding and uniformity of spread ✓ Check the stones are shaped (slightly dressed) for cubic or rectangular shape. size should be between 12 cm - 20 cm: ✓ Check stones are placed as close to each other as possible. ✓ Check gaps are filled by smaller stones ✓ Check top levels are on an even plane ✓ Check all the gaps between the stones are fully filled with gravel or sand.	After placing of kerbstones	Measuring tape and line level
Spread gravel	✓ Check thickness of gravel laid on the surface ✓ Randomly count the number of passes carried out for compaction.	After placing stone surface	Measuring tape
Construction shoulders and filter drain	✓ Check material for filter drain is in accordance with the Specification ✓ Check the dimension and locations of the filter drains ✓ Check quality of material used for shoulder is as per Specification ✓ Check level of the shoulder is the same as the top level of kerbstones and slopes toward the side drain ✓ Check the degree of compaction of the shoulder by randomly counting the number of passes during compaction.	During construction of shoulders	Measuring tape, DCP
Final check for finishing work	✓ Visual check on overall appearance: ✓ Check all remaining material has been cleared from site ✓ Check that all holes or side borrow are filled and levelled ✓ Check slope protection works are	After completion of the work	File report

	completed and the road slopes are stabilized.		
--	---	--	--

4.4. Technical Resources and Reference Materials for Stone Paved Roads.

- International Labour Office, Labour-Based Stone Paved Roads, Kampong Cham Province, Samer Al-Fayadl, ILO, Cambodia, 2001
- Overseas Unit, Transport Research Laboratory, 1982, Overseas Road Note 3, A guide to surface dressing in tropical and sub-tropical countries, Crowthorne, Berkshire, United Kingdom.
- B. Thagesen, 1996, Highway and Traffic Engineering in Developing Countries, E&FN Spon, United Kingdom.
- Overseas Unit, Transport Research Laboratory, 1988, Overseas Road Note 5, A guide to Road Project appraisal, Crowthorne, Berkshire, United Kingdom.
- Robert Petts, May 2001, Rationale for the Compilation of International Guidelines for low-cost Sustainable Road Surfacing, LCS Working Paper No 1.
- International Labour Office 1992, Stone Paving-Blocks: Quarrying, Cutting and Dressing. Training Element and Technical Guide for SPWP Workers, Booklet No.8, Geneva.
- International Labour Office 1991, Stone Masonry. Training Element and Technical Guide for SPWP Workers, Booklet No.2, Geneva.
- A Beusch et al 1997, Low Cost Road Construction in Indonesia. Labour Based Road Projects in Manggarai District, Intercooperation, Offsetdruck OD, Switzerland.
- P. N. Khanna (undated), Indian Practical Civil Engineer's Handbook, The Standard Every-Day Reference Book for all Engineers and Architects, India.
- Shadmon 1996, Stone: An introduction, Intermediate Technology Publications, London.
- International Labour Organisation, The Upstream Project 2000,
- R. Dennis (undated), Handtools for Labour Based Roadwork, Guideline for selection and procurement, Mart Publication, United Kingdom.
- Technical Manual for Labour Based Road Construction, Phnom Penh.

5. Construction of Plum Concrete Surface

Concrete pavements provide a strong and rigid surface and are common in a number of countries for roads with high traffic densities or roads in steep terrain. They are built with or without reinforcement. For rural roads the concrete pavement surface is usually built without reinforcement as traffic volumes and loads are generally low and this produces a successful pavement at a lower cost.



Plum concrete pavements are one concrete surfacing option which is suitable for rural roads that often do not have high volumes of traffic but may have steep gradients and where gravel surfacing would not be suitable. The plum concrete pavement is a mix of concrete and larger solid stones, where the volume of stones typically 30-40% reduces the volume of concrete needed, which usually reduces the costs but still provides a strong and durable pavement.

The plum concrete surfacing layer should be placed on a prepared road sub-base (sub-base or prepared sub-grade for low traffic density road). The work comprises of preparing road-base (or sub base), mixing of plum concrete, hauling and placing the concrete on a prepared road-base (or sub-base). The mix design of the Plum concrete shall be in accordance to mixing proportion determined by the Engineer or as specified in the contract Specification. The construction of the plum concrete pavement usually starts with a 5 cm blinding course of lean-mix concrete, which is placed directly on the road sub-base. Strong stones 7-10 cm (plums) are placed on the lean concrete with some 5 cm spacing. A 12 cm thick concrete layer is then constructed on top of the lean concrete. The concrete is poured in between and over the plums making sure there is a 2 cm cover over them.

5.1. Material

This concrete work consists of cement, aggregate and water, mixed to the proportions as Specified for both the Lean-mix bedding and the pavement concrete which is placed over large stones (plum) as the main concrete activity.

Cement

Cement also known as Ordinary Portland Cement (OPC) is produced from limestone and clay. The cement used for this purpose is delivered in paper bags containing of 40 kg or 50 kg of cement in each.

Aggregates

Aggregate for mixing the plum concrete can be natural aggregate from river or crushed aggregate from stone. The particular size and grading of the aggregate will affect the density, workability and strength of the concrete works. The required grading of the aggregate will be specified on the drawing or in the technical Specification. However, the maximum size of the aggregate should not exceed 50mm.

Natural gravels and sand very often contain impurities, such as clay, silt, humus, leaves and grass. It is important to work only with clean aggregates and wash them if necessary before mixing the concrete. The aggregates for the plum concrete works should be well graded. If the batch of aggregate contains a large percentage of flat or flaky particles it should be rejected.

Sand

Sand is used as a void filler in the mix and also to reduce friction between the stone particles. The sand for mixing the plum concrete must be clean, free of leaves, grass, compost, clay lumps, or dust etc. Sand should be fairly coarse clean river sand. River sand may however need to be sieved before used

to remove stones and dust. Often the best sand is a mixture of river sand and pit sand.

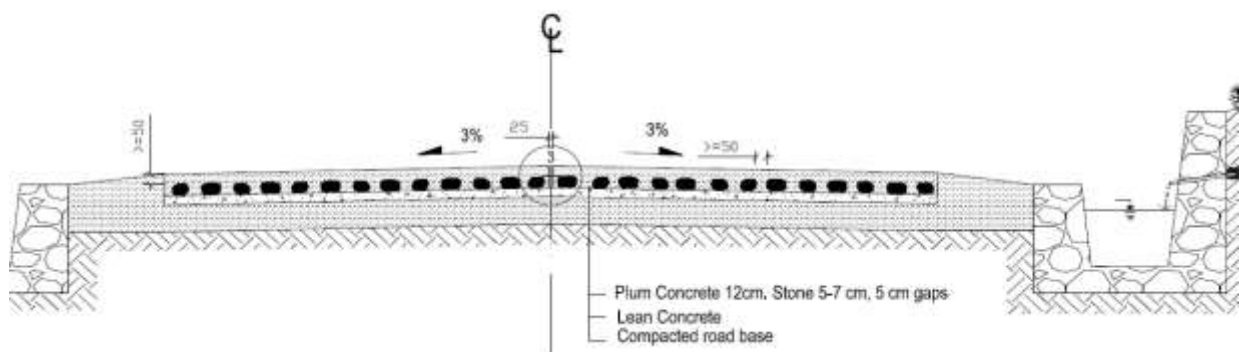
Water

Water is used for mixing and curing concrete. Water is used to activate the cement and wet the sand and aggregates during the concrete mixing. The water for this purpose must be clean. Impurities in the water affect quality of the plum concrete. The water can be taken from rivers, lakes, wells or taps. Sea water, surface run-off water, dirty water with organic particle must not be used. Dirty water can however be put in a drum and can be used after the dirt or organic particles have settled at the bottom of the drum.

Large Stones (Plums)

The large stones to be used for plum concrete work must be clean, hard, durable, solid and free from soft material or loose piece. Cracked and hollow stones should not be used. Stones can be chosen round or cubic shaped. The stone should not be able to be cracked under impact or compaction equipment or crack when dropped three times onto a hard rock surface from shoulder height. The size of the stone shall be used is specified on the drawings otherwise the maximum dimension of the stone shall not be greater than thickness of designed slab. Generally the size the large stones used for the plum concrete should be 7-10 cm and have a crushing strength of 100kg/cm^2

5.2. Work Method



The plum concrete surface should be constructed in blocks of maximum 5 meters in length and the width should be half of the road width. As the concrete work is poured in-situ on the work site, it is important to keep traffic open during the construction period. Therefore the concrete work should normally be done for half of the width of the road and with the other side open for traffic. The steps for the construction of each section should be carried out as follows:

Step 1

Setting out and placement of formwork (edge supports): Before placing formwork ensure that the road base is well compacted, clean, free from soft material. Cleaning the road-base will require the use of a broom.

The formwork should be fixed in place for half the width of the road and set to the designed height (about 17 cm – 5 cm lean mix + 12 cm pavement). The level of the formwork at the centre line must be higher than the edge support placed at the shoulder with 3% of cross fall. The Line level should be used to transfer levels from the top of the formwork at the road centre line to the edge of the road. The size of each section (box) should therefore be: width = half width of the road, and Length = 3 to 5 m. The formwork, once removed will provide a 5-10 mm gap in between the boxes which will serve as an expansion joint which will need sealing with an approved flexible filler.



Step 2

Mixing and placing plums on lean concrete: This is done on the prepared road sub base inside the form work. Mixing lean concrete should follow the mixing procedure and normal specified practice. The lean concrete should be mixed by a concrete mixer with mixing proportion as specified in the drawing or technical specifications. The mixing proportion for lean concrete is normally 1:3:6. (Cement, sand, aggregate) with a relatively low water/cement ratio.

Pour the lean concrete to the specified thickness as shown in the drawing or technical specifications.

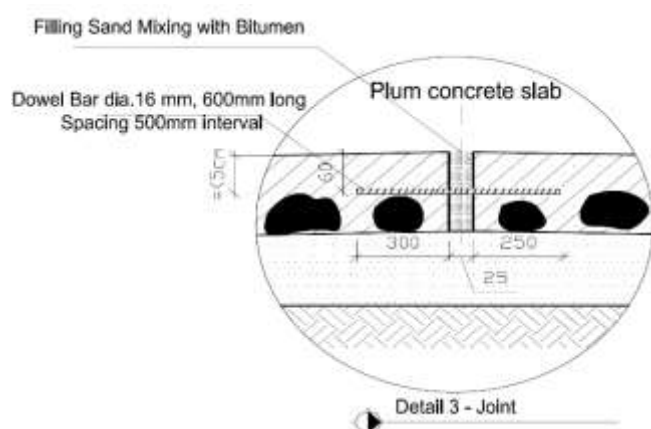


(Generally the thickness of the lean concrete is 5 cm). The large stones (plums) shall then be laid on the lean concrete while the lean-mix is still within the initial setting time. But, the concrete should then be sufficiently stiff to prevent complete submergence or toppling over of the stones. The bottom part of the stones (about 1/3 of stone thickness) should be embedded in the concrete and the remaining part exposed so as to form a key with the next layer of concrete. The plums (large stones) should be placed with gaps between them of no less than 50 mm.

Step 3

Final concrete layer: Once the large stones (plums) are placed, concrete for the last layer shall be mixed and placed following normal practice with the mixing proportion as specified in the drawings or technical specifications. (Generally 1:2:4. (Cement, sand, aggregate).

The concrete should be poured between the formwork and around the large stones ensuring 2 cm cover over the top of the stones and then tamped and compacted until all air is removed. Normally the total volume of plums should not exceed 40% of the volume of the finished concrete. If specified steel dowel bars as slab ties and for load transfers shall be installed to specification.



Step 4

Concrete finishing: The finishing of the concrete shall involve screeding with an aluminium screed board and the floating of the surface to achieve the specified surface profile. Prior to the concrete “going-off” the surface must be made safe for future traffic through either the grooving of the surface or the application of a hard broom strokes making 1 to 2 mm ridges in the concrete surface which should be align transversely and in parallel in a distinctive pattern according to the directions of the Engineer.

Step 5

Curing: The concrete formwork (edge supports) can be removed after 48 hrs, and the concrete should be cured for a minimum of 7 days and preferably 14 days. The curing shall commence 3-4 hours after the placing of the concrete. The curing process is most critical during the initial days after pouring and it is necessary to keep the concrete surfaces continuously wet during the curing period.

Curing can be achieved by:

- ✓ Sprinkling water on concrete surface, taking care to keep a permanent wet surface,
- ✓ Covering the concrete surface with either empty cement bags, or sand or sawdust (minimum 5 cm layer), wet jute, hessian mats or banana leaves. These covers must also be kept continuously wet,
- ✓ Making a pond of water on the concrete if this is practical.

Once the first half of the plum concrete surface curing has achieved the minimum required strength, it can be opened for traffic while the second half of the road can then be constructed following the steps as described for construction of first half of the road.

**5.3. Quality Control for Construction of Plum Concrete Surface**

The construction of Plum concrete surface activity includes the selection and the testing of materials, mixing, placing and curing of the concrete. Quality control and testing for these works includes checking the suitability of the material. Some tests can be carried out in the field but some tests can only be carried out in a laboratory and as specified.

Description/ Work Activity	Test/Check Method	When	Tools
Material Plum Concrete			
Aggregate, sand, cement and water	✓ All materials used shall be in accordance with the specification. Visual inspections are possible on site especially of all materials being used.		

Stone	✓ Check hardness, shape, strength, durability requirements are as per the Specification and similar to those applicable for stone masonry work ✓ Check size of stone visually to see if it is in compliance with the specified size and shape.	Written certification before procurement of the stone	Measuring tape
Construction of Plum Concrete			
Placing formwork/ edge support	Visually check that the sub base layer is compacted, cleaned and levelled Check the width, height and levels and camber of the slab section (box).	Before the start of mixing concrete	Measuring tape and line level
Lean Concrete for bedding	✓ Check mix and placement of concrete as Specified and check also dimensions, thickness and slump of the lean concrete	During lean concrete activity	Measuring tape, Slump cone test.
Placing stone, mixing and pouring concrete	✓ Placing large stones (Plums) ✓ Check gap between each stone is not less than 5 cm ✓ Check no stones are placed overlapping each other ✓ Check top level of the large stones are not higher than level of edge support ✓ Concrete work ✓ Prepare 3 concrete cubes for strength testing in a laboratory ✓ Check mix and placement of the concrete is per Specification. ✓ Check the concrete fills all gaps (voids) of the large stones and is well compacted ✓ Check the depth of the concrete is as specified. ✓ Check surface levels are as specified ✓ Check surface has been grooved or hard broom brushed for roughness	During the carrying out the actual concreting work	Measuring tape and Laboratory test results
Curing	✓ Check finished concrete is being kept wet or damp using one of the recommended or Specified methods for curing.	Regular checks needed for min. 14 days	Keep photographic record
Final check for finishing work	✓ Undertake general visual check: ✓ Check all remaining materials have been cleared from site ✓ Check formwork is removed after minimum of 14 days and taken away from site ✓ Ensure joint filling is completed as specified ✓ Check that shoulder works and slope	After completion of the work	Prepare report

	protection works have been satisfactorily completed		
--	---	--	--

6. Construction of Un-reinforced Concrete (UPC) Pavements

Most low volume rural road concrete pavements constructed today are unreinforced and jointing requirements depend on the traffic volume and loading. Unreinforced concrete roads are commonly designed in 4m to 5m long slabs that may be full carriageway width or half width depending on the geometry of the road or the ease of traffic diversions during construction.

The first overall design consideration is the need for the subgrade/sub-base to be well prepared to specification and be overlaid with a 25 mm blinding layer of fine aggregate or sand to enable essential slab movement and expansion/contraction after construction.

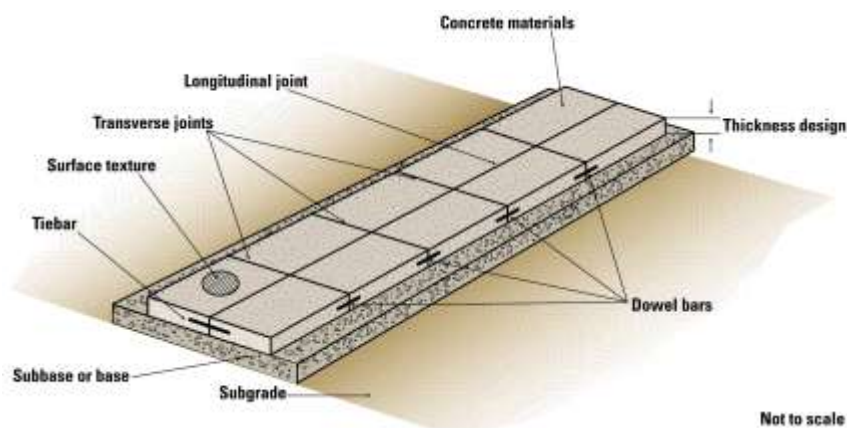
The second overall design consideration involves ensuring that there is adequate side drainage to avoid the undermining of the pavement through scour damage and in some cases it will be appropriate for the installation of immediately adjacent concrete swale drains or deep section stone masonry drainage with appropriate bio-engineering works for Slope protection.

In the event that there is no necessity for adjacent drainage structures, special attention must be paid to ensuring that the shoulders are well constructed and that the slopes are well protected.

Longitudinal and transverse jointing where necessary can be formed either with interlocking formed concrete joints or with moveable (sliding) dowel tie-bars.

In addition the first and last slabs, adjoining unpaved or flexible surfacing will require careful detailing to accommodate the impact loading of heavy wheels moving onto the slabs and to ensure a smooth surface transition. Slab thickening or local reinforcing may be used for this purpose if necessary. In the event that jointing is not specified for the works it is expected that there will be some small spacing (10 ~15 mm) between slabs once the formwork is removed and that these joints will be filled with a flexible waterproof compound after curing of the concrete.

A qualified Engineer shall certify the design requirements of the un-reinforced concrete pavement and appropriate designs are included in The Australian (ARRB) document on sealed rural road design which provides comprehensive guidance and charts for both un-reinforced and reinforced concrete pavements. DFID's SEACAP work in Lao PDR also provides an example of a specific un-reinforced concrete design table for light traffic and the Ethiopian Roads Authority design manuals (2013) provide even more detailed design catalogues for un-reinforced concrete.



Typical Unreinforced Concrete pavement Features

6.1. Alternative Concrete Pavement Options

These can include *dual concrete strips* which can be appropriate for very low trafficked locations with steep inclines and their use can be justified as a cost saving approach.



Likewise the South African developed cast-in-situ “hyson cells²” or geo-cells provide a further cost effective approach and most countries are also able to hand produce or manufacture interlocking concrete pavers which can also be used successfully on rural roads.



Geo-cells during Construction



Geo-cells 2 years after construction

Reinforced concrete paving is normally considered too expensive for general application in low volume rural roads, except as part of structures such as drifts. And the *Ultra-Thin Reinforced Concrete* option which has also been used successfully within South Africa does require a high level of construction expertise and quality control.



Steel mesh reinforced concrete pavement construction in Timor-Leste

² See www.hysoncells.co.za, and www.ilo.org/wcmsp5/groups/public/@ed.../wcms_asist_8390.pdf

Finally *Brick (concrete or fired clay) pavements* provide an acceptable moderate cost solution in areas with a scarcity of aggregates or gravels. They also have the advantage of promoting local enterprises and employment.



However the most durable and still popular pavement treatments throughout most of the old town centres in Europe is the traditional Pavé or Setts - tightly packed stone long lasting wearing surfaces.



Pavé surfacing and traditional patterns

6.2. Concrete Materials

The materials used in the on-site mechanical mixing for the production of concrete have been outlined in the LBT Training Manual Module K-1. In addition the following supplementary details are usually included in current contract specifications in Timor Leste.

Generally the concrete specified for rural road un-reinforced concrete pavements involves concrete specified with a minimum working strength of 20 MPa (3000 PSI in 28 days), with minimum cement (OPC) content of 300kg/M3 and a maximum free water/cement ratio of 0.5.

Cement

Cement used should be Ordinary Portland Cement (OPC) and should be delivered to site and carefully stored immediately upon delivery at the Site, in weatherproof building (with a raised floor) which will protect the cement from dampness.

If for any reason cement becomes partially set or contains lumps of caked cement it should be rejected. Cement salvaged from discarded or used bags shall also not be used. Samples of cement shall be obtained in accordance with AASHTO T 127.

Aggregate

Aggregates used in un-reinforced concrete works shall consist of crushed stone or gravel having hard, strong, durable pieces and free from any adherent coatings. The aggregate should contain no more than one (1) mass percent of material passing the 0.075 mm (No. 200) sieve, not more than 0.25 mass percent of clay lumps, nor more than 3.5 mass percent of soft fragments. Aggregate shall also have a mass percent of wear not exceeding 40 when tested by AASHTO T 96.

Fine Aggregate/ Sand

Fine aggregate/sand shall consist of natural sand, stone screening or other inert materials with similar characteristics, or combinations thereof, having hard, strong and durable particles.

It shall not contain more than three (3) mass percent of material passing the 0.075 mm (No. 200) sieve by washing nor more than one (1) mass percent each of clay lumps or shale. The use of beach sand should not be allowed without the approval of the Engineer.

Water

Water used in mixing, curing or other designated application shall be reasonably clean and free of oil, salt, acid, alkali, grass or other substances injurious to the finished product. Water which is drinkable may be used without test.

Admixtures

Air-entraining admixtures shall conform to the requirements of AASHTO M 154 and their use be approved by the Engineer. Chemical admixtures, if specified or permitted, shall conform to the requirements of AASHTO M 194.

Curing Materials

If water availability is an issue, hessian mats, banana leaves, water proof paper, white sheeting (film) materials should be used and kept dampened. Likewise a liquid membrane forming compound may be used as approved by the Engineer.

6.3. Work Method

The introduction to General Concrete Works is included in the existing LBT Concrete Training Module KI and addresses the essential areas of: materials, types and grades, mixing, transporting, placing and compaction, curing, slump test and quality control.

To achieve good results it is important that the mix is workable (with the use of admixtures where necessary). Concreting work should also be carried out when the shade temperature is no more than 40 degrees C. In Timor Leste this means that at certain times of the year concreting work must be restricted to cooler hours of the day only.

Step 1

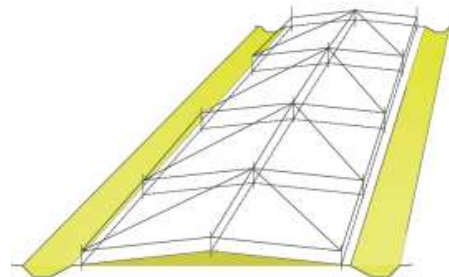
Set-out and formwork placement: The setting out procedure for un-reinforced concrete works is similar to that described for plum concrete, however each slab shall be individually formed preferably a half pavement width wide and 4 to 5 metres in length. Before placing the formwork, ensure that the road subgrade is well compacted, clean, free from soft material and dry brushed with a hard broom.

The steel or timber formwork should be fixed in place to the designed height above the subgrade (~ 15 cm – 10cm pavement and 5cm blinding course) and the level of the formwork at the center line must be higher than the outside edge support placed at the shoulder with minimum 3 % of cross fall.

Line levels should be used to transfer the level on top of the formwork from the road center line to edge of the road. The formwork, once removed will provide a 10 ~ 15 mm gap in between the slabs which will serve as expansion joints which will require waterproofing with a suitable flexible filler material.

For effective grade control it is also recommended that the slabs be constructed in an “alternate” pattern so enabling the initially unconstructed slabs to be accurately aligned with the already constructed slabs and to incorporate effective provision for expansion and slab connection and good grade control. Refer to the figure which follows.

Side 1	1	6	3	8
Side 2	5	2	7	4



Typical Alternate Slab Construction Sequence

(If permitted by traffic conditions)

Step 2

Formwork: The formwork must be sufficiently rigid and tight to prevent loss of grout or mortar from the concrete at all stages and for the appropriate method of placing and compacting the concrete within Specification. All formwork shall have its surface scraped smooth and clean before re-use. Any damage to formwork shall be repaired before re-use.

Forms and headers shall be either wood or metal. They shall be set plumb and true to line and grade, with the upper edge thereof set to the grade of the pavement to be constructed; and shall be rigidly installed on a true alignment and so maintained for a distance in advance of placing the pavement to provide for at least a one-day run of concrete. Headers shall rest firmly on the subgrade or base. They shall be oiled immediately prior to the placing of the concrete and shall remain in place for at least 48 hours after concrete has been placed. Forms and headers must be removed before the work will be accepted.

Step 3

Blinding/bedding course: The road sub-base/sub-grade must firstly be checked for compliance with the Specification and rectified if it does not comply. Once the sub-base/sub-grade surface is accepted as compliant then the blinding layer of course sand or fines aggregate as specified shall be laid to a depth of 5cm, levelled and watered. Before any concrete is placed, an inspection shall be made to ensure that no dirt, shavings, loose stones, etc. have been allowed to remain in or about the formwork.

Step 4

Concrete Mixing: Concrete shall be mixed by purpose-made, power-driven concrete mixers. Hand-mixing of concrete will not be permitted. Each batch shall be mixed until the concrete is uniform in colour and consistency and for not less than three (3) minutes, which shall be measured from the time when all the solid material is in the mixing drum. All the mixing water shall have been introduced before 25 percent of the mixing period has elapsed. No further water shall be added to the mix once it has left the mixer. Any concrete which has become partly set or too stiff to compact properly shall be discarded.

Volume batching shall be done in purpose-made boxes or by calibrated concrete mixers or with carrying handles which shall be carefully supervised to ensure that the boxes are struck level each time. Water must be measured by volume.

The concrete shall be transported from the mixer to the position of placing quickly and in such a way that segregation does not occur. The time between mixing and placing shall not exceed 10 minutes.

The mixer and associated batching and placing equipment shall be thoroughly cleaned out at the end of each day's work.

Step 5

Concrete placing: The fine granular layer covering the completed subgrade must be sufficiently dampened to ensure that no moisture will be absorbed from the fresh concrete.

Formwork and any reinforcement shall also be well watered immediately prior to placing the new concrete. Immediately after being mixed, the concrete shall be deposited on the layer of fines covering the subgrade to the required depth over the entire width of the section. For steep inclines it is essential that the slump of the concrete is not excessive as to create unmanageable flow.

Concrete shall be placed gently in position to avoid segregation and not allowed to fall freely from a height greater than 2 metres. All concrete shall be hand spread with shovels and rakes within the formwork and fully compacted by means of immersion type vibrators.



At the end of each day's run, or at any time when operations are stopped for a period of more than 40 minutes, a rigid transverse header shall be placed vertically and at a right angle across the pavement at the location designated by the Engineer and the pavement shall be finished to form a square vertical joint against which the work may be resumed. Hand-mixing may be used only if necessary to provide sufficient concrete to complete paving to the expedient header.

Step 6

Concrete Finishing:

Tamping/vibrating. The concrete shall be distributed uniformly between the side forms as soon as it is placed, after which the concrete shall be struck off and tamped. Hand tamping should be undertaken systematically at right angles to the centreline of the pavement, and tamping continued until the concrete is thoroughly consolidated to the specified cross section and sufficient mortar for finishing purposes has been brought to the surface. Approved concrete vibrating equipment shall be used in conjunction with the hand tamping to consolidate the concrete.

Floating/Finishing. After tamping, the surface of the concrete shall be screeded with a stable straightedge and then floated with a long-handled float at least 1.5M wide, following which the surface of the concrete shall be finished smooth and true to grade, with a wooden float 2.5M long, 50mm thick, and 150mm wide. Ensure a true and flat surface on the float under-side at all times. The edge of the float shall be used to cut down all high areas, and the material so removed shall be floated into the depressions until a true surface is obtained.

Straight-edge Testing and Surface Correction. After the floating has been completed and the excess water removed, but while the concrete is still plastic, the surface of the concrete shall be tested for trueness with a 3-m long straight-edge. Any depressions found shall be immediately filled with freshly

mixed concrete, struck off, consolidated and refinished. High areas shall be cut down and refinished.

Final Finishing. After being finished, the outside edges of pavement shall be beveled using a steel bevelling tool with approximately a 12mm radius; and transverse joints, expansion joints, and joints adjacent to an existing pavement shall be rounded to 6mm radius. After working to a smooth finish, either insert fine grooves in the surface or draw a stiff bristled broom heavily across the surface of the slab to produce an even non-slip finish of course parallel lines free from ridges and depressions 1.5mm in depth.

Step 7

Concrete Curing: Immediately after the finishing operations have been completed and as soon the concrete has “gone off”, the entire surface of the newly placed concrete shall be covered and cured. Curing is likely to require hessian or similar material being kept wet or white polythene sheeting in close contact with the surface or the application of a sprayed on membrane curing compound.



Step 8

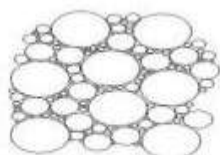
Form Removal and Joint Filling: Forms shall not be removed for at least 48hrs after the concrete pour. Joints shall be sealed with a flexible water-proof compound soon after completion of the curing period and before the pavement is opened to traffic, including the Contractor's equipment. Just prior to sealing, each joint shall be thoroughly cleaned of all foreign materials including membrane curing compound and the joint faces shall be clean and surface dry when the seal is applied.

6.4. Quality Control for Un-reinforced Concrete Pavement Construction

The quality control of concrete is essential for optimal results. Materials must meet specified standards, concrete work must involve correct mix design and correct procedures for mixing, placing, spreading, finishing and curing. Each stage is as important as the other.

Summary of Critical Factors that Make for Good Un-reinforced Concrete Pavement Construction

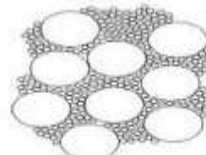
- A skilled and dedicated crew
- Good subgrade finish and a fine material overlay bedding for the concrete
- Well graded aggregate for controlled workability and lower drying shrinkage



Well Graded



Poorly Graded



Gap Graded

- A good (lower slump for steeper inclines) concrete mix
- Controlled density of concrete – just the right vibration & finishing
- Good string-line and grade control for paving
- Continuous supply of concrete to pavement works
- Appropriate joint (expansion/contraction) control
- A safe non-skid surface finish
- Well managed curing.

Quality Control of Un-reinforced Concrete

Description/ Work Activity	Test/Check Method	When	Tools
Materials for un-reinforced concrete			
Aggregate, sand, cement and water	✓ All materials used shall be in accordance with the specification. Visual inspections are necessary on site for all materials being used.		
Construction of un-reinforced concrete			
Placing formwork/ edge support	✓ Visually check that the sub-base layer is compacted, cleaned and levelled ✓ Check the width, height and levels and camber of the slab section (box).	Before the start of mixing concrete	Measuring tape and line level
Blinding for Concrete bedding	✓ Check bedding materials quality and placement as specified and check also dimensions and thickness of the bedding material.	During carrying out lean concrete activity	Measuring tape. Spade.
Mixing, Placing, working and finishing the concrete	✓ Concrete work ✓ Prepare concrete cubes for strength testing in a laboratory as required by the Specification ✓ Check mix and placement of the concrete is per Specification. ✓ Check the concrete fills all gaps (voids) and is well compacted and vibrated ✓ Check the depth of the concrete is as	During the carrying out the actual concreting work	Measuring tape and Laboratory test results

	specified. ✓ Check surface levels are as specified ✓ Check surface has been grooved or hard broom brushed for roughness		
Curing	✓ Check finished concrete is being kept wet or damp using one of the recommended or Specified methods for curing.	Regular checks needed over 14 days	Keep photographic record
Final check for finishing work	✓ Undertake general visual check: ✓ Check all remaining materials have been cleared from site ✓ Check formwork is removed after 14 days and taken away from site ✓ Check joint filling has been satisfactorily completed ✓ Check shoulder and slope protection works have been satisfactorily completed and where necessary are under regular management and maintenance	After completion of the work	Prepare report

6.5. Technical Resources and Reference Material for Un-reinforced Concrete Pavements:

- Guide for Design of Pavement Structures. American Association of State Highway and Transportation Officials (1993). AASHTO
- Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavements USA. (M--E PDG) (NCHRP 2004)
- Ethiopian Roads Authority, Pavement Design Manual Volume II Chapter 4 Rigid Pavements – 2013
- Low volume concrete roads, Brian Perrie, Cement and Concrete Institute, South Africa
- Highways Department, Hong Kong, Research & Development Division, Sept 2013, (RD/GN/017)
- New Zealand Standard Specification for Concrete production (NZS 3104, 2003)
- PWD Montserrat, West Indies
- Concrete roads in developing countries, TRL, DFID, PA1150/85
- Road Building in the Tropics: State-of-the- Art Review, TRL, No. 9. TRL, 1993.

ERA Enhancing Rural Access	WORK SHEET
Item: Construction of Rural Road Cobblestone Pavement	WS-CSP
Specification: The activity pre-requisite is an understanding of the need for an acceptable subgrade for a rigid pavement to ensure an equal load bearing capacity by the cobblestones. (Subgrade failure is the most common cause of cobblestone pavement distortions which can also result for poor drainage). Cobblestone pavements are produced using the natural shape of the stone and placing it by hand in its tightest possible positions by minimizing the size of the joints. The joints are then be filled by smaller stones and fine material. The stone surface can also be produced by cutting stone into regular and reasonably precise cubic or rectangular shapes in order to ensure that they are placed a very tight pattern. Cutting (or dressing) stones in this way means the final surface will be smoother than the stone using only its natural shape. In both options the stones are laid on a prepared road sub base with a blinding layer of sand cushion about 5 cm between the stones and the road sub-base layers. The sand cushion accommodates irregularities in the stones allowing the stones to be assembled with a smooth and level riding surface. The sand blinding layer is also acts as a drainage layer for any water entering between the stones and therefore require regular drainage outlets. The stone surface is then covered by a layer of fine gravel filling gaps between the stones and providing a smother riding surface for traffic. Strict and careful setting out of all stones is essential for a good pavement result.	
Work Method: • Construct subgrade in accordance with the standard Worksheet WS-5 requirements as for a base-course pavements. • Set out profiles for the formwork of the road level and camber of 4 to 5% cross fall using steel pins (rebar) and string lines. Steel pins are to be set at road centre-line and road edges with 4 to 5 m longitudinal distance intervals between the pegs and 2 m distance laterally unless there is a one way cross fall in the pavement design or alternative geometric specifications. Mark designated levels on the steel pins and use the string line and stable straight edges as the basis for setting up formwork. • Install kerbstones. Excavate for kerbstones along road edges (25-30cm wide and 15-20 cm deep) and keep a careful check on line and grade. Place kerbstones in a vertical position keeping the top of the kerbstone to line and	

level as set out provided for. Backfill and compact the kerbstones with a hand rammer.

- **Bedding for cobblestones.** Supply, spread, wet and compact a 50 mm layer of fine aggregate (<0.3mm) or sand over the completed subgrade as a base layer for setting the cobblestones between the completed kerbs.
- **Placement of cobblestones.** Use accurate string line control to place the stones on the spread sand as close together as possible. Where some stones are slightly wedge-shape it is necessary to place the wider end down onto the sand layer. The stones should be placed starting from the outside edge and then working towards the centre line of the road. Ensure the top level of the stones is at the level set by the string line and adjust each stone height and position. After the large stones are placed use small stones to tighten the larger stones by inserting them into gaps between the large stones.
- **Surface gravelling and compaction.** A thin layer of sand is spread over the stone surface and washed into the voids by water. In order to make the stone surface water-tight and to provide a smoother surface for vehicles, the stone paving should then be covered by a thin layer (5 cm) of selected gravel which is compacted by 2-3 passes using a 3-5 tonnes rollers. Vibration during the compaction should not be used. The compaction should be carried out from road edge towards the centre-line of the road
- **Constructing road shoulders.** Road shoulders shall be filled by using gravel. Before filling, the existing shoulder should be watered. The shoulders are filled and shaped to the same level as the kerbstones and the fill material should form a slope of 7-8% away from the road. Compaction is then carried out by vibrating pedestrian roller or plate compactor/vibrating tamper.
- **Constructing filter drains.** The filter drains should be provided at interval 5 - 10 m for both sides of road shoulder. The filter drains should be constructed at the time of filling of the road shoulders by excavating the drain across the road shoulders in rectangular shapes of 20-30 cm wide with the invert (bottom level) of the drain the same as bottom level of the kerbstone and sloping slightly away from the road. The

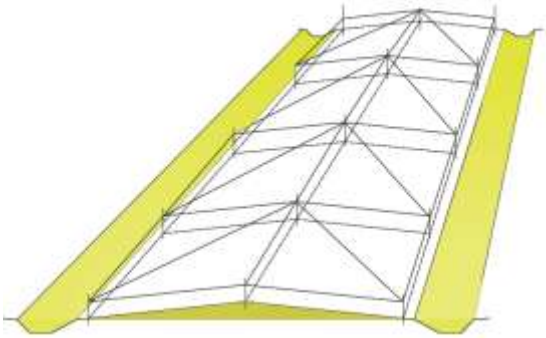


excavated rectangular box is filled with broken stone and surfacing should be the same material as that of the road shoulders. • Slope protection. The road shoulders and slopes should be protected from erosion by planting grass and turfing. Where necessary bio-engineering work methods shall be engaged as required (Refer to separate LBT Slope protection Manual).																													
Manpower: • 1 Supervisor(part time) • 2 part time workers for setting out and constant checking of levels and alignment • 2 Work gangs for placement of blinding course, cobblestones and gravel surfacing and attending to drainage works, shoulder construction and any slope protection works. • 1 Work gang working on adjustments to stone profiles and making or selecting smaller packing stone material.		Tools + Equipment: • Tape Measures, (30 m and 5 m) • String line & Hammer • Wooden/ steel Pegs & Strings • 2 X 3 M straight edge • 2 x Wheel barrows and baskets • 2 tamping bars, crowbars, sledgehammers, club hammers, stone cutters/splitters • 3 shovels, spades, mattocks, steel rakes, • 3 sledgehammers • Plate-compactor and roller.		Material: • Sand, aggregate, and clean water • Selected timber or steel support for kerbstones where necessary.																									
Quality Control: <table><tr><td>Before activity is carried out:</td><td>✓</td><td>Check subgrade completed to geometric standards and to specified compaction standards?</td></tr><tr><td></td><td>✓</td><td>Check steel pegs and string line placed correctly?</td></tr><tr><td></td><td>✓</td><td>Check traffic control, quality control and safety measures in place?</td></tr><tr><td>While activity is carried out:</td><td>✓</td><td>Check the operational set up ensures a constant delivery of cobblestones and smaller filler rock</td></tr><tr><td></td><td>✓</td><td>Balance the cobblestone production and delivery with the capacity to lay the pavement</td></tr><tr><td></td><td>✓</td><td>Check that the pavement thickness and finish tolerances are to specification</td></tr><tr><td></td><td>✓</td><td>Check that the setting out is checked and correct at all times.</td></tr><tr><td></td><td>✓</td><td>Carry out regular visual checks on the regularity of the finished surface and make adjustments where necessary.</td></tr></table>						Before activity is carried out:	✓	Check subgrade completed to geometric standards and to specified compaction standards?		✓	Check steel pegs and string line placed correctly?		✓	Check traffic control, quality control and safety measures in place?	While activity is carried out:	✓	Check the operational set up ensures a constant delivery of cobblestones and smaller filler rock		✓	Balance the cobblestone production and delivery with the capacity to lay the pavement		✓	Check that the pavement thickness and finish tolerances are to specification		✓	Check that the setting out is checked and correct at all times.		✓	Carry out regular visual checks on the regularity of the finished surface and make adjustments where necessary.
Before activity is carried out:	✓	Check subgrade completed to geometric standards and to specified compaction standards?																											
	✓	Check steel pegs and string line placed correctly?																											
	✓	Check traffic control, quality control and safety measures in place?																											
While activity is carried out:	✓	Check the operational set up ensures a constant delivery of cobblestones and smaller filler rock																											
	✓	Balance the cobblestone production and delivery with the capacity to lay the pavement																											
	✓	Check that the pavement thickness and finish tolerances are to specification																											
	✓	Check that the setting out is checked and correct at all times.																											
	✓	Carry out regular visual checks on the regularity of the finished surface and make adjustments where necessary.																											

- | | |
|--------------|---|
| Final check: | <ul style="list-style-type: none">✓ After heavy rain make sure the cobblestones remain tightly packed with no interstices or voids.✓ Replace the fine gravel surface if necessary to maintain an even traffic load distribution on the pavement✓ Check that shoulders are also well constructed as these may be the surface of choice for cyclist and motorcyclists✓ Ensure that all drainage is installed and operational✓ Check any slope protection works are completed and being well maintained. |
|--------------|---|

Suggested Productivity: (Depends on weather, traffic control and gang numbers and other factors)

- Spreading and hauling of delivered gravel ~ 4-5 m³/ WD
- Breaking stone boulders ~ 150mm blocks ~ 20/WD
- Shaping/dressing blocks ~ 50 to 100/ WD
- Packing stones ~ 6 M²/WD
- Void filling ~ 30 M²/WD
- Shoulder construction ~ 20 M²/WD.

ERA Enhancing Rural Access	WORK SHEET
Item: Construction of Rural Road Plum Concrete Pavement	WS-PCP
Specification: The activity pre-requisite is an understanding of the need for an acceptable subgrade for a rigid pavement to ensure an equal load bearing capacity over the concrete slabs. (Subgrade failure is the most common cause of concrete pavement cracking and failure). The plum concrete slabs are formed from a mix of large stones (plums) and concrete where the volume of stones is typically 30-40% of the total volume. The work comprises of preparing road base (or sub-base), mixing of concrete, hauling and placing the concrete on a prepared road base (or sub-base). The mix design of the concrete shall be in accordance to mixing proportion determined by the Engineer or as specified in the contract specification. The construction of the plum concrete pavement usually starts with a 5 cm blinding course of lean-mix concrete, which is placed directly on the road sub-base. Strong stones 7-10 cm (plums) are placed on the lean concrete with some 5 cm spacing. The activity also involves on-site production and placement and finishing of low-slump 20MPa concrete (1:2:4) prepared with a mobile mixer unit for which there are separate Worksheets and an ERA Guideline on Quality Control and a Manual on Road Rehabilitation (Section J7). A 12 cm thick concrete layer is then constructed on top of the lean concrete. The concrete is poured in between and over the plums making sure there is a 2cm cover over them. Special attention must be given to the slab jointing if specified and pavement thickness details as provided for in the current ILO Standards applicable in Timor Leste.	
Work Method: • Construct subgrade in accordance with the standard Worksheet WS-5 requirements as for a base-course pavement • Set out profiles for the 17 cm high (12 cm pavement and 5cm lean-mix) formwork of the road level and camber of 3% cross fall using steel pins (rebar) and string lines. Steel pins are to be set at road centre line and road edges with 4 m longitudinal distance intervals between the pegs and 2 m distance laterally unless there is a one way cross fall in the pavement design or alternative geometric specifications. Mark designated levels on the steel pins and use the string line and stable straight edges as the basis for setting up formwork. • Formwork can be either from well finished timber true to line or from steel shutters or guide rails similar to those illustrated in WS - 11 and 14 for the construction of base course	

filling and cold-mix asphalt roads. The timber formwork and or steel shutters shall have depth dimensions at least as great as the specified pavement depth and be able to incorporate access for steel tie-bar placement if specified.

- Supply, spread, and compact a 50 mm bedding **layer of lean-mix concrete (1:3:6) (cement: sand: aggregate)** over the completed and broomed subgrade as a base layer for placement of the rock (plums).
- **Place plums** (of the specified dimensions) in the lean mix concrete layer with a gap between them of no more than 50mm while the lean-mix is still within the initial setting time so they do not completely submerge or topple over. The bottom of the stones (about 1/3 of stone thickness) should be embedded in the concrete and the remaining part exposed so as to form a key with the next layer of concrete.
- **Final concrete layer (1:2:4) (cement:sand:aggregate) of 12 cm depth** shall be produced to the specified strength and slump and shall be machine produced in site in accordance with the Concrete WS and the operation organized such that there is a continuous production line. Initial trials will however be necessary to determine the adjusted water-cement ratio necessary for achieving a slump meeting the specification and to prevent flow. Concrete mixers should all be located close to the road to minimise haulage by wheel barrows which should not be overloaded. The concrete shall be placed, spread and screeded by workers with proper hand tools (hoes, rakes, spreaders and screeding bars) to the set levels and provide a 2cm cover over the plums. A mechanical vibrator shall be used on site to remove air voids and to thoroughly distribute the concrete within the formwork.
- **Jointing.** Only where specified steel dowel slab joint load transfer and tie-bars shall be inserted into the slab pours and shall include the cap or sleeve necessary for movement.
- **Screeding and finishing.** Spreading, vibrating (but not excessively) and screeding are continuous operations especially with low-slump concrete. Special steel screed bars shall be used to ensure that the final finish meets design tolerances. Most importantly is the lateral brushing of the near finished surface

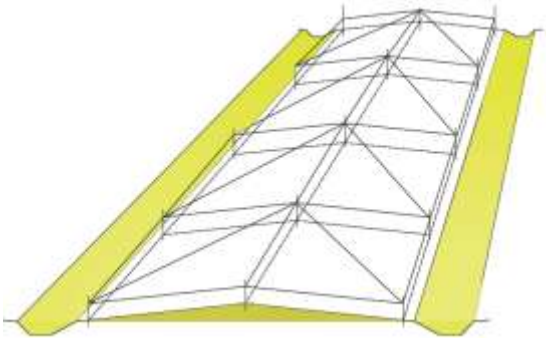


to provide a safe and slip free surface. • Curing. Curing is essential for achieving a good result. The concrete should be cured as per the various options discussed in the ERA Road reconstruction Manual Section J7. (Watering, covering with hessian, banana leaves or white plastic).									
Manpower: • 1 Supervisor(part time) • 2 part time workers for setting out and checking of formwork levels and alignment • 2 Work gang mixing concrete (2 mixers) and hauling by 2 wheelbarrows • 1to 2 Work gangs for spreading lean-mix concrete blinding layer then placing plums and then spreading, vibrating and finishing the delivered concrete and installing the jointing tie-bars (if specified). • At least 1 part-time worker for cleaning up site, undertaking curing works and joint sealing as well as any shoulder repairs and slope stabilization works.		Tools + Equipment: • Tape Measures, (30 m and 5 m) • String line & Club Hammer • Wooden/ steel Pegs & Strings • 2 X 3 M straight edged screeding tools (steel/aluminium) • 2 steel rakes • 4 concrete shovels • 3 x Concrete finishing steel trowels • 2 x mechanical concrete mixers • 2 x Wheel barrows • 1 x mechanical vibrator • Camber board/ straight edge (aluminium).		Material: • Sand, aggregate, cement and clean water for concrete production • Admix (for improving workability of concrete if necessary) • Timber or steel formwork • Rock plums.					
Quality Control: <table><tr><td>Before activity is carried out:</td><td> ✓ Check subgrade completed to geometric and compaction standards? ✓ Check steel pegs and string line placed correctly? ✓ Check formwork for the day's pour correctly set out and secure? ✓ Check and monitor the weather conditions and temperature suitable for concrete construction on a steep incline? ✓ Check traffic control, quality control and safety measures in place? ✓ Check the materials to be used on site been certified as meeting the specifications </td></tr><tr><td>While activity is carried out:</td><td> ✓ Check the operational set up ensures a constant delivery of concrete to complete each slab ✓ Check that the spreading and vibrating operations can keep pace with the concrete delivery ✓ Check that the concrete thickness and finish tolerances are to specification </td></tr></table>						Before activity is carried out:	✓ Check subgrade completed to geometric and compaction standards? ✓ Check steel pegs and string line placed correctly? ✓ Check formwork for the day's pour correctly set out and secure? ✓ Check and monitor the weather conditions and temperature suitable for concrete construction on a steep incline? ✓ Check traffic control, quality control and safety measures in place? ✓ Check the materials to be used on site been certified as meeting the specifications	While activity is carried out:	✓ Check the operational set up ensures a constant delivery of concrete to complete each slab ✓ Check that the spreading and vibrating operations can keep pace with the concrete delivery ✓ Check that the concrete thickness and finish tolerances are to specification
Before activity is carried out:	✓ Check subgrade completed to geometric and compaction standards? ✓ Check steel pegs and string line placed correctly? ✓ Check formwork for the day's pour correctly set out and secure? ✓ Check and monitor the weather conditions and temperature suitable for concrete construction on a steep incline? ✓ Check traffic control, quality control and safety measures in place? ✓ Check the materials to be used on site been certified as meeting the specifications								
While activity is carried out:	✓ Check the operational set up ensures a constant delivery of concrete to complete each slab ✓ Check that the spreading and vibrating operations can keep pace with the concrete delivery ✓ Check that the concrete thickness and finish tolerances are to specification								

Final check:

- ✓ Ensure that the tie bars and dowel bars (if specified) are placed correctly.
- ✓ Carry out regular slump test to ensure the mix is consistent and appropriate and take samples for strength testing
- ✓ Check the concrete finish has been brushed with a hard broom as specified for safety (This may be more than several hours after completion)
- ✓ Make sure that before the day's work is completed that all curing arrangements are in place for the completed work
- ✓ Check that concrete sampling has been carried out and that the samples for laboratory testing have been identified clearly.
- ✓ Prepare for ongoing attention to curing and prepare for slab joint sealing
- ✓ Check that traffic control is such that no traffic is permitted on the pavement for 28 days after the completion of the works
- ✓ Check that all shoulder work and slope protection has been carried out as required
- ✓ Undertake Schmidt hammer testing in-situ 14 days after the concrete work has been completed.

Suggested Productivity: Spreading and hauling of delivered gravel 4-5 m³/ Wd (Depends on weather, traffic control and gang numbers).

ERA Enhancing Rural Access	WORK SHEET
Item: Construction of Rural Road Un-Reinforced Concrete Pavement	WS-UCP
Specification: The activity pre-requisite is an understanding of the need for an acceptable subgrade for a rigid pavement to ensure an equal load bearing capacity over the concrete slabs. (Subgrade failure is the most common cause of concrete pavement cracking and failure). The concrete slabs will be formed on a blinding layer of fines placed over the subgrade as new slabs require free movement while drying. The blinding later will extend 20 cm beyond the exterior dimensions of the slab unless kerbs are set in the slab pour. Strict control is necessary over the setting out and finishing necessary for an effective concrete pavement. The activity then involves the on-site production, placement and finishing of the site mixed 20 MPa concrete in a slab formation preferably involving an alternate pattern for pouring of the slabs and associated side drainage. Special attention must be given to the slab jointing and thickness details as provided for in the current ILO Standards applicable in Timor Leste. Reference is also made to separate Worksheets on concrete works and an ERA Guideline on Concrete Quality Control (Section J7).	
Work Method: • Construct subgrade in accordance with the standard Worksheet WS-5 requirements as for a base-course pavement • Supply, spread, wet and compact a 25mm blinding layer of fine aggregate (<0.3mm) or sand over the completed subgrade as a base layer for pouring the concrete. Dampen before concrete pour. • Set out profiles for the formwork of the road level and camber of 3% cross fall using steel pins (rebar) and string lines. Steel pins are to be set at road centre-line and road edges with 4 m longitudinal distance intervals between the pegs and 2 m distance laterally unless there is a one way cross fall in the pavement design or alternative geometric specifications. Mark designated levels on the steel pins and use the string line and stable straight edges as the basis for setting up formwork. • Formwork can be either from well finished timber true to line or from steel shutters or guide rails similar to those illustrated in ERA WS – 11 and 14 for the construction of base course filling and cold-mix asphalt roads. The timber formwork and or steel shutters shall have depth dimensions at least as great as the specified	 

pavement depth and be able to incorporate access for steel tie-bar placement.

- **Concrete** to the specified strength shall be machine produced on site in accordance with the Concrete WS and a continuous production line is important to complete the patterned work slab by slab. Initial trials will however be necessary to determine the adjusted water-cement ration necessary for achieving a low-slump concrete meeting the specification. Concrete mixers shall be located close to the concrete pour to minimize haulage by wheel barrow (not overloaded). The concrete shall be placed, spread and screeded by workers with proper hand tools (hoes, rakes, spreaders and screeding bars) to the set levels. A mechanical vibrator shall be used on site to remove air voids and to thoroughly distribute the concrete within the formwork. The actual number of wheelbarrow loads required per slab needs to be known from the outset of the work. Concrete samples must be taken for testing as specified and regular slump tests should also be conducted.
- **Jointing.** Most un-reinforced concrete roads do not have steel dowel slab joint tie-bars. However, if specified these shall be inserted into the initial pattern of slab pours and shall include the cap or sleeve necessary for movement. When the adjoining slab is poured the supervisor shall ensure that movement for expansion has been maintained otherwise s/he shall again make provision for that in the new pour over the same dowel.
- **Screeding and finishing.** Spreading, vibrating (but not excessively) and screeding are continuous operations especially with low-slump concrete necessary for roads on steep inclines. Special steel screed bars shall be used to ensure that the final finish meets design tolerances. Very important is the lateral brushing of the near finished surface to provide a safe and slip free surface. This work may not be possible for 6 or more hours after the pour. Care should be given to maintain accurate lateral strokes of the hard broom used for this work.
- **Curing.** Curing is essential for achieving a good result. The concrete should be cured as per the various options discussed in the ERA Road reconstruction Manual Section J7.



Manpower: • 1 Supervisor(part time) • 2 part time workers for setting out and checking of formwork levels and alignment • 2 Work gang mixing concrete (2 mixers) and hauling by 2 wheelbarrows • 1 Work gang spreading, vibrating and finishing the delivered concrete and installing the jointing tie-bars (if specified). • At least 1 part-time worker for cleaning up site, undertaking curing works and joint sealing as well as any shoulder repairs and slope stabilization works.	Tools + Equipment: • Tape Measures, (30 m and 5 m) • String line & Hammer • Wooden/ steel Pegs & Strings • 2 X 3 M straight edged screeding tools (steel/aluminium) • 3 x Concrete finishing steel trowels • 2 x mechanical concrete mixers • 2 x Wheel barrows • 2 concrete shovels • 2 steel rakes • 1 x mechanical vibrator • Camber board/ straight edge (steel aluminium).	Material: • Sand, aggregate, cement and clean water for concrete production • Admix (for improving workability of concrete if necessary) • Timber or steel formwork.				
Quality Control: <table><tr><td>Before activity is carried out:</td><td> ✓ Check the subgrade is completed to geometric standards and to specified compaction standards? ✓ Check steel pegs and string line placed correctly? ✓ Check formwork for the day's pour correctly set out and secure? ✓ Check the weather conditions and temperature suitable for concrete construction on a steep incline? ✓ Check there a matching of the concrete production and haulage crews with the spreading and finishing crews? ✓ Check all materials to be used on site been certified as meeting the specifications? ✓ Check traffic control, quality control and safety measures in place? </td></tr><tr><td>While activity is carried out:</td><td> ✓ Check the operational set up ensures a constant delivery of concrete to complete each slab ✓ Check that the spreading and vibrating operations can keep pace with the concrete delivery ✓ Check that the concrete thickness and finish tolerances are to specification ✓ Ensure that the tie bars and dowel bars (if any) are placed correctly. ✓ Carry out regular slump test to ensure the mix is consistent and appropriate and that samples have been taken for strength testing. </td></tr></table>			Before activity is carried out:	✓ Check the subgrade is completed to geometric standards and to specified compaction standards? ✓ Check steel pegs and string line placed correctly? ✓ Check formwork for the day's pour correctly set out and secure? ✓ Check the weather conditions and temperature suitable for concrete construction on a steep incline? ✓ Check there a matching of the concrete production and haulage crews with the spreading and finishing crews? ✓ Check all materials to be used on site been certified as meeting the specifications? ✓ Check traffic control, quality control and safety measures in place?	While activity is carried out:	✓ Check the operational set up ensures a constant delivery of concrete to complete each slab ✓ Check that the spreading and vibrating operations can keep pace with the concrete delivery ✓ Check that the concrete thickness and finish tolerances are to specification ✓ Ensure that the tie bars and dowel bars (if any) are placed correctly. ✓ Carry out regular slump test to ensure the mix is consistent and appropriate and that samples have been taken for strength testing.
Before activity is carried out:	✓ Check the subgrade is completed to geometric standards and to specified compaction standards? ✓ Check steel pegs and string line placed correctly? ✓ Check formwork for the day's pour correctly set out and secure? ✓ Check the weather conditions and temperature suitable for concrete construction on a steep incline? ✓ Check there a matching of the concrete production and haulage crews with the spreading and finishing crews? ✓ Check all materials to be used on site been certified as meeting the specifications? ✓ Check traffic control, quality control and safety measures in place?					
While activity is carried out:	✓ Check the operational set up ensures a constant delivery of concrete to complete each slab ✓ Check that the spreading and vibrating operations can keep pace with the concrete delivery ✓ Check that the concrete thickness and finish tolerances are to specification ✓ Ensure that the tie bars and dowel bars (if any) are placed correctly. ✓ Carry out regular slump test to ensure the mix is consistent and appropriate and that samples have been taken for strength testing.					

Final check:

- ✓ Check the concrete finish has been brushed with a hard broom as specified for safety (This may be more than 6 hours after completion)
- ✓ Check that before the day's work is completed that all curing arrangements are in place for the completed work
- ✓ Check that concrete sampling has been carried out and that the samples for laboratory testing have been identified clearly.
- ✓ Prepare for ongoing attention to curing and prepare for slab joint sealing
- ✓ Check that traffic control is such that no traffic is permitted on the pavement for at least 14 days after the completion of the works
- ✓ Undertake Schmidt hammer compressive testing in-situ 14 days after the concrete work has been completed.

Suggested Productivity: Spreading and hauling of delivered gravel 4-5 m³/ Work day (Depends on number of concrete mixers, weather, traffic control and gang numbers).

Training Manual

Construction of Rural Road Pavements Utilizing Labour-Based Technology

Part 2. Flexible Pavements

Flexible Pavements

Table of Contents

1.	Glossary of Technical Terms for Flexible Pavements.....	1
2.	Introduction to Flexible Pavement Construction: Labour-Based Bituminous Surfaces.....	3
3.	Safe Handling of Bitumen, Emulsions and Sealing Aggregates.....	4
3.1.	General.....	4
3.2.	Health and Safety for Bitumen Work.....	4
4.	Legal Requirements	6
5.	Hazards to Health from Bitumen Sealing Materials	7
5.1.	Personal Protective Equipment (PPE).....	8
5.2.	First Aid	8
5.3.	Burn Hazards.....	9
6.	Road User and Worker Safety.....	12
7.	Bitumen and Emulsion Seals – Overview of Materials and Equipment.....	13
7.1.	Materials	13
7.2.	Prime Coat.....	15
7.3.	Overview of Construction Plant and Equipment	16
7.4.	Preparations for Sealing Operations.....	17
7.5.	Work Planning and Preparation.....	17
7.6.	Operation of the Motorized Bitumen Sprayer.....	19
8.	Latasir Labour-Based Hotmix (HMP)	28
8.1.	Description of Work	28
8.2.	Materials	28
8.3.	Mixture.....	29
8.4.	Execution of the Work	30
8.5.	Equipment.....	30
8.6.	Mixing.....	30
8.7.	Spreading and Hauling	31
8.8.	Compacting	32
8.9.	Measurement and Payment	32
8.10.	Quality Control for Construction of Latasir Pavement	32
8.11.	Technical Resources and Reference Materials for Latasir (Hotmx) Surfaced Roads	34
9.	Coldmix Asphalt (CMP)	35
9.1.	Description	35
9.2.	Materials	35
9.3.	Trial Mix	35

9.4. Equipment and Tools	35
9.5. Construction.....	36
9.6. Quality Control for Construction of Cold Mix Sealed Pavement	38
9.7. Technical Resources and Reference Materials for Coldmix Surfaced Roads.....	40
10. Penetration Macadam (Pen-Mac) Surfacing (PMP).....	41
10.1. Materials	41
10.2. Work Method.....	42
10.3. Hand Tools and Equipment.....	43
10.4. Quality Control for Construction of Prime Coat and Penetration Macadam	44
10.5. Technical Resources and Reference Materials for Penetration Macadam Surface Seals ..	46
11. Bitumen Emulsion Surface Treatment (ESP).....	47
11.1. Materials	47
11.2. Hand-tools and Equipment	48
11.3. Applying the First Coat.....	49
11.4. Applying the Aggregates	49
11.5. Rolling	50
11.6. Applying the Penetration Spray	50
11.7. Constructing a Double Surface Dressing.....	50
11.8. Weather Constraints	51
12. Equipment-based Methods	52
12.1. Application of Bitumen Binder.....	52
12.2. Application of Stone Chippings	52
12.3. Application Rates for Bitumen Emulsion Seals – Equipment-based.....	54
12.4. Application Rate (Binder, Tack Coat, Prime and Fog Spray)	55
12.5. Quality Control for Construction of Bitumen Emulsion Seals.....	56
12.6. Technical Resources and Reference Materials for Bitumen Emulsion Surface Seals	58

Worksheets

Item: Safety in Working with Hot Bitumen, Solvents and Aggregates	59
Item: Asphalt Sand Sheet “LATASIR”	64
Item: Cold Mix Asphalt (Manual Mixing of Asphalt).....	67
Item: Cold Mix Asphalt (Using Concrete Mixer)	71
Item: Penetration Macadam (Pen-Mac) Pavement.....	75
Item: Bitumen and Emulsion Seals	78

Flexible Pavements

1. Glossary of Technical Terms for Flexible Pavements

Aggregate (Sealing)

Sized road gravel of specified hardness used in the bitumen and bitumen emulsion surface seals for protection of the road surface from traffic damage and to preserve the weather tightness of the bitumen and emulsion layers.

Bitumen

Commercially available 60/70 or 80/100 penetration grade bitumen.

Cold Mix Asphalt (CMP)

Cold Mix Asphalt is a pre-mix of continuously graded aggregate and cationic mix grade emulsion. It can be mixed and placed by hand or a concrete mixer using labour-based methods and simple hand tools and purpose made implements, thus eliminating the need for sophisticated and expensive construction plant except for a suitably sized roller.

Cut-back Bitumen

Cut-back bitumen use solvents like kerosene (normally 35% to 40%) and/or diesel).

Double Bitumen Emulsion Surface Treatment (ESP)

Double bitumen emulsion surface treatments consist of two layers of bituminous emulsion binder followed by separate applications of aggregate or stone chippings. The layers of binder act as a waterproofing seal preventing entry of surface water into the road structure while the two layers of graded aggregates protect this film from damage by vehicle tyres and provide a strong and durable road surface.

Emulsion

Standard bitumen emulsions consist of droplets of bitumen dispersed in the water, and normally contain from 40% to 75% bitumen, 0.1% to 2.5% emulsifier, 25% to 60% water plus some minor components. The advantage of bitumen emulsions is that they can be used at ambient temperatures. Low temperature techniques for construction and maintenance reduce emissions, reduce energy consumption, avoid oxidation of the asphalt, and are less hazardous than sealing techniques using hot bitumen.

Filler

Graded Mineral matter composed of particles smaller than 0.075mm and can comprise limestone dust, dolomite dust, Portland cement fly ash, cement kiln dust or other non-plastic mineral material from sources approved by engineer.

Latisar Asphaltic Surface Seal (HMP)

Latisar is an Indonesian engineering expression derived from: Lapisar (layer), tipis (thin), aspal (asphalt) and pasir (sand) and describes a asphaltic hotmix suitable for construction using labour-based approaches.

Local Resources

These can be human resources, local government, private, NGO, and community institutions, local entrepreneurs such as contractors, consultants, entrepreneurs, artisans, local labour (skilled and unskilled), locally made or fabricated hand tools or intermediate equipment, local materials such as locally produced aggregates, timber and other materials or inputs.

Low Volume Road

Roads carrying up to about 300 motor vehicles per day and intended to carry less than about 1 million equivalent standard axles over their design life.

Pen Mac Surface Seal (PMP)

The penetration macadam pavement is used as surface layer on roads and consists of providing bitumen stabilized aggregate over a new or repaired base course layer. The penetration macadam surface constitutes a 50 mm consolidated thickness, obtained by two or three applications of hot bitumen alternated with three applied layers of aggregates.

2. Introduction to Flexible Pavement Construction: Labour-Based Bituminous Surfaces

This training guide Part 2 covers the construction of labour-based (LB) flexible asphaltic surfaces comprising the following bituminous treatments:

1. Latasir³ or LB Hotmix (**HMP**);
2. Coldmix (**CMP**);
3. Penetration macadam (**PMP**);
4. Double Bitumen Emulsion Seal Treatment) (**ESP**).

Each is dealt with separately in this Section of the manual following general sections on the safe handling of hot bitumen, dusty aggregates, solvents and general site safety requirements and summary information describing bitumen, cutback emulsions developed from bitumen and aggregates (sealing chips, sands and other products) used in the surface treatments.

³ Latasir is an Indonesian engineering expression derived from; Lapisan (layer), tipis (thin), aspal (asphalt) and pasir (sand).

3. Safe Handling of Bitumen, Emulsions and Sealing Aggregates

3.1. General

Working with bitumen and emulsions can be hazardous and all people involved need to familiarise themselves with the safety requirements demanded by the hazards encountered when handling sealing materials and carrying out sealing operations. Hazards include burns, steam scalds, explosions and fire, fire-fighting, toxic fumes, asphyxiation, handling flammable and corrosive materials, transportation of dangerous goods, and the need for traffic control in the work area.

This Section of the manual summarises the main occupational health and safety requirements and borrows from several reference documents.⁴ The occupational health and safety requirements of the ERA labour-based training manual will also apply and should, in addition, be rigorously adhered to.

Employers have a duty to ensure that their employees are either sufficiently trained and experienced to do their work safely or supervised by a trained and experienced person. In addition employees must be adequately trained in the safe use of equipment in their place of work, including use of protective clothing. Inexperienced individuals, regardless of position, must take advice from trained and experienced operators until they have received the appropriate level of training. Employers should arrange such training including courses on safety and first aid.

3.2. Health and Safety for Bitumen Work

All the pavement surfaces described in this module involve the use of bituminous binders during construction. Depending on the particular surfaces or the availability of binder, they may be hot bitumen or bituminous emulsions.

Emulsions that can be sprayed cold or at low to medium temperature and only need slight heating in a mobile heater tank are most suitable for labour-based methods. There is no evidence to suggest serious health hazards are associated with the use of bitumen emulsions. However, repeated or prolonged skin contact should be avoided to minimize the chance of skin irritation. Contact with skin can be avoided by the wearing of protective clothing, rubber gloves and boots. At the end of the working day, the workforce should thoroughly wash exposed skin with soap and water. The wearing of goggles will protect eyes but where eyes are accidentally splashed, they should be flushed with large amounts of water and medical help sought.

The use of hot bitumen can however present hazards for a work force. Generally, heating of bitumen should be carried out in a purpose made towable heater tank typically fitted with a spray bar or hand lance for labour-based work. A hazard is the risk of burns to exposed skin. Burns should be immediately drenched with cold water for at least 10 minutes or until cool. In many cases heating of bitumen is done by making a fire under a drum containing the bitumen and then carry the heated bitumen manually in locally made spraying buckets. This method of heating the bitumen poses a lot of risks during heating, carrying and spraying the heated bitumen. To minimize the risk, protective heat resistant gloves, masks and footwear should be worn.

It is essential for the safety and health of the workforce that good working practices are observed at all times. The operators of equipment such as heating, bitumen spraying operator and hand sprayers must be fully trained and familiar with their use.

⁴ Roading New Zealand Code of Practice (COP) BCA 9904 (NZPBCA2000) and Ethiopian Roads Authority Bituminous Sealing of Low Volume Roads using Labour Based Methods. Note that NZ PBCA (NZ Pavement & Bitumen Contractors' Association) is now **Roading New Zealand** as from 26/06/2004. However, as COP BCA 9904 was published in 2000 by the then PBCA, it keeps its original publication number.



Heating and carrying hot bitumen

Note danger- too many bystanders and dangerous carrying, risk of spillage of hot bitumen

The following minimum practical requirements for working with bitumen will involve:

- ✚ The issue of protective clothing; boots, gloves, overalls, etc. to the workers is essential. This is particularly applicable to labour working on, or in close proximity to, distributors and/or sprayers;
- ✚ The use of diesoline by workers to clean hands, arms and tools, when working with bitumen, must be discouraged – the use of paraffin (kerosene) is preferable;
- ✚ A properly equipped first aid kit must be available at all times;
- ✚ No children must be allowed on the construction site;
- ✚ Fire extinguishers in good working order must be available when working with hot bitumen binders.

4. Legal Requirements

Designs and specifications and construction activities must be compatible with safe practices and comply with Timor Leste Occupational Health and Safety and handling of hazardous material requirements.

5. Hazards to Health from Bitumen Sealing Materials

Hot bitumen products and cut-back bitumen, which are heated to between 130°C and 180°C, are extremely flammable and must be stored, handled and sprayed with extreme care to avoid injuries and damage to personnel and equipment. Even cutback bitumen primes like MC 30 or MC 70 that are heated to 50°C and 70°C respectively, can easily ignite and cause injuries if the heating is not controlled properly.

Some of the materials used in bitumen sealing can present hazards to health if they are handled incorrectly. Detailed information on health and safety, environmental hazards, chemical and physical properties for bitumen binders and associated materials used in pavement sealing will be available in material safety data sheets for bitumen, bitumen cutback, kerosene, turpentine, and diesel. These must be obtained from the supplier and studied.

The temperatures at which heated bituminous binders will catch fire are useful to know and they are:

Flash Point – the lowest temperature at which a flammable liquid gives off enough vapour to flash momentarily when a small flame is applied. For bitumen it is 240°C–320°C, and for kerosene 43°C–48°C.

Ignition Point – the temperature at which a solid, liquid or gas will take fire and continue to burn. The ignition points for bitumen are 500°C, and for kerosene 255°C.

Fire

The normal spraying temperature of a binder is in the range of 140°C–170°C, depending on the type of bitumen and amount of diluents in it. Straight-run bitumen at these normal spraying temperatures is below its flash point (i.e. 240°C–320°C) and is relatively safe. However, binders containing kerosene or AGO (automotive gas oil or diesel) have spraying temperatures above the flash points of these diluents and are therefore hazardous. Containers exposed to intense heat from fires should be cooled with water to prevent vapour pressure build-up, which could result in container rupture. Containers exposed directly to flames should be cooled with large quantities of water.

Explosions

Explosions associated with sealing works cause injury and significant damage. The industry has set procedures to avoid situations that will cause explosions.

Explosions Caused by Vapour in Confined Spaces

Cutback binders give off vapours at temperatures lower than their flash points. These vapours build up in confined spaces such as the bitumen tanker. All sources of ignition, including obvious sources such as matches and lighters, and less obvious sources such as torches, transistor radios, steel boot caps and hobnails must be kept at least 1.5 m away from such areas to prevent explosions. Many areas of reseal operations must therefore be no-smoking zones for safety reasons, and ideally should be 'smoke-free'.

Explosions Caused by Water in Binder

Other potentially explosive situations can occur by the introduction of water to a hot binder. Because water expands approximately 1500 times in volume when converted to steam, even a small amount of water introduced into a binder that is hotter than 100°C can result in a dangerously violent foaming eruption. Water should be kept away from resealing activities and bulk bitumen should be free of water. Drums must not be stored in a manner which allows water to pond on the surface of the lids.

Extinguishing Bitumen Fires

NEVER USE A WATER JET! Bitumen fires must be extinguished by smothering so that the continued supply of oxygen can be prevented. Small fires can be put out with a blanket of foam, dry powder or

carbon dioxide extinguishers.

Emulsion Drums

When heating drums of emulsion on site to raise the temperature (although to a much lower temperature than hot penetration bitumen binders), it is essential to stir the binder while heating, to avoid overheating the binder in contact with the base of the drum. This will cause the binder to generate steam, resulting in the binder frothing and boiling over. A person must be in charge of the heating of the drum at all times and should continuously stir the contents in the drum.

5.1. Personal Protective Equipment (PPE)

The following PPE must be issued to the labourers in accordance with their work assignments:

-  Overalls;
-  Safety vests;
-  Boots (for bitumen works);
-  Dust masks (for spray operations and handling of dusty aggregates);
-  Gloves;
-  Goggles or face shield if handling hot bitumen;
-  Respiratory equipment if workers are exposed to toxic fumes;
-  Containers of clean water for flushing eyes and rinsing wounds.

Full PPE and clothing must be worn at all times when working with hot bitumen, even on the hottest days, for protection against operational hazards. Site workers often work in very hot operating conditions while wearing full cover protective clothing, and supervisors should consider how this affects their staff. Appropriate rest periods and drinking water, should be available. Ensure that there are no unnecessary spectators standing near or adjacent to the work - accidents do happen. Do not allow children to play around on the stockpile of drums of emulsion, or near the work area, especially during sealing operations.

Workers involved in sealing and applying bitumen must wear appropriate clothing and gear (Personal Protective Equipment) (PPE) so that they are protected when dealing with hot binder containing bitumen, cutter, and additives. This clothing is also used when working with emulsion and polymer modified binders.

5.2. First Aid

Any victim of a burn or other serious injury should be evacuated to a medical centre immediately rather than be treated on site. However, suitable first-aid equipment for dealing with bitumen burns must be provided on site. In the case of a burn injury from hot bitumen falling onto exposed skin, cooling of the burn area should be carried out by applying cold water or an ice pack. Firmly adhering bitumen should not be removed from the skin; it must either be allowed to fall off gradually or it may be removed by warm medicinal paraffin. A standard bandage must not be applied to burnt skin, as this will stick to the burnt area. If eyes are affected they should be washed for fifteen minutes. In the case of ingested bitumen, vomiting must not be induced. If vomiting is unavoidable, breathing should be monitored. In the case of inhalation of bituminous fumes, the victim must be moved to an uncontaminated area. Trained personnel should administer artificial respiration if breathing stops, or CPR if the heart stops. In all cases of direct exposure to hot bitumen or bitumen fumes, medical



attention must be sought immediately. For treatment of other injuries on site, at least one person should have undergone training in First Aid. A well stocked First Aid kit must always be present on site and be replenished as the various items are being used.

5.3. Burn Hazards

As binder is usually sprayed at temperatures between 150°C and 200°C, contact with it at these temperatures causes very severe burns that are possibly fatal or disabling. Binder sticks to the skin and the heat continues to burn the victim, but the binder must be left in place because removing it will cause far greater damage. Because it traps heat, keep cooling the binder by pouring cold water all over the area for at least 10-15 minutes. Treat as for other burns and for shock.

Because bitumen sticks to the skin, special first aid procedures are required that is not usually covered in basic first aid courses. Also because they do not occur often, the appropriate treatment procedures are often not understood by doctors and other medical staff. For this reason the industry in New Zealand has, in conjunction with specialist Burns Units, developed procedures for treatment. It has developed a Bitumen Burns Card outlining the correct treatment of bitumen burns. All individuals working in the industry are required to make themselves aware of these treatment procedures for bitumen and emulsion burns.

In the unfortunate instance of a burn, the card is attached to the victim with string through eyelets on the card to make sure that doctors are aware of these procedures when they receive the burn patient for treatment. Experience has shown that attaching the card to the patient and relying on the doctor to read it, as well as to treat the patient, may not be enough. Therefore a person must accompany the patient to ensure that the treating doctor is aware of the card, and that he/she reads it before beginning treatment.

The figures on the following pages illustrate the front and reverse side of a Burn Card suitable for the Timor Leste situation.

IMMEDIATE FIRST AID FOR

BITUMEN BURNS

1. **DO NOT ATTEMPT TO REMOVE ANY BITUMEN**
2. COOL THE AFFECTED AREA WITH WATER.
3. KEEP ON COOLING UNTIL MEDICAL AID IS AVAILABLE.
4. HANDLE PATIENT CAREFULLY TO AVOID DISTURBING THE BURN.
5. REMOVE BELTS AND ANY OTHER CONSTRICTIONS.
6. DO NOT ATTEMPT TO REMOVE CLOTHING.
7. DO NOT ATTEMPT TO CLEAN THE AFFECTED AREA.
8. DO NOT APPLY ANY LOTIONS OR OINTMENTS.
9. COVER BURNS WHICH ARE FREE FROM BITUMEN BUT AVOID HAIRY OR WOOLLY CLOTH.
10. KEEP THE PATIENT WARM BUT AVOID LETTING BLANKETS TOUCH BURNS OR BITUMEN.
11. EYE BURNS – FLUSH WITH WATER (for 20 minutes). DO NOT REMOVE THE BITUMEN.
12. If the patient has anything more than minimal superficial burns (minor splashes) he or she will have to be taken to the nearest Medical Centre or Hospital. Attach one of these cards and wherever possible, telephone ahead to let medical staff know that a bitumen burn case is on the way. Tell them that the attached card has special information on the treatment of bitumen burns.
13. On the way treat for shock by keeping the patient warm, comfortable and quiet. Ensure that there is plenty of fresh air.
14. Only give a small amount of liquid at frequent intervals and only if the patient is conscious and has no other injuries, e.g. fractured limbs, which may require a general anaesthetic when the patient is hospitalised. Do not give the patient alcoholic beverages of any kind.

REVERSE SIDE DETAILS

MEDICAL INFORMATION ON BITUMEN BURNS

Bitumen Burn Card (Front)

*Source NZ PBCA (now **Roading NZ**), 2001*

BURNS CAUSED BY BITUMEN REQUIRE SPECIALIST MEDICAL TREATMENT

1. SKIN BURNS

- 1.1 **In the event of hot bitumen contacting the skin, no immediate attempt should be made to remove the bitumen.**

(Except after admission to hospital and only at the direction of the burns specialist.)

- 1.2 The **burn** area should be drenched in cold running water or preferably, placed in a basin of cold water to which ice cubes have been added.
- 1.3 In the **case** of burns to the head and neck, shoulder, chest, abdomen or back, cold wet towels, which are kept in a bucket of cold water (preferably iced), should be applied to the burn area
- 1.4 The ice **water** treatment should be continued until pain no longer occurs when the burn area is removed from water. The time required is seldom less than 30 minutes.
- 1.5 Where **possible** the burned area should be continually wet until advanced medical aid is reached.
- 1.6 Remove **any** restricting rings, belts etc., and handle the patient gently to prevent further injury.
- 1.7 Cover **any** exposed burns, i.e. areas not covered by protective layer of bitumen or clothing with sterile dry dressings and lightly bandage to exclude the air. Keep the patient warm but avoid letting blankets touch burns or bitumen.
- 1.8 If there are burns to the head or face ensure that the airways for breathing are kept clear.
- 1.9 Do not apply lotions or ointments.
- 1.10 Do not pick blisters.

2. BURNS ENCIRCLING ANY PART OF THE BODY

- 2.1 When a hot hard grade of bitumen completely encircles the limb it is theoretically possible for there to be a tourniquet effect as the bitumen cools. This will diminish blood circulation in the limb – a potentially serious medical emergency.
- 2.2 In such a case, elevating the limb will normally reduce the swelling enough to allow satisfactory circulation. If it does not and advanced medical care is more than 20 minutes away it could become essential to attempt to release the tightening effects of the cooling bitumen by carefully splitting the bitumen from the top to the bottom using a heavy pair of scissors. **Extreme caution must be taken** during this procedure to ensure no damage is caused to the underlying skin. Toes and fingers require individual attention.

3. EYE BURNS

- 3.1 The eye must immediately be flushed with cold water. This should be continued for 20 minutes by pouring water, or if available, sterile saline or eye irrigation solution gently over the open eye and away from the unaffected eyes.
- 3.2 The cooling process will be most beneficial if it can be done at the same time as the casualty is being transported to hospital.
- 3.3 No attempt should be made by untrained personnel to remove the bitumen.
- 3.4 If the eye needs to be covered with a dressing, apply a sterile eye pad. Stay close, reassure and support the casualty while travelling to seek medical care.

4. FURTHER TREATMENT

- 4.1 **No attempt should be made to remove the bitumen which in itself supplies a sterile dressing to the underlying burned areas of skin.**
- 4.2 The bitumen is covered with tulle gras dressings and left for two days after which time any bitumen that can be easily removed (that is bitumen that has detached from the live dermis), is removed. The remaining burned area to which bitumen adheres is recovered with sterile tulle gras dressings and left for a further week.
- 4.3 The appearance of the burns when the dressings are first taken off, together with the body surface area involved and the general condition of the patient will dictate when removal to a specialised Burns Unit is indicated. Certainly any forced removal of bitumen should only be undertaken in a specially equipped Burns Unit.

5. BITUMEN REMOVAL

- 5.1 If for special reasons it becomes necessary to remove bitumen use peanut oil (arachis oil)

6. SPECIALIST BURNS UNIT(s)

(Provide details and contact numbers for local specialised Burns Units.

Bitumen Burn Card (Reverse)

Source NZ PBCA (now Roadking NZ), 2001

6. Road User and Worker Safety

Any road works on trafficked roads have the potential to be hazardous to both workers and the travelling public. Sealing operations present traffic problems because they affect lengths of road at the time of sealing, and they progress at a slow speed. Close liaison between the contractor, the road controlling authority, road users, affected properties and general public is important. This is to manage any impacts or disruption to sealing, and to traffic flows. Traffic control should be exercised with the aim of alerting all road users, to minimise risk to themselves or their vehicles. Drivers of the construction equipment should check that tyre treads are not clogged with bitumen and chip.

Conversely, workers on foot should also be alert to all vehicle movements, and avoid placing themselves in dangerous situations. So they can be seen, workers must wear high visibility garments at all times. Suitable road signs and warning devices should be erected and safety requirements for the accommodation of traffic will be laid down in the relevant specifications, referred to in the scope of the work, in the contract documents.

Chip Spreading Hazards

If truck mounted aggregate spreaders are used, most modern roller spreaders mounted on the rear of chip-spreading trucks are equipped with operating controls on the driver's side of the vehicle. These trucks are operated in reverse, and the driver and the chip-spreading operator should be visible to each other at all times. Truck drivers should also check for tray clearance from overhead wires, protruding objects and the like before commencing work.

Hazards to the Environment from Bitumen (Chip) Sealing

Sealing activities have the potential to cause both good and bad effects on the natural environment and on neighbouring communities. To avoid costly remedial work and unwanted negative publicity, such effects should be considered early when planning bitumen sealing works. Responsible management should consider the likely environmental impacts and should incorporate the duty to "avoid, remedy, or mitigate any adverse effect on the environment" in the planning of the works. They also have a duty to reduce production of air pollutants.

7. Bitumen and Emulsion Seals – Overview of Materials and Equipment

7.1. Materials

Paving Bitumen

Paving bitumen's are produced from the atmospheric distillation of petroleum crude oil followed by further processing such as vacuum distillation, thermal conversion, air-rectification or solvent precipitation. A combination of these processes can be used for production of different bitumen grades. Road paving as the name indicates is the principal use.

Normal pavement sealing uses penetration grade bitumen:

Bituminous binders for seals come either in the form of straight penetration grade bitumen (usually 80/100) conforming to the requirements of ASTM/AASHTO, or cut-back bitumen or bitumen emulsions. All of these can be modified with for instance crumbed rubber or latex to improve their properties. For this manual only un-modified bitumen emulsion binders will be discussed.



Penetration Grade and Cut-back Bitumen

Use of straight penetration grade bitumen or cut-back bitumen (using solvents like kerosene and/or diesel) has risks that need to be recognised with appropriate training for labour-based activities, for example:

-  The bitumen must be heated to between 130 and 190°C before use. At these temperatures the bitumen is extremely flammable and can easily cause severe damage and injuries to personnel if not handled carefully and in accordance with safety regulations;
-  The heating of bitumen barrels over open fires has risks;
-  Toxic fumes from hot bitumen also pose health risks to labourers.

Cut-back bitumen is commonly used for Prime coats, but is then heated only to 50-70°C and can be sprayed on the road by means of small motorized bitumen sprayers. Care must still be taken when handling the bitumen at these temperatures, but this is deemed to be within the capabilities of the small and relatively inexperienced contractors. However, for Prime coats emulsion based alternatives that are more environmental and labour friendly.

Currently, the general trend in the industry is to move away from use of hot bitumen for reasons mentioned above and the earlier part of this manual. The use of cold bitumen emulsions eliminates the health risks and the need for careful monitoring of the bitumen temperature, which is always a major challenge.

Bitumen Emulsions

An emulsion is a dispersion of small droplets of one liquid in another liquid. Typical examples include such everyday products as milk, butter, mayonnaise, and cosmetic creams.

Bitumen emulsions come in three different types: (i) oil in water; (ii) water in oil; and, (iii) multiple.

Standard bitumen emulsions are normally considered to be of the oil/water type, i.e. it has tiny droplets of bitumen dispersed in the water phase, and contains from 40% to 75% bitumen, 0.1% to 2.5% emulsifier, 25% to 60% water plus some minor components. The “water-in-oil” or water/oil emulsion is called inverted emulsion, i.e. it has tiny droplets of water dispersed in the bitumen. A type of inverted emulsion is used for prime coats.

The advantage of bitumen emulsions is that they can be used at ambient temperatures. Low temperature techniques for construction and maintenance reduce emissions, reduce energy consumption, avoid oxidation of the asphalt, and are less hazardous than techniques using hot bitumen. They are also more economical and environmentally friendly than cold techniques using cut back asphalts. The environmental benefit of asphalt emulsion is particularly positive when used for in place or on-site application which avoids the energy usage and emissions associated with heating, drying, and haulage of aggregate.

The appearance of bitumen emulsion is like a dark brown soup. The viscosity depends on the bitumen content, the higher the bitumen content, the higher the viscosity (or the thicker the soup). Bitumen emulsion are manufactured by running the base penetration grade bitumen, normally 60/70 or 80/100 penetration grade, through a mill to produce the tiny bitumen droplets, adding the emulsifier (soap) that attaches to the surface of the droplets and mixing the droplets with water. The emulsifier enables the droplets to stay in suspension without



coalescing for an extended period. Depending on the type of emulsifier being used, the droplets can be given a negative or positive electrical charge or no charge at all. The electrical charge causes the droplets to expel each other thereby enabling them to stay in suspension.

There are three categories of bitumen emulsion used for road works:

- ✚ Anionic emulsion (negatively charged);
- ✚ Cationic emulsion (positively charged);
- ✚ Non-ionic emulsion (no charge).

Bitumen emulsions are classified by the different setting times (time taken for the bitumen droplets to coalesce after application and the water to evaporate) and the stability of the emulsion (ability of the droplets to stay in suspension).

Both Anionic and Cationic emulsions can be:

- ✚ **RS.** Rapid Setting
- ✚ **MS** Medium Setting
- ✚ **SS.** Slow Setting.

The grades of bitumen emulsions are determined by the amount of emulsifier being used in the manufacturing process, hence the amount of the electrical charge on each droplet. The higher the charge - the higher the stability of the emulsion.

The emulsion grades are:

- ✚ Spray grade;
- ✚ Pre-mix grade;
- ✚ Stable grade.

When the emulsion breaks (i.e. when the separation of the bitumen from the water phase starts) the colour turns from brown to black. The time it takes for this to happen depend on the type of emulsion used (Slow Setting, Medium Setting or Rapid Setting). Different processes are involved in the breaking and curing of emulsions:

-  Chemical action (cationic);
-  Water evaporation;
-  Mechanical action (rolling).

Emulsions also differ in the amount of bitumen they contain expressed as a percentage of the total volume. For surfacing applications this percentage is normally in the range of 60 – 70%.

Different notations are used for the emulsion classification. In the ASTM classification system the letters (RS, CMS etc) denotes the rate of setting. The trailing number denotes the viscosity of the emulsion, the higher the number the higher the viscosity (higher bitumen content). The letters s or h denotes the hardness (penetration grade) of the base bitumen used for the emulsion, but the s is usually omitted when using 80/100 Penetration Grade base bitumen. RS1 (or RS1-s) thus means a rapid setting anionic emulsion of low viscosity with a soft-base bitumen, CMS2-h means a medium setting cationic emulsion of higher viscosity with a hard base bitumen.

-  Soft base bitumen is of penetration grade 80/100
-  Hard base bitumen is of penetration grade 60/70

In the more commonly used denotation CMS 65 or similar K2- 65 means a medium setting cationic emulsion with 65% bitumen content. Typical surfacing applications of the various emulsion grades are shown in the following table.

Application	Anionic			Cationic		
	RS	MS	SS	RS	MS	SS
Sand seal				✓		
Surface dressing	✓			✓		
Cold mix asphalt						✓
Tack coat		✓	✓		✓	✓

Typical Emulsion Applications

Source Ethiopian Roads Authority: Bituminous Sealing of Low Volume Roads using LB Methods

7.2. Prime Coat

The reasons for priming the base are:

-  Assists in promoting adhesion between the base and the newly applied bituminous seal;
-  Inhibit ingress of water into the base, whilst not hampering the migration of water vapour from the base;
-  Limit the absorption of binder from the next spray application;
-  Bind the upper 4-10 mm of the base to accommodate light construction traffic.

The effect of the priming depends on:

-  The porosity of the base material;
-  Viscosity of the priming material;
-  Base temperature;
-  Moisture content of the base.

Typical primes are:

-  Bitumen primes
 - Low viscosity, medium curing cutback bitumen such as MC-30, MC-70,
 - or, in some circumstances, MC-250.
-  Emulsion primes
 - Inverted emulsion prime is typically manufactured from MC 30, slightly cut back further and then water added.

The choice of prime depends primarily on the texture and density of the surface being primed. Low viscosity primes are necessary for dense cement or lime stabilized surfaces while higher viscosity primes are used for untreated, coarse-textured surfaces. Emulsion primes are not recommended for saline base courses. Bitumen primes must be heated before use. With the amount of solvent in these primes, heating must be done with care. Spraying temperatures using a bitumen hand sprayer are:

-  MC10/MC 30 40-50°C;
-  MC70 55-70°C.

Inverted and special emulsion primes can be sprayed at ambient temperatures.

7.3. Overview of Construction Plant and Equipment

7.3.1. For Labour-Based Methods

The following specialised plant and equipment is recommended to promote the construction of the single or double-seal surfacing by labour-based methods:

-  Shovels;
-  Brooms;
-  Builders' wheelbarrows (capacity ± 65 – 67 litres);
-  Hammer;
-  Setting out and other construction aids including ranging rods, profile boards, pegs and string lines, line level, ditch templates 7 mm sisal rope, 2 x 50 m rolls;
-  Reinforced paper, 4 rolls x 1 metre wide;
-  Steel pegs, 300 mm x 9 mm;
-  Chalk-line equipment;
-  Steel tape, 50 m;
-  105 litre drums open ended (Photo 3.1, Module 3 'Construction of Single Seal') with lifting handles for spotting aggregate;
-  105 litre drums (checking spray rates and cleaning spray equipment);
-  Drum lifter for lifting full drums of binder;
-  Dip stick for dipping emulsion in drums;
-  Suitably sized vibratory pedestrian roller (Bomag 75 or equivalent);
-  Motorised bitumen hand sprayer;
-  Spray screens;
-  Protective clothing; overalls, sleeved work shirts, gumboots, gloves and protective eye glasses, etc;
-  High-visibility safety vests, road cones and traffic signs;
-  Clean water in the advent of burns;
-  First aid kit.

7.3.2. For Equipment-Based Methods

The following specialised plant and equipment is recommended to promote the construction of the single or double-seal surfacing by equipment-based methods.

-  Shovels;
-  Bitumen tanker with heater, bitumen pump and spray bar;
-  Trucks with aggregate spreader;
-  Pneumatic tyre roller;
-  Smooth wheel tandem vibrating roller;
-  Brooms;
-  Builders' wheelbarrows (capacity $\pm$ 65 – 67 litres);
-  Hammers;
-  Setting out and other construction aids including ranging rods, profile boards, pegs and string lines, line level, ditch templates 7 mm sisal rope, 2 x 50 m rolls;
-  Reinforced paper, 4 rolls x 1 metre wide;
-  Steel pegs, 300 mm x 9 mm;
-  Chalk-line equipment;
-  Steel tapes, 50 m;
-  105 litre drums (cleaning hand tools and equipment);
-  Protective clothing; overalls, sleeved work shirts, gumboots, gloves and protective eye glasses, etc;
-  High-visibility safety vests, road cones and traffic signs.
-  Clean water in the advent of burns;
-  First aid kit.

7.4. Preparations for Sealing Operations

Learning objective:

-  Knowledge about work planning, site organization and preparations for the work;
-  Knowing how to operate the motorized bitumen sprayer and how to achieve uniform spray rates;

7.5. Work Planning and Preparation

The work supervisors must factor in the lead times to get everything ready before the sealing operations can commence. This involves mobilising all the resources (materials, tools and equipment, personnel) and preparing the site so that work can progress without unnecessary interruptions once operations are underway.

7.5.1. Procurement of Materials

The bitumen products to be used: Management needs to place orders in good time before the planned starting date for the sealing operations. Bitumen should be stored in a safe and easy to use manner. Emulsion drums should be stored horizontally so that they can be rolled at least twice a week until they are used to avoid settlement and coalescing of the bitumen. Normally storage time should not exceed three months.

The aggregate to be used: It can sometimes be difficult to get the correct grading of aggregate from the nearest crusher. A special production run may have to be made for the required aggregate grading and time must also be set aside for testing the aggregate and transport to site. It is therefore important to secure a guarantee from suppliers to deliver the products in good time. Allowance for possible wastage must be made when ordering aggregate.

7.5.2. Site Organization

The works supervisor must have a clear plan for how the work is to be organized in order to achieve good progress and high standard of workmanship. This will involve:

- ✚ Keeping the site tidy by removing all rubbish, debris, tools and equipment that are not required to ensure that there are no obstacles in the way for the free movement of the work force and the plant and equipment to be used;
- ✚ Making sure the aggregates are kept clean and not overly wet. If the stockpile has become soaked, measures must be taken to dry it out before it can be used. Stockpile the materials for the daily production near to the work site to minimize handling and haulage;
- ✚ Making sure hand tools and ancillary equipment are clean, in good working order and in sufficient numbers for the planned output;
- ✚ Making sure all the required consumable items are in stock in sufficient quantities;
- ✚ Making sure the right type and sufficient quantities of Personal Protective Equipment (PPE) are in stock.

7.5.3. Base Preparations

As a general rule, no part of the works should be covered up by another pavement layer before it has been tested and approved. Therefore, before the prime or seal is applied the base needs to meet all specifications in terms of:

Compaction (or density): The required density of the base should be confirmed by Sand Replacement Tests. Weak spots must be repaired with the same material as used for the base and to the same quality as the rest of the base. It may be required to repair such spots as one would repair a pothole, i.e. by squaring up the defect and remove the material down to a sound layer, then backfilling with approved material and compacting to achieve the required density. The top of the finished repair should be level with the base.

Level: Construction to the design levels with particular attention to layer thickness, vertical alignment and relative level above the drain inverts.

Surface Texture: The surface of the base should have a tightly knit structure with sufficient fines to bind the coarse particles.



Example of good base surface texture

Source Ethiopian Roads Authority: Bituminous Sealing of Low Volume Roads using LB Methods

Surface Regularity: The base should be checked with a 3 m straight edge both across and parallel to the centre line. Irregularities greater than ± 6 mm should be corrected. High spots should be removed without loosening the base. Low spots less than 10 mm deep may be corrected with slurry,

which must be allowed to cure before the seal is applied. Low spots deeper than 10 mm must be reconstructed as a pothole repair.

Cleaning the Base

Before the prime and seal is applied, the base must be cleaned of all foreign matter (debris, animal droppings and rubbish) and thoroughly swept to remove all dust from the surface. Dust will prevent proper bonding between the base and the seal.

Dampening of the Base

The prime will not penetrate into and bond properly to the base if the surface is completely dry. This is because of the surface tension of the base material that causes the material to repel the bitumen. In order to break this surface tension, the base is therefore lightly sprayed with water just prior to the application of the bitumen. A fine mist spray applied with a hose pipe and spray nozzle is best in order to avoid over application and soaking of the base. Watering cans with spray nozzles can also be used.

If for some reason the bitumen application is delayed and the base has dried out, water should again be applied before the bitumen is sprayed. Failure to break the surface tension will result in “fish-eyes”, i.e. bubbles in the bitumen with no coverage and bonding to the underlying base. These are potential weak spots, which, if not rectified, will result in premature localized failure of the seal and the early development of potholes.

7.6. Operation of the Motorized Bitumen Sprayer

For labour-based seals that require spraying of bitumen or emulsions, a motorized bitumen sprayer must be acquired. There are different types of sprayers on the market, but they all have the same basic function. Each will have its own individual operating instructions when purchased.

7.6.1. The Motorised Hand Sprayer

A typical motorised hot bitumen/ emulsion hand sprayer will normally have the following specifications, or similar:

- ✚ Engine: usual $\pm$ 5 kW diesel engine (also available with petrol engine);
- ✚ Pump: Gear type pump, direct drive from the output shaft of the engine reduction gear, through a flexible coupling. The output when spraying is approximately 17-18 litres/minute;
- ✚ Lance: 5 metre oil-resistant delivery hose, fitted to a 1 metre lance including handle grip, shut off valve and two 65° flat spray adjustable nozzles;
- ✚ Heating equipment: Ideally sized burner ring, gas regulator, air control valve, heat deflector shield and gas bottle carrying bracket.



For the efficient and extended use of the equipment, it is advisable that the working, operation and maintenance of the equipment is thoroughly understood, and that good sound practice is applied. Many hours can be wasted if the equipment is not systematically cleaned and serviced.

7.6.2. Operation

General

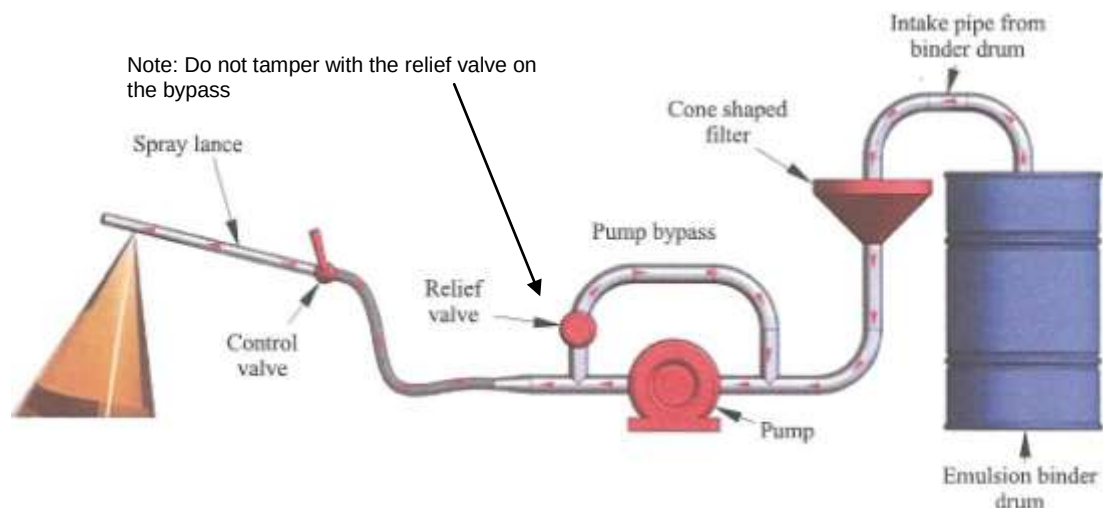
Before starting the engine, check the oil levels by unscrewing the two oil plugs at the bottom of the engine. The oil level must always be flush with the bottom rim of the oil plugs.

- ✚ Use only SAE 30 oil for the spray machine;
- ✚ Before starting the machine, if diesel powered check whether there is enough diesel in the tank. Never let the tank run dry as this will lead to the engine having to be bled;
- ✚ When removing the diesel cap, there is a filter at the tank opening to prevent dirt entering the tank. Before removing the cap, clean the areas around the cap using a mutton cloth;
- ✚ The storage of the diesel in 210 litre drums must be supervised. Check that the drum is left in one position (vertically) if a pump is used, or on a stand (slightly tilted away from the tap) if a tap/valve is used; for decanting into a clean container and allowed to stand, for at least 24 hours, to allow the sludge to settle.

Starting the Engine/Pump

The sprayer pump is self-priming. However, if the machine has not been used for a number of weeks, the sprayer pump must be primed. This is done by removing the white cone shaped filter and adding just sufficient fuel in the filter cap, so that it will not spill when fixing it in place on the engine.

- ✚ Before starting the engine, the intake pipe/sump of the spray machine must be placed in the 210 litre drum of emulsion, and the control valve on the spray lance must be open;
- ✚ Start the engine by switching it to the on position, opening the choke and pulling the starter rope. The sprayer pump will take approximately one minute to prime;
- ✚ Once primed, the control valve on the spray lance can be set to the off position. The engine can be left running as the sprayer has a built-in, automatic bypass system;
- ✚ When there is difficulty in starting the engine in cold weather, remove the rubber cap on the top of the engine, put ± 5 ml of the fuel in the tube and replace the rubber cap.



Typical schematic layout of motorised hand sprayer

Heating of Binder/Emulsion

CAUTION

-  Use the flint and not matches to light the burner. If flint is not available, use a rolled-up length of paper;
-  Never light the burner with the drum on the machine;
-  First light the burner, then place the drum in position;
-  Never leave the drum being heated, unattended – always have someone checking the temperatures and gently stirring the emulsion to prevent of the emulsion from boiling over;
-  On the top of the gas cylinder there is a valve which controls the flow of gas in the system. This valve is usually open when spray work is being done;
-  There is a flexible tube/pipe connecting the cylinder with the burner;
-  The valve controlling the gas pressure is close to the top of the cylinder and controls the intensity of the flame from the burner (i.e. the second valve). Once this valve has been set for the day's work, it should not be re-adjusted every time the machine is used, unless the flame is too weak or too strong;
-  The third valve is on the gas pipe near the burner, at the bottom of the spray machine. It is this valve which is opened for lighting the burner and adjusting the flame to the size required.

Maintenance of the Machine

-  Always keep the machine in a clean condition – not only externally but internally too by using Tar Solvent with diluted paraffin (4 parts paraffin to 1 part Tar Solvent), and applying with a brush or spray, the equipment can be washed off with a hose. The process should be done at the end of each shift, to keep the equipment clean.

Safety Precautions

-  Always use protective clothing when operating spray equipment, i.e. gloves, boots and overalls;
-  Use a special flint lighter and not matches to light the burner;
-  Make sure all valves are closed on the gas cylinder when finished spraying;
-  Store the gas cylinder in a safe place on completion of spraying;
-  Do not use diesel for cleaning spray equipment or hands.

Spray Procedure

-  Before any spraying of the emulsion commences, it is essential to have three clean half drums (105 litres) available on site. Half fill one drum with water and have the second for cleaning with kerosene;
-  Before using any drums of emulsion for spray work, it is essential to check the contents to establish if there has been settlement of the bitumen in the emulsion in the bottom of the drum;
-  Open the drum and dip a broom handle into the drum. Test the bottom of the drum for settlement. When extracting the dipper, the consistency of the emulsion coating of the dipper can be gauged visually. Settlement in the drums is a problem and the drum must not be used until the problem has been rectified. This is achieved by cutting open the drum and stirring the contents until a uniform consistency is obtained, and pumping the contents into a clean drum. The suction of the thick sludge, into the spray system, can cause severe delays and problems;

- ✚ Once the machine has been primed, with the sump/intake pipe in the drum of tested emulsion, spraying can commence;
- ✚ When the contents of one drum have been depleted, switch the engine off. Replace the empty drum with a full drum of tested emulsion. Start the engine and proceed with spraying;
- ✚ At the end of a shift or at lunch break, remove the sump from the drum and spray out the emulsion in the system. Immediately place the sump in the $\frac{1}{2}$ drum of water and continue to re-circulate the clean water through the system until there is clear water flowing through the system;
- ✚ Once the flow of water is clear, place the sump in the $\frac{1}{2}$ drum of paraffin (kerosene) and circulate the paraffin (kerosene) through the system back into the drum. Note that you have a maximum of only two minutes to move the sump from the water into the drum of paraffin;
- ✚ If the containers of water and kerosene are not ready, switch off the engine until the containers are ready. Under no circumstances must the engine run for more than two minutes without feeding the sump with emulsion, water or kerosene;
- ✚ The same kerosene must be used as much as possible – this (kerosene cannot be used for fuel);
- ✚ The water must be replaced for each daily shift;
- ✚ When spraying ceases, and after cleaning, the spray lance must not be placed on the ground with the nozzles in the dirt. Two saddles fitted to a $\frac{1}{2}$ drum will overcome this problem;
- ✚ The third $\frac{1}{2}$ drum is used for checking the rate of delivery of the pump. The rate of delivery of the pump must be determined before surfacing work commences.
- ✚ Determining the delivery rate of the sprayer.



7.6.3. Delivery Rate

Before either the tack coat or penetration sprays are applied, it is essential to check the delivery rate of the sprayer in litres per minute, against the manufacturer's specification, which is in the order of 17 litres per minute. The rate of delivery will vary for different viscosities of binder, which will also vary according to the temperature at which the binder is sprayed. The methods for testing the delivery of the pump are as follows:

Method 1:

- ✚ Spray the binder to be used into a clean standard emulsion half drum (105 litres) for one or two minutes; with the emulsion binder drum in position on the motorised hand sprayer chassis and the empty half drum on the road surface;
- ✚ With a calibrated dipstick, measure the quantity of binder sprayed in the one or two minutes;
- ✚ This will determine the delivery of the pump in litres per minute. This can be compared with the manufacturer's specification which is normally 17 l/min to 18 l/min.

Method 2:

- ✚ Dip the drums of emulsion to be sprayed with a measured dipstick – L1;
- ✚ Spray a measured area of say 3.5 m x 2 m = 7 m²;
- ✚ Dip the drum after spraying – L2;

- ✚ The quantity of emulsion sprayed in litres is $L1 - L2$;
- ✚ Record the time (T) in seconds which elapsed to spray the measured area;
- ✚ The amount of binder sprayed in litres per second is then $L1 - L2 \text{ (l/s)/T}$;
- ✚ The rate of delivery can then be compared with the manufacturer's quoted rate of delivery of $\text{XX l/m} \text{ (.XXXX l/s)}$.

Before spraying can proceed, the delivery rate **must be determined**. This is the basis for calculating the time required for spraying the binder at the specific rate of application over a certain area.

Time Control of Spray Rates

Knowing the rate of delivery of the pump in litres per minute, and the rate of application of the binder that is required for any layer of aggregate, it is possible to calculate the time, in minutes and/or seconds, that the spray operation allows for covering a certain section using a motorised hand sprayer machine ($\text{litres/m}^2 \text{ divide by litres/min} = \text{minutes/m}^2$).

7.6.4 Training of Spray Equipment Operators and Team

Uniformity

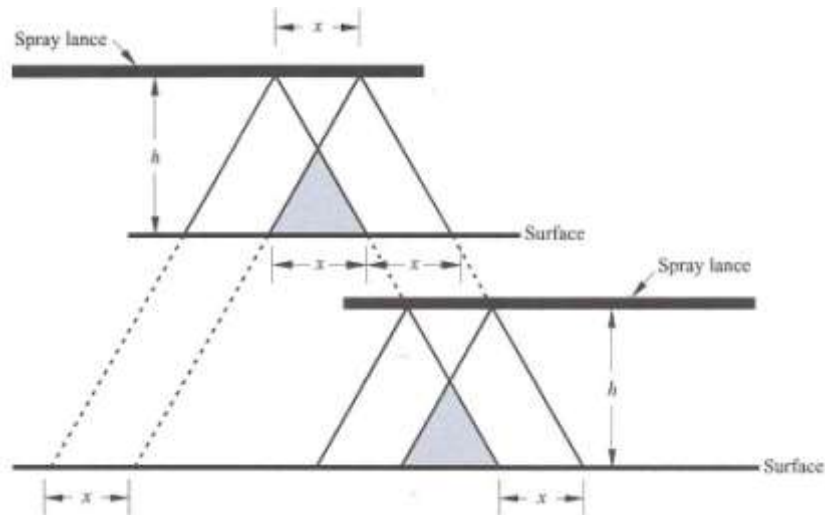
Before attempting any bituminous surfacing, it is recommended that the spray operators and team be introduced to the spray operation by first spraying water at a uniform application per square metre. Until the operator and team are fully conversant with all aspects of the operation and confident in applying a uniform application of water, spraying of diluted emulsion must not be attempted. The operations include:

- ✚ Initiating the burners;
- ✚ Starting the spray machine;
- ✚ Checking the delivery of the pump;
- ✚ Practicing the movement of the protective screens while spraying;
- ✚ Practicing initiating of the spraying by the stopwatch operator;
- ✚ Checking the rate of application for 2 m; 3 m and 4 m control sections;
- ✚ Practicing keeping the spray lance at a uniform height above the surface to be covered while spraying;
- ✚ Recording the results of the times and dipstick readings.

Once the unit is comfortable in all the phases/aspects of the spray operation, the next step is to apply the emulsion on the section of road to be surfaced. At the same time, the use of the protective screens to protect any concrete works, such as kerbing, channelling, etc. must be introduced, and the labour trained in the systematic moving of the screens along the edge of the area to be surfaced. (For a clean operation this is essential.) The screens must move slightly ahead of the binder application.

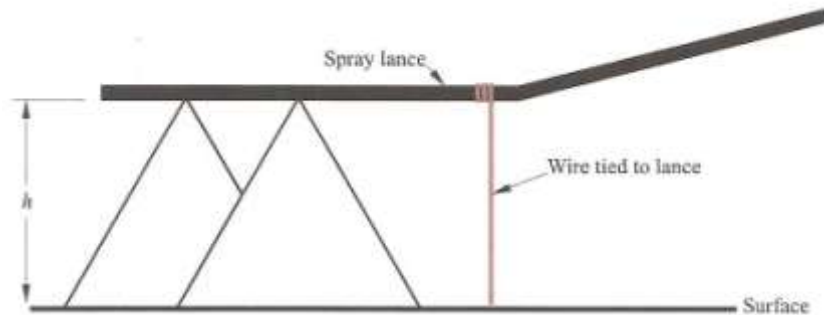


The ideal height h of the spray lance must be in such a position that it obtains an overlap of approximately half the width of one jet. It is better to have h slightly higher than lower. Try to keep h a constant height while spraying, to obtain a uniform overlap and therefore a uniform application.



Spraying height and sequence of spraying

Once the correct height h for spraying above the road surface has been determined, it can be maintained by tying a piece of wire of the correct length to the lance as illustrated below.



Maintaining Correct Height for Spraying

7.6.4. Application of Binder

Checks

Before spraying of the binder commences, the following checks must be carried out:

- ✚ Ensure that there is sufficient emulsion, aggregate, diesel fuel and paraffin on site to complete the work. To do this, the area to be surfaced and the rate of application of the binder and aggregate, must be established.

The delivery rate of the pump must be established as described.



Spraying operation

- ✚ That the aggregate has been correctly supplied and spotted;
- ✚ That the surface to be sealed is clean, and any repairs required properly attended to;
- ✚ That the area to be surfaced has been correctly set out;
- ✚ Those arrangements to protect the kerbs, etc. are in place;
- ✚ Reinforced paper has been placed at the start and finish joints;

- ✚ That all members of the team are at their posts and ready for action, i.e. labour for spreading the chips and moving the spray screens, and recording operators are in position.

Control of Application using a Trial/Control Section

For accurate application of the binders, the work must be controlled by counting off the time it takes to apply the calculated amount of binder over a determined area. It is recommended that two metre control sections are set out and the time to spray each section recorded. The time, required to spray each two metre section at the required rate, has to be calculated. Before a trial section can be done, the following information must be established:

- ✚ The rate of delivery of the pump (l/min);
- ✚ The rate of application of the binder (l/m²);
- ✚ The area of the trial section (2 m long, 3.5 m width) (m²);
- ✚ The volume to be sprayed must be calculated in litres (l);
- ✚ The time for spraying the volume must be determined (minutes or seconds) (1 minute = 60 seconds).

For accurate application of the binder, the work must be controlled by a separate operator using a stopwatch and calling out the seconds as the work progresses, so that the spray operator can control his work.

The time keeper must record the time taken to spray each of four or five control sections, as well as guide the sprayer operator time-wise, either to speed up or slow down the coverage of the area.

Example

Delivery rate of sprayer: 0,283 litres per second (17 l/min divide by 60)

Spray application rate of penetration layer: 1.7 litre/m² (tack coat of 0.7 litres/m² subtracted from total requirement)

Width of road: 3.5 m

Control length: 2 m

Area of control section: 7 m² (2 m² 3.5 m)

Amount to be applied to control section: 7 x 1.7 = 11.9 litres

Time to apply 11.9 litres over control section: 11.9/0.283 = 42 seconds

Control section metres	Calculated time for spraying
0 – 2	0 – 42 seconds
2 – 4	0 – 42 seconds*
4 – 6	42 – 1 min 24 sec
6 – 8	1 min 24 sec – 2 min 06 sec
8 – 10	2 min 06 sec – 2 min 48 sec
*clock reset to zero	

Calculated times for spraying control section

Every time the spraying stops at the end of a control section, be it one control section initially or four sections in total, the dipstick readings must be taken and recorded, before the commencement of the next spray. It must also be taken at the end of the initial control section and at the end of control

section 4 (or 5 if 5 sections are sprayed).

The rate of application of binder using the time (clock), and delivery rate of the sprayer described in earlier, should be checked against dipstick readings as illustrated below.

1	2	3	4	5	6	7	8
Area to be sprayed (length x breadth) A (m ²)	Application rate (Pump delivery (D-litres/sec) and time (T))				Check using dips as described in this section		
	Calculated time of spray (A x R)/D Tc (sec)	Actual time of spray Ta (sec)	Volume of spray applied (Ta x D) (sec)	Rate of application (Ta x D)/A Rd (litres/m ²)	Initial dip D1 (litres)	End of spray dip D2 (litres)	Rate of application (D1 – D2)/A (litres/m ²)
A0							
A1							
A2 etc.							

Checking using dips

Once the time for spraying control section 1 for the 2 m length of road has been calculated and sprayed, the clock must be set at zero and the time taken for spraying sections 2, 3, 4 (and 5) must be calculated and the spray operator guided for each section by the time controller. The time the spray operator actually takes for each section must be recorded in column 3. The variation of spray application can be checked by comparing the actual application rate calculated in column 5, with the design spray rate. The recording of the times in column 3 must be done by a separate operator (recording operator) as it cannot be done by the time controller.

Where:

Column	Symbol	Description	Unit
1	A0	Control area to be sprayed (width x 2 m length) m ²	m ²
	A1;A2 etc	Subsequent control areas to be sprayed (width x length) m ²	m ²
2	Tc	Time Calculated to spray control area and subsequent control areas ((A x R)/D) where R is the required application rate	Seconds
3	Ta	Actual time for spraying control area and subsequent areas	Seconds
4	Ta x D	Volume of binder applied to the control area and subsequent control areas, based on pump delivery and spray time	Litres
5	Rd	Rate of application of binder to control area and subsequent areas, based on pump delivery and spray time	Litres/m ²
6 & 7	D1 – D2	Volume of binder sprayed, based on dip readings	Litres
8	Ra	Rate of application of binder, based on dip readings	Litres/m ²

The dipstick readings are done by using a steel rod calibrated/graduated in 10 litre intervals up to 210 litres. The amount of emulsion sprayed for each cycle of spraying is recorded in litres. The time controller, recording operator and spray operator must work very closely together. Spraying can only commence after the time controller has zeroed the stopwatch and gives the signal to start spraying.

The recording operator will mark the separate sections for checking at 2 m intervals and record the time at the end of each 2 m section that is sprayed. From these readings, a double check of the

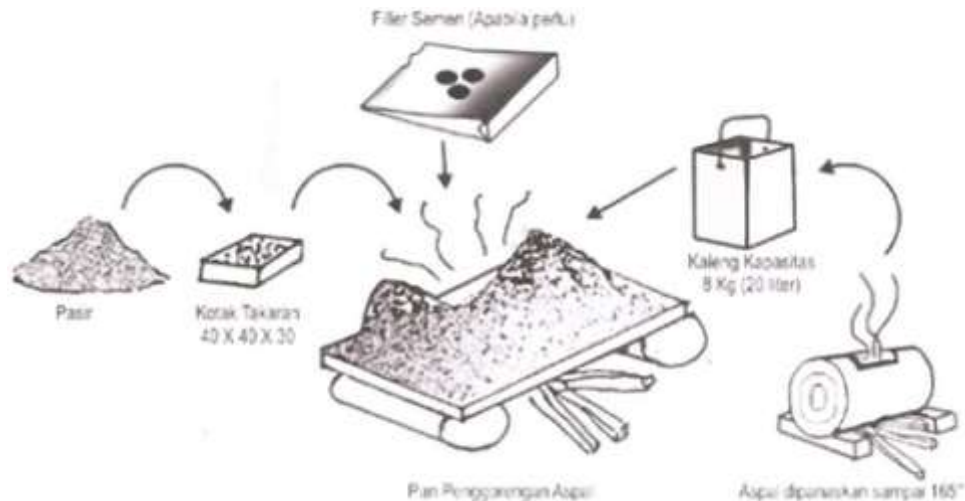
accuracy of the work can be established by multiplying the pump delivery D by the time taken to spray each section.

The spray operator must control his rate of moving the spray lance by listening to the time controller calling out the seconds required for each 2 m section, using his wrist watch (or preferably a stopwatch) and bearing in mind the number of seconds he has to cover each 2 m section of road.

8. Latasir⁵ Labour-Based Hotmix (HMP)

8.1. Description of Work

Latasir Asphalt Sand Sheet is a wearing course asphaltic mixture composed of continuous graded natural sand and asphaltic materials mixed in central plant (or on site) and spreading and compacting the mixture at a certain temperature on a prepared road base in accordance with the following guidelines and in conformity with the alignment and longitudinal and transverse sections shown on construction drawings.



Latasir asphaltic mix

Legend

Pasir = sand

Kotak Takaran = Batching box

Filler Semen (Apabila perlu) = Cement filler (if necessary)

Kalena Kapasitas = can of indicated capacity

Pan Penggorengan Aspal = Asphalt heating pan

Aspal dipanaskan = heated asphalt to indicated temperature.

8.2. Materials

Materials used in the work shall meet the following requirements:

Sand

Sand shall be a continuous graded material and should not contain any organic material. The properties of the sand should be:

-  Sand Equivalent (AASHTO -176) minimum 50 %;
-  Organic Content (PB0207 – 76) minimum 3 %;
-  Atterberg Limit (PB 10109-76 and PB 0110 -76), non plastic.

Filler

If a filler needs to be used, the filler material could be limestone dust, dolomite dust, portland cement fly ash, cement kiln dust or other non plastic mineral material from sources approved by engineer.

⁵ Latasir is an Indonesian engineering expression derived from: Lapisar (layer), tipis (thin), aspal (asphalt) and pasir (sand)

The grading requirement for the filler is shown in table below:

Sieve Size	Percent by Weight Passing
0.595/ 30	100
0.177/80	95-100
0.073/200	65-100

Grading of filler material

Bituminous Material

Bituminous material shall be either AC-10 grade asphalt cement (which is approximately equivalent to 80/100 Pen.) or AC-20 grade asphalt cement (which is approximately equivalent to 60/70 Pen.) conforming to AASHTO M 226-78.

8.3. Mixture

Grading of the mixture shall be as shown in the following table.

Sieve Size (inch/mm)	Percent by Weight Passing	
	Type 1	Type 2
3/8 (9.52)	100	-
No. 4 (4.76)	85-100	100
No. 8 (2.38)	80-100	95-100
No. 16 (1.19)	70-89	85-98
No. 30 (0.595)	55-80	70-95
No. 50 (0.279)	30-60	40-75
No. 100 (0.149)	10-35	20-40
No. 200 (0.074)	4-14	8-16
Normal Bitumen Content (%)	7.0-11.0	7.5-12.0
Compacted Layer Thickness (cm)	2	1

Grading requirements

The bitumen content shall be determined using the Marshall method to the specification (PB 0201-76). Optimum bitumen content is the bitumen content in the condition where the mixtures meet the required mix property shown in the following table.

Mix Property	Mid-Design Life Average Daily Traffic	
	Example 1 (300-3.000)	Example 2 (dibawah 300)
Marshall Stability (Kg)	250	250
Flow (mm)	2-4.5	2-5
Air Void Content of Compacted mix (%)	3-5	3-5
Voids Bitumen Filled (%)	75-85	75-85
Numbers of blows	2x50	2x35

Optimum bitumen content

8.4. Execution of the Work

Contractor shall make an effort to keep a good workmanship in order to obtain acceptance in accordance with the specifications, following all related requirements and conditions.

8.5. Equipment

Mixing Equipment

The sand sheet mixtures could be produced in Asphalt Mixing Plant or manually using simple equipment such as a flat pan.

Spreading and Compacting Equipment

Spreading of the sand sheet mixtures shall be done manually by workers. Compacting shall be carried out using mechanical equipment. The following equipment and tools will be required.

- ✚ 4-6 ton Tandem Roller;
- ✚ Motorised hand sprayer (application of asphalt or emulsion for prime or tack coat – also can be carried out manually using perforated cans);
- ✚ Shovels, builders wheel barrows, brooms and spreading rakes.

8.6. Mixing

- ✚ Proportion of mixture materials shall be in accordance with Job Mix Formula which is determined and approved by engineer after trial;
- ✚ Mixing shall be thorough so that a homogenous mixture obtained;
- ✚ Aggregate/sand shall be heated to a temperature up to maximum 175°C. Temperature of asphalt shall be not less than temperature of the aggregate with the different not greater than 15°C. The mixture temperature is based on the bituminous material used.
 - - For AC-20 grade (80/100 Pen) : 130°C - 165°C
 - - For AC-10 grade (60/70 Pen) : 124°C - 162°C
- ✚ Contractor shall consider the condition of compacting equipment on site and the weather condition before producing the sand sheet mixtures and to control the quality of mixtures time to time.



Mixing materials

8.7. Spreading and Hauling

Before spreading the mixture material the following requirements should be satisfied.

- ✚ Longitudinal and cross section where the asphalt sand sheet to be placed should be in conformity with the lines, grades and cross sections shown on the construction drawings or as required by engineer;
- ✚ Immediately before placing the mixture, the existing surface shall be cleaned of loose or deleterious material by sweeping with broom;
- ✚ A tack coat or prime Coat shall be applied in accordance with the specification or as directed by engineer;
- ✚ The bituminous Tack Coat and or Prime Coat shall be either AC-10 grade (80/100 Pen.) or AC-20 (60/70 Pen.) diluted with kerosene. Unless otherwise directed by the engineer, the proportion of kerosene used shall be 80 parts of kerosene per 100 parts of asphalt cement (80 pph). Generally, the application rate will fall within the following range.
 - Prime Coat : 0,5 to 1,3 litres per m² for Aggregate Base Class A
 - Tack Coat : 0,20 – 0,35 litres per m² for old porous weather surface
- ✚ Hauling of the mixture from central plant to the work site shall involve a truck fitted with a steel deck and tray which shall be clean, syringed with soapy-water, fuel, paraffin oil or lime-water.
- ✚ During transporting, the container shall be covered with canvas to retain the heat of the mix and protect the material from the weather and to prevent contamination from waste material.
- ✚ Spreading shall start from the point further away from the asphalt mixing unit and be ended at the nearest point.
- ✚ The asphalt mixture shall be spread to a monitored depth giving adequate thickness in accordance with the specified requirements.
- ✚ The mixtures shall be spread at minimum temperature 120°C.



Spreading and rolling Latasir mix

8.8. Compacting

- ✚ Temperature of initial rolling or breakdown rolling shall be 98°C - 100°C. Compactor shall be a Tandem Roller 4 – 6 ton moving at a velocity of 3 – 4 km/hour.
- ✚ Finishing Rolling shall be minimum 85°C. Finishing rolling shall show no roller tracks or marks in the finished road surface.

8.9. Measurement and Payment

The unit of measurement for the Latasir Asphalt Sand Sheet is square metres (m²). The quantity shall be taken as the area of the compacted layer of asphalt sand sheet at the adequate thickness indicated on the construction drawings or as directed by the Engineer. The Prime Coat or Tack Coat is normally inclusive in the unit rate for the Asphalt Sand sheet.

8.10. Quality Control for Construction of Latasir Pavement

The construction of a Latasir pavement includes the selection and checking of the correct bitumen and emulsion materials for the Prime (tack) coat and the Latasir mix. Quality control for this work includes checking the suitability of the materials and control of the work activities.

<i>Description/ Work Activity</i>	<i>Test/Check Method</i>	<i>When</i>	<i>Tools</i>
Material for Latasir Asphalt			
Aggregate: Purity +grading	✓ Check grading of sand and any filler. ✓ visual check of cleanness: free from soil, salt, dust, tree root, tree branch or leaves	Before procurement	LAB
Bitumen	✓ visual check emulsion refer to specification ✓ if the dump is leakage	Before procurement	NA
Kerosene for cutback and cleaning	✓ visual check of purity of the kerosene for producing the cutback for the Prime coat	Before procurement	NA
Construction of Prime coat for Latasir			
Prime coat	✓ visual check of base course layer are clean ✓ check if pegs and string line are used for every 10 m interval at both edges of the	During carrying out the activity	Thermometer

	road to control area of spraying the prime coat ✓ check heating temperature of bitumen/emulsion (refer to specification) ✓ check mixing rate of heated bitumen with kerosene (30-40% of kerosene) ✓ check spraying rate i.e. measure cutback use and divide with road area covered.		
Latasir	✓ Check emulsion grade ✓ Check emulsion is mixed ✓ Check material quantities and ratio for mixing ✓ Check adequacy of the mixing	During carrying out the activity	NA
Before activity is carried out:	✓ Check if the equipment: heated mixing plate and hand tools are in good condition ✓ Make sure guide rails are in placed correctly, if used. Otherwise check uniformity of unconsolidated application. ✓ Make sure road surface is cleaned. ✓ Make sure to use the correct type of bituminous emulsion. ✓ Make sure Latasir hot mix temperature complies to specification	During carrying out the activity	NA
While activity is carried out:	Make sure mixing proportions (water, emulsion, sand) are correct and the mixing is properly done. Make sure to spread Latasir mix to level of guide rails, or uniform depth with no waves in the completion surface. In any places where low spots become apparent, asphalt shall be used for filling the spots before commencing compaction. Make sure that compaction activities are assumed as soon as material has been spread and control passes of the rolling. Make sure compaction is uniform regarding rolling pattern and number of passes. Also ensure that there is always a lateral overlap of at least 20 cm from pass to pass	During carrying out the activity	NA
Final check:	Make sure road surface is even and well compacted. Make sure all tools and equipment have been cleaned after using Make sure all guide rails, if used have been removed and continuing use to other road sections	On completion	NA

	Make sure exceeded material(sand and emulsion) have been hauled and reused to other uncompleted sections Make sure remaining asphalt on completed sections or road section to be sealed are cleaned.		
--	---	--	--

8.11. Technical Resources and Reference Materials for Latasir (Hotmx) Surfaced Roads

- Roading New Zealand Code of Practice (COP) BCA 9904 (NZPBCA2000)
- Manual for the labour-based construction of bituminous surfacings on low-volume roads, TRL, 2003
- ERA Bituminous LBT Training Manual and Surface Treatments Worksheets, 2015
- Manual 4 Bituminous Seals, Construction Industry Development Board (cidb), South Africa, March 2007
- Bituminous Sealing of Low Volume Roads using Labour Based Methods, Ethiopian Roads Authority Training Manual, June 2013
- AFCAP, Low Volume Rural Road Surfacing and Pavements A Guide to Good Practice, June 2013
- Overseas Unit, Transport Research Laboratory, 1993, Overseas Road Note 31, A guide to the structural design of bitumen surfaced roads in tropical and sub-tropical countries, Crowthorne, Berkshire, United Kingdom.

9. Coldmix Asphalt (CMP)

9.1. Description

Cold Mix Asphalt is a pre-mix of continuously graded aggregate and cationic mix grade emulsion. It can be mixed and placed by hand or a concrete mixer using labour-based methods and simple hand tools and purpose made implements, thus eliminating the need for sophisticated and expensive construction plant except for a suitably sized roller. The seal is therefore eminently suited to labour based sealing of low volume roads. It does not require highly skilled supervisors and the techniques for mixing and constructing the seal is easily learnt by the labourers.

The work comprises mixing of the cold mix, hauling and placing the asphalt, spreading on a bituminous emulsion tack coat at the predetermined application rate and compaction. The mixing of the asphalt is in accordance with a mixing proportion determined by engineer and normally specified in the work specification. The aggregates shall be free of dust and organic material.

This guideline describes both the mixing of the asphalt cold mix manually and using a concrete mixer.

9.2. Materials

Emulsion Binder

A medium setting cationic mix grade emulsion CMS2 h has been found to give the best results in Timor Leste. The medium setting emulsion also gives ample time for spreading and levelling the asphalt before the emulsion breaks and the mix becomes sticky and difficult to spread.

Tack Coat

Anionic Stable Grade SS60 1s diluted 1:1 with clean water is used for a thin tack coat prior to sealing. The tack coat should be dry before sealing starts to avoid pick-up of bitumen during the sealing.

9.3. Trial Mix

For every new source of aggregate to be used, small trial mixes should be carried out to establish the optimal mix proportions. For very porous aggregates, the amount of emulsion must be increased. The increase may be established in a laboratory, but practical trials will give a good indication of the required amount of emulsion to be used. The ready mix should have a wet look and all aggregates should be properly covered.

9.4. Equipment and Tools

For the construction of Cold Mix Asphalt with labour based methods the following plant and equipment is required:

-  Tandem vibratory roller (3 - 5 tonnes);
-  Mixing pan(s) constructed of 3mm steel;
-  Wheelbarrows;
-  6mm rope, 2 x 50m rolls;
-  Flat, square nosed spades;
-  Hard brooms;
-  Hammer;
-  75mm nails for holding down guide rails;
-  Chalk line equipment;
-  Steel tapes, 5 m and 50m;
-  Steel squeegees;
-  20mm steel box sections as guide rails for placing asphalt (four lengths each of 2m and 3m long) with three 4mm diameter nail holes per section;

-  6mm x 50mm steel flat bar to accommodate wet to dry asphalt (four lengths each of 2m and 3m long);
-  2m straight edge (Screeds);
-  6 No. 20 litre measuring containers;
-  5 No. 10 litre measuring containers;
-  1 No. 5 litre measuring jug;
-  Steel framed stand for decanting emulsion drums;
-  50 mm diameter ball valve for decanting emulsion from drums.

9.5. Construction

Site and Base Preparation

The base must be swept clean of all dust, debris and foreign matter before the sealing commences. Animal droppings must be carefully removed using a spade and a stiff brush taking care not to damage the prime. Any defects in the prime must be repaired by reapplying prime and letting it cure. Stake out the width of road to be surfaced, marking out the edge of the road with a 6mm rope.

The asphalt should be laid in strips usually not wider than 1.20 m at a time. If the base does not have a perfect camber, i.e. it has a slight dome shape or bulge in between the guide rails, the asphalt will be too thin on top of the bulge if wider strips are set out. This should be checked using the straight edge before sealing work starts.

The strips should be marked out such that the joints do not come in the wheel paths. The number and width of the strips depends on the width of the lane. The strips should also not be too narrow as this will increase the number of longitudinal joints. A 3.0 m wide lane is then constructed in 3 strips of 1 m width.



Guiderrails placed, tack coat applied

Work Organisation

Place guide rails: (20mm x 20mm steel box sections) along road edges and road centre line and quarter points of the road. Check accuracy level of the guide rails, where lower than 20mm make an adjustment with extra asphalt or piece of aggregate to achieve the same level.

Apply tack coat: using bituminous emulsion of 60% CSS 1s. The emulsion shall be diluted with water of a composition 1:1. Use watering can and broom for tack coating between the guide rails. Application rate of the tack coat should be 0.6-0.7 litres/m².

Place mixing pans and aggregates: the mixing pens should be placed in situ with the spacing between calculated based on the required volume of asphalt to be placed. The mixing pans are to be moved continuously forward after discharging the mixed asphalt. The aggregate for the mixing is to be deposited on a completed road section nearest to the road section to be sealed.



Mixing pans, manual mixing and placement

Manual mixing the cold mix asphalt: using measuring cans add the correct predetermined amount of aggregate to the mixing pans. The size of the aggregate shall be to a grading approved by engineer. Apply water lightly of an amount 1% of the mass of the aggregate and mix thoroughly.

Pour bituminous emulsion of 65% CMS 2h (company code: E-71) on the heap of wet aggregate in the pans at the correct amount pre- determined by the engineer. In most cases the proportion of bituminous emulsion should be 8.5-9.5% of the mass of the asphalt.

Start manually mixing immediately by using proper hand tools, i.e. spreader or hoes and shovels. The mixing shall be done continuously until all parts of the aggregate are covered by bitumen.

Immediate after the mixing, the mixed asphalt shall be discharged direct from the pans to tack coat base at middle point between the two guide rails. After discharging the asphalt from the mixing pans, the mixing pans will then move to other unsealed section and continue the above sequent for the mixing process.

Mechanical mixing (concrete mixer) the cold mix asphalt: use measuring cans to add the correct amount of the aggregate to the mixture while the mixing drum is operating. The proportions of the mix shall be determined by the engineer or shall be as specified in the technical specification. Water is then added slowly to the drum and the mixing should continue until the aggregate is thoroughly dampened. The amount of the water should be 1% of the mass of the aggregate.

Add bituminous emulsion 65% CMS 2 h (company code: E-71) by slowly pouring into the drum continuously while the mixer is operating. Continue operating the mixer until all parts of the aggregate are covered by bitumen. The mixer should be operated as slowly as possible with the angle of the drum half way between vertical and horizontal, (i.e. 45°). The composition of the aggregate and emulsion shall be predetermined by the engineer or shall be as specified in the technical specification. In most cases, the proportion of bituminous emulsion should be 8.5-9.5% of the mass of the asphalt.

The mixer drum shall not be loaded above a level of 1/3 of the volume of the drum. Immediately after the mixing, the asphalt should be discharged to a wheel barrow and transported to a prepared section of the road base (ready tack coated) for spreading. The wheel barrow load should not be more than half of the capacity of the wheel barrow and the haul distance should desirably be no greater than 200m. Space for unloading the wheel barrow should be known and marked before the asphalt is tipped onto the prepared base, with the asphalt being into the middle between the two guide rails.



Materials batched for mixing and concrete mixing

Spreading shall be commenced immediately after unloaded the asphalt from the wheel barrows. The spreading shall commence from heaped material toward the guide rails, ensuring the spreading level of the asphalt to the same as level of the guide rails. Screeding shall follow the spreading to ensure a level and smooth surface.



Placing material mixed in mixer, and spreading

Compaction: once the screeding has been completed, the guide rails should be removed to allow compaction. The rolling can then commence using a 3 -5 ton tandem wheel roller operating at a slow speed of less than 5 km per hours The roller wheels shall be wet by water to avoid asphalt sticking to the wheels. Compaction shall involve 6 - 8 passes. It is recommended that, rolling of first 2 passes should be done in static mod. The vibrating mode can be started after 3 pass and continue until finished.

Cleaning equipment: all hand tools for spreading the asphalt shall be continuously cleaned using kerosene. Cleaning of the concrete mixer is recommended after every 2 to 3 mixes. The cleaning of the mixer can be carried out by using a shovel with round blade to clean all the fine asphalt sticking in the mixer bowl, using kerosene if necessary when the residue asphalt is too sticky or hard and difficult to remove.

9.6. Quality Control for Construction of Cold Mix Sealed Pavement

The construction of a Cold Mix sealed pavement includes the selection and checking of the correct bitumen and emulsion materials for the Prime (tack) coat and the cold mix. Quality control for this work includes checking the suitability of the materials and control of the work activities.

Description/ Work Activity	Test/Check Method	When	Tools
Material for Coldmix Asphalt			
Aggregate: Purity +grading	✓ Check grading of filler. ✓ visual check of cleanness: free from soil, dust, tree root, tree branch or leaves	Before procurement	LAB
Bitumen	✓ visual check emulsion refer to specification ✓ if the dump is leakage	Before procurement	NA
Construction of Tack coat Cold mix			
Tack coat	✓ visual check of base course layer are clean ✓ check if pegs and string line are used for every 10 m interval at both edges of the road to control area of spraying the prime coat ✓ check mixing rate emulsion and water (refer to specification) ✓ check spraying rate i.e. binder use and divide with road area covered.	During carrying out the activity	NA
Coldmix	✓ Check emulsion grade ✓ Check emulsion is mixed ✓ Check material quantities and ratio for mixing ✓ Check adequacy of the mixing	During carrying out the activity	NA
Before activity is carried out:	✓ Check if the equipment: mixing pans and hand tools are in good condition ✓ Make sure guide rails are in placed correctly. ✓ Make sure aggregates are cleaned. ✓ Make sure to use the correct type of bituminous emulsion. ✓ Make sure the temperature of the emulsion is in rank 45-60°C	During carrying out the activity	NA
While activity is carried out:	Make sure mixing proportions (water, emulsion, aggregate) are correct and the mixing is properly done. Make sure to spread asphalt to level of guide rails and with no waves in the completion surface. In any places where low spots become apparent, asphalt shall be used for filling the spots before commencing compaction. Make sure that compaction activities are assumed as soon as material has been spread and control passes of the rolling. Make sure compaction is uniform regarding	During carrying out the activity	NA

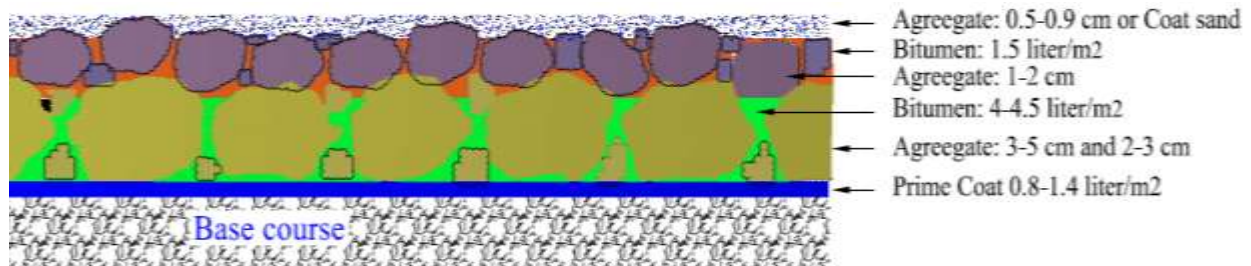
	rolling pattern and number of passes. Also ensure that there is always a lateral overlap of at least 20 cm from pass to pass		
Final check:	Make sure road surface is even and well compacted. Make sure all tools and equipment have been cleaned after using Make sure all guide rails have been removed and continuing use to other road sections Make sure exceeded material (aggregate and sand) have been hauled and reused to other uncompleted sections Make sure remaining asphalt on completed sections or road section to be sealed are cleaned.	On completion	NA

9.7. Technical Resources and Reference Materials for Coldmix Surfaced Roads

- Roading New Zealand Code of Practice (COP) BCA 9904 (NZPBCA2000)
- Manual for the labour-based construction of bituminous surfacings on low-volume roads, TRL, 2003
- ERA Bituminous LBT Training Manual and Surface Treatments Worksheets, 2015
- Manual 4 Bituminous Seals, Construction Industry Development Board (cidb), South Africa, March 2007
- Bituminous Sealing of Low Volume Roads using Labour Based Methods, Ethiopian Roads Authority Training Manual, June 2013
- AFCAP, Low Volume Rural Road Surfacing and Pavements A Guide to Good Practice, June 2013
- Overseas Unit, Transport Research Laboratory, 1993, Overseas Road Note 31, A guide to the structural design of bitumen surfaced roads in tropical and sub-tropical countries, Crowthorne, Berkshire, United Kingdom.

10. Penetration Macadam (Pen-Mac) Surfacing (PMP)

The penetration macadam pavement is commonly used as surface layer on roads worldwide. The work consists of providing bitumen stabilized aggregate over a new or repaired base course. The penetration macadam surface constitutes a consolidated layer thickness of 50 mm, obtained by two or three application of hot bitumen, alternated with three applications of aggregates.



Penetration Macadam surface is a surfacing option that is commonly used in Timor Leste. This type of surface is suitable for rural roads with higher traffic density and road sections with steep gradients. Bitumen for the Penetration Macadam can be cold emulsion or hot bitumen depending on local availability and price. Crushed aggregate is normally used because this material helps to generate a stable interlocking layer after it has been compacted. A heavy (6-8 Ton) roller should be used for compaction.

Based on experiences from Timor Leste and elsewhere the use of Penetration Macadam road construction methods can yield good and durable results for low to medium traffic rural roads. The construction of a penetration macadam surface can easily be done in rural areas, eg through communities, and is well suited to a labour-based approach. The labour-based approach and use of locally suitable materials create employment and income opportunities for rural communities. The technology has a number of advantages:

- ✚ Cheaper than normal asphalt construction technologies
- ✚ Work method is suited for Labour based approach
- ✚ Can use crushed stone which is manually produced, which could create significant employment opportunities.

10.1. Materials

The Penetration Macadam construction process is done in a number of different layers. Each layer of the Penetration Macadam consists of different sized aggregates and bitumen. The macadam layer can be spread using manual labour and hand tools. A completed Penetration Macadam surface layer is as a minimum 50 mm thick.

Aggregate

The quality of the coarse aggregate is the key to a good Penetration Macadam surface. The preferred material is crushed or broken stone. Angular stone is preferable as it provides better interlocking and a denser structure. The aggregate used for this surfacing layer consist of a particle size ranging from 5 mm to 50 mm. The normal source of the fine material is from the crushing process when producing the coarse aggregate. It is also possible to use natural sources of coat sand instead of crushed fine aggregate in the top layer of the surface. Clean crushed aggregate produced by hand knapping and screening can be used for the Penetration Macadam.

The aggregates for the Penetration Macadam layers shall consist of coarse aggregates. The required sizes are: 30-50 mm, 20-30 mm, 10-20 mm and 5-9 mm (or coat sand). Before commencing the work, the aggregates shall be delivered and stored separately to prevent mixing and shall be kept clean of foreign matters.

Bitumen: The bitumen binder shall be any one of the followings: Penetration grade bitumen 60-70 pen or 80-100 pen.

10.2. Work Method

The different sizes of crushed aggregate to be used for the penetration macadam surface shall be placed along the road in orderly arranged heaps.

Apply the first layer of crushed aggregate of sizes 30-50 mm, interlocked with aggregate in sizes 20-30 mm at an amount rate of about 80-100 kg/m² on the primed surface uniformly. Apply compaction immediately using an 6-8 tons steel wheel roller for 8-10 passes at a speed of not more than 3 km/h.

Spray heated bitumen on the compacted coarse aggregates. Application rate shall be 4.0 litres to 4.5 litres/m², applied as uniformly as possible, at the temperature stated in the specification.



While the first application of bituminous material is still warm and plastic, the second layer of aggregate of sizes 10-20 mm is spread uniformly at a rate of about 20 to 25 kg/m². Apply compaction immediately using a 6-8 tons roller for 8 - 10 passes at a speed of not more than 3 km/h.

The next layer of bitumen is to be sprayed at a rate of 1.5 litres / m² on top of the previous compacted aggregate layer at temperatures stated in the below table.

While the bituminous material is still warm and sticky, the third layer of fine aggregate or coat sand in sizes 5mm to 9mm (or aggregate chippings) shall be spread at a rate of about 8-10 kg/m². Apply compaction immediately using a 6-8 tons roller for 3-5 passes at a speed of not more than 3 km/h. The last passes shall make sure the final surface is smooth and even.

Table below provides summary of the material required for each layer of Penetration Madam and the required



temperature for heating bitumen.

Details of materials applied per square meter (m²) of Penetration Macadam surfacing

Type of Material	Penetration Macadam thickness 50-60mm
1 st Layer: coarse aggregates size 30-50mm interlocked with aggregate size 20-30mm	80-100 kg/m ²
1 st Layer: spraying bitumen	4 - 4.5 litres/ m ²
2 nd Layer: aggregates size 10-20mm	20-25 kg/m ²
2 nd Layer: spraying bitumen	1.0-20 litres/ m ²
3 rd Layer: aggregate size 5-9mm (or coat sand)	8-10 kg/m ²
Spraying Temperatures of bitumen: 150-200°C	

10.3. Hand Tools and Equipment

The types of tools and equipment that are essential for the construction of the Penetration Macadam surface when using a labour-based approach are listed below. The numbers of each item will depend upon the size of the construction project.

Manpower	Tools and Equipment
• 1 supervisor • 1 work gang for hauling and spreading aggregate • 1 heating bitumen workers • 1-2 hand spray bitumen operator • 2-4 workers for hauling heated bitumen • 1 roller operator.	• Brooms • String line, pegs • Wheel barrows • Steel pegs and string line, 5 m and 30 m measuring tapes • Bitumen tanker and distributor or bucket for spraying bitumen • Pickaxes. • Shovels • Hoes. • Rakes. • measuring can • Roller of minimum capacity 6 Tonns • Air compressor.



Aggregate layers – base, intermediate and surface



Rolling intermediate layer; applying penetration coat for surface layer

10.4. Quality Control for Construction of Prime Coat and Penetration Macadam

The construction of Prime coat and Penetration Macadam (Pen-Mac) activities include selection and test of material, heat and spray bitumen, spreading aggregate and compaction. Quality control and test for these works include checking the suitability of the material, grading of the material, check application rate of spraying bitumen and spread rate of aggregate of each layer. Some test can be carried out in the field and some test should be done in laboratory if required by a client.

Description/ work activity	Test/check method	When	Tools
Material for Prime coat and Pen-Mac			
Aggregate: Purity +grading	✓ Take a sample from a crusher for testing. ✓ Conduct grading tests of different sized aggregate: sieve analysis (refer to specification) ✓ Check on cleanliness: free from soil, dust, tree root, tree branch or leaves	Before procurement	LAB
Bitumen	✓ Check type (penetration grade) refer to specification ✓ Check if the storage area is leaking and	Before procurement	NA

	remedy immediately		
Kerosene for cutback	✓ Check quality of the kerosene for producing the cutback	Before procurement	NA
Construction of Prime coat and Pen-Mac			
Prime coat	✓ Check base course layer is compacted and clean ✓ Check pegs and string line every 10 m interval at both edges of the road to control area of spraying the prime coat ✓ Check heated temperature of bitumen (refer to specification) ✓ Check mixing rate of heated bitumen with kerosene (30-40% of kerosene) ✓ Check spraying rate (i.e. measure cutback use for road area covered).	During carrying out the activity	Thermometer
Pen-Mac	✓ Check peg and string line every 10 m interval at both edges of the road at area to cover the Pen-Mac ✓ Check quantities for the different sized aggregates for area of road to be treated ✓ Check quantity and specification of bitumen delivered ✓ Check the heating operation and bitumen sprayer are equipped with all safety controls ✓ Check safety equipment/clothing of workers	Before commencing the Pen-Mac activity.	Measuring tape
	✓ Check heating temperature of the bitumen as required (normally 150-200 °C) or refer to the specification. ✓ Check spreading rate for each layer of the heated bitumen i.e calculating the quantity of bitumen for area to be sprayed. ✓ Check the spread rate of crushed aggregate of each layer .i.e. calculating quantity of the aggregate for area to be covered. ✓ Check each layer of aggregate is spread evenly . ✓ Randomly count number of passes of compaction for each layer ✓ Ensure all three layers of the Pen-Mac are completed within a maximum of 2 to 3 days.	During carrying out the Pen-Mac activity	Measuring tape and thermometer

Final check	✓ Ensure all remaining material including empty bitumen drums are cleared from site ✓ Check area used for heating the bitumen is restored and any excavation for heating bitumen are filled and levelled	After completion of the work	NA
-------------	---	------------------------------	----

10.5. Technical Resources and Reference Materials for Penetration Macadam Surface Seals

- Roading New Zealand Code of Practice (COP) BCA 9904 (NZPBCA2000)
- Manual for the labour-based construction of bituminous surfacings on low-volume roads, TRL, 2003
- ERA Bituminous LBT Training Manual and Surface Treatments Worksheets, 2015
- Manual 4 Bituminous Seals, Construction Industry Development Board (cidb), South Africa, March 2007
- Bituminous Sealing of Low Volume Roads using Labour Based Methods, Ethiopian Roads Authority Training Manual, June 2013
- AFCAP, Low Volume Rural Road Surfacing and Pavements A Guide to Good Practice, June 2013
- Overseas Unit, Transport Research Laboratory, 1993, Overseas Road Note 31, A guide to the structural design of bitumen surfaced roads in tropical and sub-tropical countries, Crowthorne, Berkshire, United Kingdom.

11. Bitumen Emulsion Surface Treatment (ESP)

Bitumen emulsion surface dressings consist of a spray of bituminous emulsion binder followed by the application of a layer of aggregate or stone chippings. The binder acts as a waterproofing seal preventing entry of surface water into the road structure while the chippings protect this film from damage by vehicle tyres. Surface Dressings are also called Chip Seals or Surface Treatments in different countries.

Surface Dressings can be used for a number of purposes, including:

-  New construction (normally Double Surface Dressings only);
-  Temporary by-passes (normally Single Surface Dressings);
-  Maintenance resealing (normally Single Surface Dressing).

The bitumen emulsions can be applied under labour-based arrangements using motorised hand sprayers and hand spray cans, or under equipment based activities using bitumen tankers and spray bars. This training manual covers both methods of application.

11.1. Materials

The materials required for construction of Surface Dressings by labour based methods are:

-  Surfacing aggregate of the specified size (obtained from a commercial source/quarry)
-  Bituminous binder in the form of a bitumen emulsion, either Anionic spray grade emulsion RS60 or Cationic spray grade emulsion CRS 65 or CRS 70. Cationic emulsion is preferred because it has better flow properties (higher viscosity).

Aggregate Quality

The chippings must have a maximum Los Angeles Abrasion (LAA) value of 30 after 500 revolutions. The aggregate crushing value (ACV) is an indication of chipping strength and allowable values usually lie in the range of 20 to 35. Medium to heavily trafficked roads must have chippings with a maximum ACV of 20. On lightly trafficked roads it may be acceptable to have an ACV up to 35 but it is preferable to have chippings with a maximum ACV of 20.

Aggregate Size and Grading

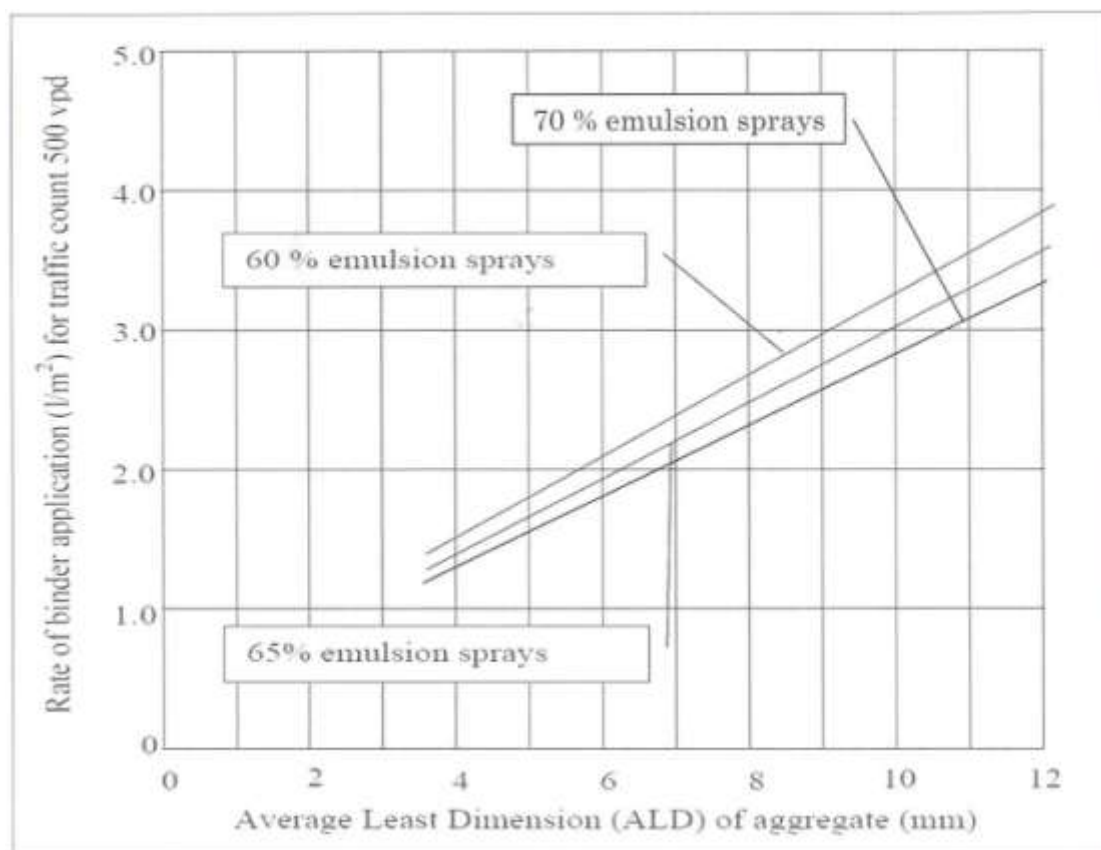
For a Double Surface Dressing typically 12 mm and 8 mm aggregates are used for the first and second layer respectively. The first chip coat shall be clean, hard, dry, tough, sound, crushed stone or crushed gravel of uniform quality free from dust, clay or organic matter. Nominal size of stone shall be 12 mm, 100% Passing 20 mm sieve and retained on 10 mm sieve. The aggregate for the second coat shall also be clean, hard, dry, tough, sound, crushed stone or crushed gravel of uniform quality free from dust, clay or organic matter. Nominal size of stone shall be 8 mm, 100% Passing 12.5 mm sieve and retained on 6.3 mm sieve.

The application rate for the aggregate shall be:

-  First layer: nominal stone size 12 mm at 0.015 m³ per m²;
-  Second layer: nominal stone size 8 mm 0.008 m³ per m².

Binder application rate

-  First layer: bitumen emulsion 1.2 to 1.4 kg per m²;
-  Second layer: bitumen emulsion 0.8 to 1.0 kg per m²;
-  Having determined the average least dimension (ALD) of the aggregates, the total binder application rate can be determined from the following graph.



Emulsion binder application rate

Source: Ethiopian Roads Authority Bituminous Sealing of Low Volume Roads using LB Methods

11.2. Hand-tools and Equipment

The following specialized plant and equipment is recommended for construction of Surface Dressings by labour based methods:

- ✚ Shovels;
- ✚ Brooms;
- ✚ Builders wheelbarrows;
- ✚ Hammer;
- ✚ 6mm rope, 2 x 50m rolls;
- ✚ Reinforced paper, 4 rolls x 1 metre wide;
- ✚ Steel pegs, 300mm x 9mm;
- ✚ Chalk line equipment;
- ✚ Steel tape, 5m and 50m;
- ✚ 5 x 25 litre measuring containers with lifting handle;
- ✚ 5 x 10 litre measuring containers;
- ✚ 105 litre drums with lifting handles for spotting aggregate;
- ✚ Motorized bitumen sprayer;
- ✚ Calibrated dip stick;
- ✚ 105 litre drums for checking spray rates and cleaning spray equipment;
- ✚ Spray screens;
- ✚ Drum lifter for lifting full drums of binder;
- ✚ Suitably sized roller, under 8 ton;
- ✚ Bitumen tanker and spray bar, and truck mounted aggregate spreaders for equipment-based approach.

11.3. Applying the First Coat

Because of the low viscosity of the emulsion (compared with a penetration bitumen) it is not possible to spray emulsion at more than $0.6 - 0.7 \text{ ltr/m}^2$ without the binder tending to flow (even on the “flattest” surfaces). Therefore, to overcome this problem, the tack coat is sprayed at $0.6 - 0.7 \text{ ltr/m}^2$, and the balance of the calculated tack coat application is applied as the penetration spray, where the aggregate will inhibit any untoward flow of the binder. The prime coat shall conform with Worksheet WS-17 in the LBT training manual.



Neat construction joint due to use of reinforced paper

11.4. Applying the Aggregates

The application of aggregate should follow close after the application of binder, but must only commence after approximately 4m of road has been sprayed to avoid aggregate falling on unsprayed road.

There are two methods of applying the aggregate:

-  Spotting of aggregate and spreading by hand;
-  Application of aggregate by mechanical chip spreader.

Spotting and spreading of aggregates Has been described previously. For manual application when placing the aggregates on the sprayed surface, a shovel of aggregate is taken and pitched into the air and in the process the shovel twisted rapidly. In so doing the chips are sprayed uniformly over the area to be covered and the stones will fall onto the wet tack coat while the dust, if any, will fall onto the top of the stone or, if there is a breeze, will be blown across the road away from the surface.



Spotting of aggregate

Once sufficient stones have been applied so that one can walk on the surface without coming into contact with the wet binder, the bare spaces are filled with additional aggregates. Gently broom the surface to distribute the aggregate uniformly.

11.5. Rolling

As soon as the surface has been covered with the aggregate without bare patches of binder showing, rolling, with a suitable 3-5 ton roller can commence. After the surface has been rolled once (i.e. a complete coverage of the roller) attention must be given again to covering bare patches. The first roll must be done without vibration but subsequent rolling, when the aggregate is properly placed with full coverage obtained, can be done with the intermediate vibration of the roller. The rolling carried out in straight lines parallel to the centre line or edges of the road. It is essential that rolling is uniformly done across the width of the road surface. Typically three passes should be sufficient to seat the aggregate.

11.6. Applying the Penetration Spray

The remainder of the bitumen emulsion that was not applied in the tack coat is now sprayed as a penetration spray. The same precautions regarding joints and protection of kerbs, drains and surface boxes etc. apply as was the case for the tack coat. It is recommended to apply the penetration spray within 24 hours. If the surface for some reason has been left open for any period before applying the penetration spray, the following must be attended to:

- ✚ Any dust, dirt or sand blown onto the surface voids must be removed/blown out with a compressor;
- ✚ The surface must be broomed and rolled once to reseal any aggregate that may have been unseated or disturbed by unauthorized traffic. No traffic should be allowed on this surface before the second layer of binder has been applied;
- ✚ After the application of the penetration spray, crusher dust or sand should be applied to prevent the roller and vehicles from picking up bitumen.

11.7. Constructing a Double Surface Dressing

Double surface dressings are robust and should be used when:

- ✚ A new road base is surface dressed;
- ✚ Extra 'cover' is required on an existing bituminous road surface because of its condition (e.g. when the surface is slightly cracked or patched);



There is a requirement to maximise durability and minimise the frequency of maintenance and resealing operations.

The quality of a double surface dressing will be greatly enhanced if traffic is allowed to run on the first dressing for a minimum period of 2-3 weeks before the second dressing is applied. This allows the chippings of the first dressing to adopt a stable interlocking mosaic which provides a firm foundation for the second dressing. However, traffic and animals may cause contamination of the surface with mud or soil during this period and this must be thoroughly swept off before the second dressing is applied. Such cleaning is sometimes difficult to achieve and the early application of the second seal to prevent such contamination may give a better result.

Applying the Second Spray

When a Double Surface Dressing is constructed it should be possible to apply sufficient binder in the second spray to give the required total rate of spray for the finished dressing since the first layer of aggregates will prevent run-off of the binder.

Applying the Second Layers of Aggregates

The same procedures are followed as for the first layer.

11.8. Weather Constraints

Spray applications should only be applied during the day and only in good weather conditions and when rain is not imminent. The road surface temperature should be above 10°C. Care should be taken when spraying on a windy day as the spray may be carried some distance and damage property or passing vehicles down-wind of the operation.

The rolling of a surface dressing plays an important part in ensuring the retention of the chippings by assisting in the initial orientation and bedding down of the chippings in the binder. Traditionally, steel-wheeled rollers have been used but these tend to crush weaker aggregates and to crack poorly shaped chippings.

Accordingly, if steel-wheeled rollers are used they should not exceed 8 tonnes in weight and should only be used on chippings which are strong enough. Some steel wheeled rollers are fitted with rubber sleeves which makes them more suitable for surface dressing work but, as for any roller of this type, they will 'bridge' depressions in the existing road surface. In general pneumatic tyred rollers are preferred because the tyres have a kneading action which tends to manoeuvre the chippings into a tight mosaic without splitting them and they do not 'bridge' depressions. In favourable conditions, adhesion should be well established within 30 minutes of rolling after which considerable benefit can be obtained by allowing slow moving traffic, particularly heavy lorries, to traverse the dressing provided that traffic speed is kept below 20 to 30 km/hr. This is very important and the use of a lead vehicle to 'convoy' traffic at slow speed is recommended.

12. Equipment-based Methods

12.1. Application of Bitumen Binder

Plan the work to provide for the construction of the seal on one side of the road at a time.

Check all spray nozzles are operating and delivering uniform application of bitumen. Mark out spray runs on road surface as a guide to the driver and place reinforced paper or sacrificial layer of chip on the road at the end of the spray run to provide a clean end to the seal run. Cover all surface boxes with weighed down reinforced paper or sacrificial chip (aggregate) that can be removed to expose surface boxes after the application of the seal coat. Check the spray bar and nozzles for uniform application prior to starting the spray run, and remove excess bitumen. Reinforced paper can be used for this purpose. Spray rate application can be checked using paper pads of a uniform size.



Even application all spray nozzles



Spray run marked with guide for driver

12.2. Application of Stone Chippings

Only dry stone chippings shall be used. Immediately after application of the binder, stone chippings shall be spread uniformly on the surface, by means of an approved aggregate spreader (see photo page 48), or manually so as to cover the surface completely. If necessary the surface shall be swept to ensure uniform spread of chippings. The chippings shall be spread when the emulsion breaks. Hand spreading requires the 'broadcasting' of the chip evenly onto the fresh bitumen emulsion surface.

Application can be checked by placing a paper pad or a steel tray of a known area under spreading run and then checking the quantity of chip placed over the pad or tray.



Stone chipping (aggregate) applied uniformly after bitumen spray



Mechanical spreader and speed of truck governs application

Rolling

Immediately after spreading the stone chippings the whole surface shall be rolled with either a smooth wheeled steel roller or a pneumatic tyred roller. While rolling is in progress additional chippings shall be spread by hand sufficient to correct any irregularities in the surface. Rolling shall continue until the stone chippings are firmly embedded in the bitumen and not easily removed by hand.



Sweep stone chippings or broadcast additional for even coverage



Roll with pneumatic tyre or smooth wheel tandem roller

Note test plate on ground



Rolling follows immediately after placement of stone chippings



Bitumen run about to start with placement of stone chipping and rolling immediately following application of bitumen binder

12.3. Application Rates for Bitumen Emulsion Seals – Equipment-based

General

This section includes procedures for sampling and site control of all work where bituminous distributors are in use, i.e. surface treatments, tack coat, prime, fog spray and work with related aggregates for these seals.

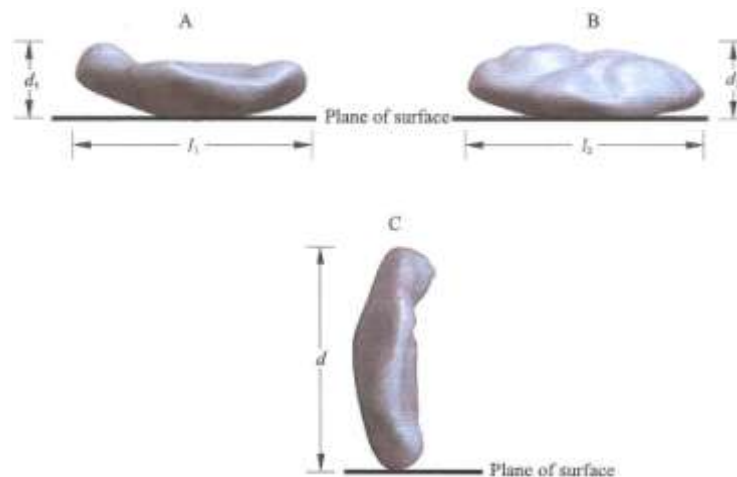
Average Least Dimension (ALD)

This expression is used as one of the characteristics for stone (aggregate) used in bituminous seals for surfacing e.g. single seal, double seal, etc., and is of importance when determining the rate at which the aggregate must be spread to prevent over or under application of the aggregate, and in determining the appropriate application rate for the bitumen emulsion binder..

The ALD can be described as follows:

Any particle of aggregate that is not perfect in shape i.e. a 19 mm aggregate is not 19 mm in all directions, it has long and short sides. If dropped on a surface it will always fall on the surface with its smallest dimension vertical to the plane of the surface.

It does not matter what the shape of the particle of aggregate is, it will always fall on the road with d_1 and d_2 (see following figure) i.e. the least or smallest dimension vertical to the road surface; e.g. a sample, if dropped in the road, will never come to rest on the road in this position where (d) the maximum dimension is vertical to the road surface.



ALD of aggregate

Rate of Application

The rate of application of a product or material is the amount of that material or product applied over a certain area. Examples of rates of application are:

Activity	Unit
Spraying of bituminous binder or emulsion	Litres per square metre (l/m^2)
Spreading of aggregate for surfacing	Cubic metres per square metre (m^3/m^2)

Unit rates of application

12.4. Application Rate (Binder, Tack Coat, Prime and Fog Spray)

General

Control of application rates of bituminous binders requires knowledge about the specified application rates and sometimes the relationship between weight, volume and temperature of the sprayed material. Bituminous materials change their density as a function of temperature and it is important to clarify whether the aimed application rate is by weight in kg per area, or whether it is a volume measure in litres per area.



The spray bar shall be tested before start and sprayed binder shall be removed.

It is important to obtain field testing results that are either directly comparable with the aimed spray rates, or to make sure that reliable conversion factors are applied to ensure comparability between the specified application rates.

Site Measurement by Volume (Dipstick)

Measurement by DIPSTICK gives the application rate in VOLUME AT SPRAYING TEMPERATURE and is the most convenient and reliable method for site control. Measurement by dipstick has a further advantage in that it gives a measure of consumed material and eliminates any temptation to under-apply binder and compensate for this by manually adjusting the spray rate where sample plates are placed. Sample plates, usually non-porous pads of a known area of say 300 mm x 300 mm are placed under the spray run to provide a measure of the application rate relative to area and can be interpolated to a kg/m^2 measure.

Site Measurement by Weight (Sample Plates)

Measurement BY SAMPLE PLATES gives the application rate in MASS AT ANY TEMPERATURE. This method has to be employed where the contractor cannot produce certificates of reliable calibration of his spraying equipment. A sample plate measurement in kg/m^2 is used directly without correction.

Aggregate Spread Rate

The aggregate spread rate should be inspected visually when a new aggregate type or size starts to be used. Measurement of aggregate spread rate for site control should as a rule be carried out by the quantity consumed and spread on the road surface by visual inspection unless there are cases of dispute which requires specific measurement. Commonly there is experience of over-application of aggregate by the site staff rather than the opposite. Site measurement of spread rate for starting up and special control is best carried out with a plate of known area and weighing of aggregate that covers the plate. Proprietary trays can be used. Aggregate spread rate is commonly specified and paid for by volume and this method requires that a reliable bulk density of the aggregate is applied in the

calculations following weighing of the sample plates.



Application of aggregate



Useful equipment can be obtained for control of aggregate spread rate.

Source: TANROADS Field Testing Manual

Equipment Control and Calibration

All equipment used for the work with bituminous materials shall be checked and calibrated. The status on calibration of tank and dipstick of bitumen distributors will determine whether the site control can be undertaken by volume measurements with dipstick or whether control by sample plates on the road has to be undertaken.

12.5. Quality Control for Construction of Bitumen Emulsion Seals

The construction of tack coat and second emulsion layer require selection and testing of material, and the application rates of the binders and aggregates. Quality control and testing includes checking the suitability of the materials, grading of the aggregates, checking the application rates of the bitumen emulsion layers and the spread rate of aggregates of each layer. Some test can be carried out in the

field and some test should be done in laboratory if required by a client.

<i>Description/ Work Activity</i>	<i>Test/Check Method</i>	<i>When</i>	<i>Tools</i>
Construction of Bitumen Emulsion Seal Coats			
Before activity is carried out	✓ Check setting out, pegs and string line every 10 m interval at both edges of the road to control area of spraying the prime coat ✓ Check the grade of emulsion against the specification ✓ Check spraying rate for first (tack/prime) and second layers, and application rate, i.e. calculate emulsion use for road area covered. ✓ Check aggregate size and grading for first and second layers, and application rate, i.e. calculate quantity for road area to be sealed. ✓ Check delivery of bitumen emulsion and sealing aggregates. ✓ Make sure basecourse layer is compacted, clean and levelled.	Before commencing the activity	NA
While activity is carried out	✓ Check heating temperature of emulsion, if specified. ✓ Check application rate for each layer of the emulsion binder, i.e calculating the quantity of emulsion compared to area to be sprayed. ✓ Check the spread rate of each layer of sealing aggregate, .i.e. calculating quantity of the aggregate compared to area to be covered. ✓ Check the aggregate of each layer is spread uniformly. ✓ Check actual application rate of bitumen binder, and application rate of aggregates using test pads (plates) and measuring weight and calculation application against specified rates. Adjust application rates as necessary. ✓ Randomly count number of passes of compaction for each layer ✓ Ensure the two layers of the bitumen emulsion seal are completed within a maximum of 15 days.	During carrying out the bitumen emulsion seal layers	Measuring tape, scales and thermometer
Final check	✓ Check all remaining materials including empty bitumen drums are cleared from site	After completion of	NA

	✓ Make sure road surface is even and well compacted. ✓ Ensure all tools and equipment are cleaned after use. ✓ Ensure the work site is clean and free of debris.	the work	
--	--	----------	--

12.6. Technical Resources and Reference Materials for Bitumen Emulsion Surface Seals

- Roading New Zealand Code of Practice (COP) BCA 9904 (NZPBCA2000)
- Manual for the labour-based construction of bituminous surfaces on low-volume roads, TRL, 2003
- ERA Bituminous LBT Training Manual and Surface Treatments Worksheets, 2015
- Manual 4 Bituminous Seals, Construction Industry Development Board (cidb), South Africa, March 2007
- Bituminous Sealing of Low Volume Roads using Labour Based Methods, Ethiopian Roads Authority Training Manual, June 2013
- AFCAP, Low Volume Rural Road Surfacing and Pavements A Guide to Good Practice, June 2013
- Overseas Unit, Transport Research Laboratory, 1993, Overseas Road Note 31, A guide to the structural design of bitumen surfaced roads in tropical and sub-tropical countries, Crowthorne, Berkshire, United Kingdom.

ERA Enhancing Rural Access	WORK SHEET
Item: Safety in Working with Hot Bitumen, Solvents and Aggregates	WS-OSH Bit
Specification: Hazards and safety issues associated with the handling of hot bitumen, dusty aggregates, solvents and site safety requirements.	
Safety in the pavement sealing industry All people working with hot bitumen need to familiarise themselves with the safety requirements demanded by the hazards encountered when handling sealing materials and carrying out sealing operations. Hazards include burns, steam scalds, explosions and fire, fire fighting, toxic fumes, asphyxiation, handling flammable and corrosive materials and work site operations. This manual summarises the main safety points of the Roding New Zealand⁶ Code of Practice BCA 9904 (NZ PBCA 2000). Employers have a duty to ensure that their employees are either sufficiently trained and experienced to do their work safely or supervised by a trained and experienced person. In addition employees must be adequately trained in the safe use of equipment in their place of work, including use of protective clothing. Inexperienced individuals, regardless of position, must take advice from trained and experienced operators until they have received the appropriate level of training. Employers should arrange such training including courses on safety and first aid. The following minimum practical requirements for working with bitumen will involve: • The issue of protective clothing; boots, gloves, overalls, etc. to the workers is essential;	 Protective Clothing  Bitumen fires can be very violent The temperatures at which heated bituminous

⁶ NZ PBCA (NZ Pavement & Bitumen Contractors' Association) is now Roding New Zealand as from 26/06/2004. However, as COP BCA 9904 was published in 2000 by the then PBCA, it keeps its original publication number.

- The use of diesoline by workers to clean hands, arms and tools, when working with bitumen, must be discouraged – the use of paraffin (kerosene) is preferable;
- A properly equipped first aid kit must be available at all times;
- No children must be allowed on the construction site;
- Fire extinguishers (smothering foam powder or CO²) and in good working order must be available especially when working with hot bitumen binders.

Legal requirements

Designs and specifications must be compatible with safe practices in the bitumen sealing work place and operations, and comply with Timor-Leste Occupational Health and Safety requirements.

Hazards to health from bitumen sealing materials

Some of the materials used in bitumen sealing can present hazards to health if they are handled incorrectly. Be familiar with material safety data sheet for bitumen (attached to training manual single bitumen surface treatment (SBST) and double bitumen treatment surface treatment (DBST) testing.

Fire

The normal spraying temperature of a bitumen binder is in the range of 140°C–170°C, depending on the type of bitumen and amount of diluents in it. Straight-run bitumen at these normal spraying temperatures is below its flash point (i.e. 240°C–320°C) and is relatively safe. However, binders containing kerosene or AGO (automotive gas oil or diesel) have spraying temperatures above the flash points of these diluents and are therefore hazardous.

Explosions

Explosions associated with sealing works cause injury and significant damage. The industry has set procedures to avoid situations that will cause explosions.

Explosions caused by Vapour in Confined Spaces

Cutback binders give off vapours at temperatures lower than their flash points. These vapours build up in confined spaces such as the bitumen tanker. All sources of ignition, including obvious sources

binders will catch fire are useful to know:

Flash Point – the lowest temperature at which a flammable liquid gives off enough vapour to flash momentarily when a small flame is applied. For bitumen it is 240°C–320°C, and for kerosene 43°C–48°C.

Ignition Point – the temperature at which a solid, liquid or gas will take fire and continue to burn. The ignition points for bitumen are 500°C, and for kerosene 255°C.



Bitumen Burn Card (Front)

Source NZ PBCA (now Roadking NZ), 2001

Burn hazards

In the road industry burns can be caused by hot bitumen. Burns can also be caused when bare skin or flammable clothing come in contact with the hot surfaces of spraying equipment. Scalds (burns from moist heat) can be caused by steam or foam flashing off if water comes into contact with hot bitumen.

Treat these burns and scalds by pouring cold water over the burnt or scalded area immediately. Continue for at least 10-15 minutes or longer until pain subsides, and get the victim to medical treatment.

As binder is usually sprayed at temperatures between 150°C and 200°C, contact with it at

such as matches and lighters, and less obvious sources such as torches, transistor radios, steel boot caps and hob nail boots must be kept at least 1.5 m away. Areas of reseal operations must therefore be no-smoking zones for safety reasons, and ideally should be 'smoke-free'.

Explosions caused by Water in Binder

Other potentially explosive situations can occur by the introduction of water to a hot binder. Because water expands approximately 1500 times in volume when converted to steam, even a small amount of water introduced into a binder that is hotter than 100°C can result in a dangerously violent foaming eruption.

Water should be kept away from resealing activities and bulk bitumen should be free of water.

Extinguishing bitumen fires

NEVER USE A WATER JET! Bitumen fires must be extinguished by smothering so that the continued supply of oxygen can be prevented. Small fires can be put out with a blanket of foam, dry powder or carbon dioxide extinguishers.

Hazards to health from bitumen operations

Bitumen sealing work can be hazardous and, according employers must take steps wherever practicable to eliminate the hazard, or if that is not practicable to isolate the hazard, or if both these actions are impracticable to minimise the hazard to employees.

The following stages of pavement sealing present the most hazards:

- Filling tanks with cutback binders (i.e. binder containing kerosene);
- Emptying tanks of binders;
- Blending binders;
- Venting tanks, working around tank vents and hatches;
- Using spray bars;
- Heating binders using flame tubes, electric elements, with potential for spot heating;
- Accidental mixing of water with binders.

Distributor Tankers

When hot binders are delivered to site in distributor tankers below spraying temperature; burners (open flame) will be used for heating the

these temperatures causes very severe burns.

BURNS CAUSED BY BITUMEN REQUIRE SPECIALIST MEDICAL TREATMENT	
1. SKIN BURNS	
1.1	In the event of hot bitumen contacting the skin, no immediate attempt should be made to remove the bitumen. (Except after admission to hospital and only at the direction of the burns specialist.)
1.2	The burn area should be drenched in cold running water or preferably, placed in a basin of cold water to which ice cubes have been added.
1.3	In the case of burns to the head and neck, shoulder, chest, abdomen or back, cold wet towels, which are kept in a bucket of cold water (preferably iced), should be applied to the burn area.
1.4	The ice water treatment should be continued until pain no longer occurs when the burn area is removed from water. This time required is seldom less than 30 minutes.
1.5	Where possible the burned area should be continually wet until advanced medical aid is reached.
1.6	Remove any restricting rings, belts etc., and handle the patient gently to prevent further injury.
1.7	Cover any exposed burns, i.e. areas not covered by protective layer of bitumen or clothing with sterile dry dressings and lightly bandage to exclude the air. Keep the patient warm but avoid letting blankets touch burns or blisters.
1.8	If there are burns to the head or face ensure that the airways for breathing are kept clear.
1.9	Do not apply lotions or ointments.
1.10	Do not pick blisters.
2. BURNS ENCIRCLING ANY PART OF THE BODY	
2.1	When a hot hard grade of bitumen completely encircles the limb it is theoretically possible for there to be a tourniquet effect as the bitumen cools. This will diminish blood circulation in the limb – a potentially serious medical emergency.
2.2	In such a case, elevating the limb will normally reduce the swelling enough to allow satisfactory circulation. If it does not and advanced medical care is more than 20 minutes away it could become essential to attempt to release the tightening effects of the cooling bitumen by carefully splitting the bitumen from the top to the bottom using a heavy pair of scissors. Extreme caution must be taken during this procedure to ensure no damage is caused to the underlying skin. Toes and fingers require individual attention.
3. EYE BURNS	
3.1	The eye must immediately be flushed with cold water. This should be continued for 20 minutes by pouring water, or if available, sterile saline or eye irrigation solution gently over the open eye and away from the unaffected eye.
3.2	The cooling process will be most beneficial if it can be done at the same time as the casualty is being transported to hospital.
3.3	No attempt should be made by untrained personnel to remove the bitumen.
3.4	If the eye needs to be covered with a dressing, apply a sterile eye pad. Stay close, reassure and support the casualty while travelling to seek medical care.
4. FURTHER TREATMENT	
4.1	No attempt should be made to remove the bitumen which in itself supplies a sterile dressing to the underlying burned areas of skin.
4.2	The bitumen is covered with tube gas dressings and left for two days after which time any bitumen that can be easily removed (that is bitumen that has detached from the live dermis) is removed. The remaining burned area to which bitumen adheres is recovered with sterile tube gas dressings and left for a further week.
4.3	The appearance of the burns when the dressings are first taken off, together with the body surface area involved and the general condition of the patient will decide when removal to a specialised Burns Unit is indicated. Certainly any forced removal of bitumen should only be undertaken in a specially equipped Burns Unit.
5. BITUMEN REMOVAL	
5.1	If for special reasons it becomes necessary to remove bitumen use peanut oil (arachis oil).
6. SPECIALIST BURNS UNIT(s) (Provide details and contact numbers for local specialised Burns Units)	

Bitumen Burn Card (Reverse)

Source NZ PBCA (now Rooding NZ), 2001

Binder sticks to the skin and the heat continues to burn the victim, but the binder must be left in place because removing it will cause far greater damage. Because it traps heat, keep cooling the binder by pouring cold water all over the area for at least 10-15 minutes. Treat as for other burns and for shock.

Because bitumen sticks to the skin, special first aid procedures are required beyond that usually covered in basic first aid courses. The industry in New Zealand, in conjunction with specialist Burns Units, developed procedures for treatment. It has published, in its Bitumen Safety Book (NZ PBCA 2001), the yellow Bitumen Burns Card which outlined the correct treatment of bitumen burns.

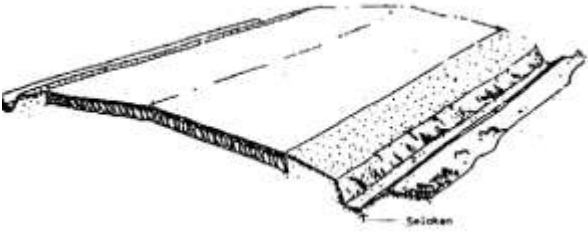
In the instance of a burn, the card is attached to the victim with string through the eyelets on the card to make sure that doctors are aware of these procedures when they receive the burn patient for treatment. A person must accompany the patient to ensure that the treating doctor is aware of the card, and that he/she reads it before beginning treatment.

binders to the required temperature for spraying and there will be fire risks. Therefore, it is advisable to check that binder supplier's tanker trucks are equipped with fire extinguishers. Heating spray bars with open flames, to rectify blocked jets, is also a fire hazard. Emulsion Drums When heating drums of emulsion on site to raise the temperature (although to a much lower temperature than hot penetration bitumen binders), it is essential to stir the binder while heating, to avoid overheating the binder in contact with the base of the drum. This will cause the binder to generate steam, resulting in the binder frothing and boiling over. A person must be in charge of the heating of the drum at all times and should continuously stir the contents in the drum.		Also dial the emergency number to alert the Accident and Emergency ward at the hospital of the specialised nature of the accident.							
Manpower: • Supervisor as site safety personnel • Trained and knowledgeable workers aware of hazards from hot bitumen and bitumen related products and work activities.		Tools + Equipment: • Appropriately worded burn cards for Timor-Leste. • Adequate supply of clean water. • Personal safety equipment; overalls, gumboots, gloves, visors/safety glasses. • Safety day-glow vests for teams working on roads. • Hand cleaning solvents (or paraffin (kerosene) • Fire extinguishers (dry powder or CO²).		Material: • None					
Quality Control: <table><tr><td>Before activity is carried out:</td><td> ✓ Understanding of the risks and management of the work site to avoid the risks? ✓ Brief work site personnel on the risks and safety requirement, and emergency actions in the case of burns or scalds? ✓ Ensure burn cards for Timor-Leste are available in the Tetum language? </td></tr><tr><td>While activity is carried out:</td><td> ✓ Management the work site to avoid risk to workers and the public. Ensure availability of fire extinguishers with supplier's tanker, or provided by contractor. ✓ Ensure workers have required safety clothing and equipment and that no-smoking requirement is observed. ✓ Keep children and public away from work site and vicinity of bitumen spraying and associated plant. </td></tr></table>						Before activity is carried out:	✓ Understanding of the risks and management of the work site to avoid the risks? ✓ Brief work site personnel on the risks and safety requirement, and emergency actions in the case of burns or scalds? ✓ Ensure burn cards for Timor-Leste are available in the Tetum language?	While activity is carried out:	✓ Management the work site to avoid risk to workers and the public. Ensure availability of fire extinguishers with supplier's tanker, or provided by contractor. ✓ Ensure workers have required safety clothing and equipment and that no-smoking requirement is observed. ✓ Keep children and public away from work site and vicinity of bitumen spraying and associated plant.
Before activity is carried out:	✓ Understanding of the risks and management of the work site to avoid the risks? ✓ Brief work site personnel on the risks and safety requirement, and emergency actions in the case of burns or scalds? ✓ Ensure burn cards for Timor-Leste are available in the Tetum language?								
While activity is carried out:	✓ Management the work site to avoid risk to workers and the public. Ensure availability of fire extinguishers with supplier's tanker, or provided by contractor. ✓ Ensure workers have required safety clothing and equipment and that no-smoking requirement is observed. ✓ Keep children and public away from work site and vicinity of bitumen spraying and associated plant.								

Final check:

- ✓ Review work and safety measures throughout the bitumen application and seal work.
- ✓ Stop work if a risk is evident and adjust the site management and safety precautions
- ✓ Hold debriefing to review safety precautions following completion of work.

ERA Enhancing Rural Access	WORK SHEET
Item: Asphalt Sand Sheet "LATASIR"	WS-HMP
Specification: Asphalt Sand Sheet (LATASIR) is a wearing course asphalt mixture composed of continuously graded natural sand and asphalt materials mixed either in a central plant or at the works site. The works consists of spreading and compaction of the asphalt mixture at a certain temperature on a prepared base surface in accordance with the specifications given in drawings & technical descriptions.	
Work Method: • Setting out pegs and string at road edges and centre line in 10 m intervals. • The sand sheet mixtures can be produced in Asphalt Mixing Plant or manually using simple equipment such as steel pan and shovel. Although, it is of greatest importance to insure that the correct temperature of the mix according to specification is achieved. • Sand and bitumen shall be measured before mixing to ensure proper proportions of mixture. The proportion of bitumen in relation to sand shall be 7 % to 11 %. • Aggregate/ sand shall be heated separately to the temperature as specified in the specification. After this is done, mix the heated sand and bitumen. • The correct hauling technique of the mixed material from central plant to the location where it should be spread is of great importance. Truck with metal container shall be used for hauling long distance. The container shall be clean, syringed with soap-water, fuel, paraffin oil or lime-water. For short distances of less than 200m, wheel barrow can be used for the transportation. • During transporting, the container shall be covered with canvas for weather protection, keeping the mix from losing temperature, and also preventing the mix from getting contaminated by waste material. • Spreading shall be started from the point furthest away from the asphalt mixing unit and ended at the nearest point. • The asphalt mixture shall be spread in adequate and uniform thickness in accordance with the specification. To apply uniform thickness, timber formwork shall be used at road centre	Legend: Pasir = sand; Kotak Takaran = Batching box; Filler Semen (Apabila perlu) = Cement filler (if necessary); Kalena Kapasitas = can of indicated capacity; Pang Penggorengan Aspal = Asphalt heating pan; Aspal dipanaskan = heated asphalt to indicated temperature

line and road edges. • The mixtures shall be spread at minimum temperature of 120°C. • Compaction shall be applied immediately after the spreading activity using pneumatic or steel wheeled roller. Watering during the compaction shall be provided until compaction is finished.		
		
Manpower: • 1 Supervisor (part time) • 2 part time workers for setting out set pegs and tie string • Work gang mixing the sand asphalt • Work gang to spread the mixed sand and asphalt to the designed level and thickness.	Tools + Equipment: • Tape Measures, 30 m and 5m • String line • Timber formwork • Asphalt frying pan or asphalt mixing plant • Spreader • Baskets • Wheel barrow • Pneumatic roller. • Bitumen thermometer • High visibility vests and protective clothing • First aid kit.	Material: • Sand • Bitumen • Fire wood.

Quality Control:	
Before activity is carried out:	✓ Check if setting out is done correctly? ✓ Check pegs and string line placed correctly? ✓ Check if camber board used? ✓ Check that all OSH procedures are known and in place ✓ Check the road longitudinal level (from one edge to edge) conforms with proper camber during compaction. ✓ Check that sand of correct properties& course is used, and that aggregate/ coat sand is free from dust, dirt and clay.
✓ While activity is carried out:	✓ Check use the correct type of bitumen. ✓ Re-check all OSH measures are in place ✓ Check the right mixing proportions of sand/ bitumen are used. ✓ Check the bitumen and is heated individually to correct temperature as specified. ✓ Check that the mix temperature is according to specification. ✓ Check the asphalt sand sheet layer thickness is uniform. ✓ Check the mixing time is not too long as it leads to separation of materials. ✓ Check heated bitumen is used after 1 day.
Final check:	✓ Make sure road surface is even and well compacted.

ERA Enhancing Rural Access	WORK SHEET
Item: Cold Mix Asphalt (Manual Mixing of Asphalt)	WS-CMP1
Specification: Cold mix asphalt seal is a premix seal of bituminous emulsion and continuous sizes of graded aggregates. The work comprises mixing of the cold mix, hauling and placing the asphalt mix, spreading on a bituminous emulsion tack coat applied at the predetermined application rate, and compaction. The mixing of the asphalt shall occur in accordance to mixing proportions determined by engineer and specified in the specification. The aggregates shall be free of dust and organic material. Mixing of the asphalt cold mix can be done by concrete mixer or in situ manually. This work sheet demonstrates mixing of the asphalt cold mix manually.	
Work Method - Place guide rails (20mm x 20mm steel box sections) along the road edges and road centre line and at the quarter points of the road. Check the accuracy of the level of the guide rails; where lower than 20mm it should be adjusted with extra asphalt or aggregate to achieve the same level. - Apply tack coat using bituminous emulsion of 60% CSS 1s. The emulsion shall be diluted with water at the ration of 1:1. Use a watering can and broom for tack coating between the guide rails. Application rate of the tack coat should be 0.6-0.7 litre/m². <u>Placing mixing pans and aggregates:</u> - The mixing pans should be placed in situ where spacing from one to other should be calculated based on the required volume of asphalt to be placed. The mixing pans are moved continuously forward after discharging the mixed asphalt. Aggregate for the mixing can be deposited on a completed the road section nearest to the road section to be sealed. <u>Mixing the cold mix asphalt:</u> - Use measuring cans and add correct predetermined amount of aggregate to the mixing pans. Size of the aggregate shall be applied as per grading envelope and approved by engineer before being added to the mixing pan. Apply water lightly at an amount of 1% of mass of aggregate and mix thoroughly. - Pour bituminous emulsion of 65% CMS 2h (company code: E-71) on the heap of wet aggregate in the pans at the correct pre-	

determined amount. Usually, the proportion of bituminous emulsion should be 8.5-9.5% of the mass of the asphalt mix.

- Start mixing manually immediately by using proper hand tools like spreaders or hoes and shovels. The mixing shall be done continuously until all parts of the mix are covered by bitumen.
- Immediate after the mixing, the mixed asphalt shall be discharged directly from the mixing pans onto the tack coated road base at middle point between the two guide rails.
- After discharging the asphalt from the mixing pans, the mixing pans will then be moved to other unsealed sections and continue the sequence of the mixing process.
- Spreading shall be commenced immediately after the asphalt has been discharged from the mixing pans. The spreading commences from heap of the asphalt toward guide rails. Ensuring the spread level of the asphalt is the same as the level of the guide rails. The area adjacent to the guide rails is to be filled by asphalt. Screeding will follow the spreading to ensure level of the spread asphalt is as smooth as possible.
- Once the screeding has been completed, the guide rails shall be removed to allow compaction. Rolling can then commence with at a slow speed of less than 5 km per hour using a 3-5 tons tandem steel wheel roller. Wet the wheels of the roller before commencing the compaction to avoid asphalt sticking to the wheels. Compaction should be carried out for 6-8 passes. It is recommended that, rolling of first 2 passes should be done in static mode. Vibrating mode can started from the 3rd pass until completed

Cleaning the equipment:

- All hand tools used for spreading the asphalt should be continuously cleaned using kerosene.
- The mixing pans shall be cleaned for every 2-3 mixes to avoid asphalt sticking in the pans. The pans can be cleaned using a shovel to remove the remaining asphalt.



		
Manpower: • 1 supervisor (part time) • 1 tack coating worker (part time) • 1 part time worker for setting out guide rails. • 1 work gang for hauling crushed aggregate and measure for mixing (size of the gang depend on demand progress of work) • 1-2 workers for each mixing pens • 1 work gang for spreading and screeding asphalt (size of the gang depend on demand progress of work) • 1 roller operator.	Tools + Equipment: • Tape Measures, 30 m and 5m • Guide rails (steel hollow box 20mm x 20mm) • Hammers • Nails • Hand broom • Spreaders • Buckets • Wheel barrows • Roller. • Shovels • Mixing pans • steel box (steel hollow box 30mmx30mm) for screeding • Measuring cans • High visibility vests and protective clothing • First aid kit.	Material: • Bituminous Emulsion bituminous for tack coat 60% CSS 1s • Bituminous for asphalt 65% CMS 2 h (company code E-71) • Kerosene • Crushed Aggregates.
Quality Control: Before activity is carried out: ✓ Check if the equipment: mixing pans and hand tools are in good condition ✓ Check guide rails are in placed correctly. ✓ Check aggregates are clean. ✓ Check using the correct type/spec of bituminous emulsion. ✓ Check temperature of the emulsion is in rang of 45-60°C ✓ Check all OSH measures are in place While activity is carried out: ✓ Check the mixing proportions (water, emulsion, aggregate) are correct and the mixing is properly done. ✓ Check the asphalt is correctly spread to level of guide rails and with no waves in the completion surface. In any places where low spots become apparent, asphalt shall be used for filling the spots before commencing compaction. ✓ Check compaction activities are carried out as soon as the material has been spread ✓ Control passes of the roller. ✓ Check compaction is uniform regarding rolling pattern and number of passes. ✓ Ensure that there is always a lateral overlap of at least 20 cm from pass to pass		

Final check – after construction:	✓ Check road surface is even and well compacted. ✓ Check all tools and equipment have been cleaned after using ✓ Check all guide rails have been removed and continuing use to other road sections ✓ Check surplus aggregate and sand have been hauled for reuse on other uncompleted sections ✓ Remove and dispose of any surplus asphalt ✓ Leave worksite in safe and properly restored condition
-----------------------------------	---

ERA Enhancing Rural Access	WORK SHEET
Item: Cold Mix Asphalt (Using Concrete Mixer)	WS-CMP2
Specification: Cold mix asphalt seal is a premix seal of bituminous emulsion and continue size of graded aggregate. The work comprises mixing of the cold mix, hauling and placing the asphalt, spreading on a bituminous emulsion tack coat at the predetermined application rate and compaction. The mixing of the asphalt shall comply with the mixing proportions determined by the engineer and specified in the specification. The aggregates shall be free of dust and organic material. Mixing of the asphalt cold mix can be done by concrete mixer or in situ manually. This work sheet is demonstrates mixing of the asphalt using a concrete mixer.	
Work Method: - Place the guide rails (20mm x 20mm steel box sections) along road edges and road centre line and the quarter points of the road. Check the accuracy of the level of the guide rails; where lower than 20mm the level difference should be accommodated with extra asphalt to achieve same level. - Apply tack coat using bituminous emulsion of 60% CSS 1 s. The emulsion shall be diluted with water of a composition 1:1. Use watering can and broom for tack coating between the guide rails. The application rate of the tack coat should be 0.6-0.7 litre/m². <u>Placing mixture and aggregate:</u> - The area for the concrete mixer stand should be at the shoulder where there is space available. The mixer should be as close as possible to the pouring point to avoid longer hauling of the asphalt that has been mixed. Aggregate for the mix should be deposited close to the mixer. Use buckets of known volume for measuring aggregate for mixing. <u>Mixing the cold mix asphalt:</u> - Use measuring cans to add correct amounts of aggregate to the mixer while the mixing drum is operating. The proportions of the mix shall be determined by the engineer or as specified in the technical specification. Water is then added slowly to the drum and mixing continued until the aggregate is thoroughly dampened. The amount of the water should be 1% of the mass of the aggregate. - Add bituminous emulsion 65% CMS 2h (company	

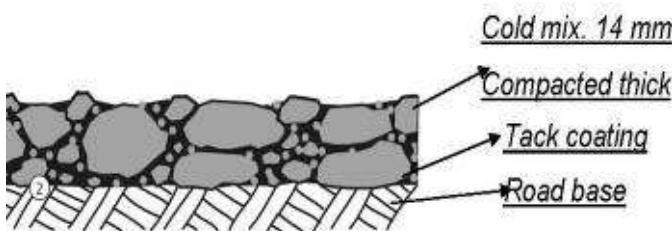
code: E-71) slowly pour into the drum continuously while the mixer is operating. Continue operating the mixer until the all parts of aggregates are covered by the bitumen. The mixer should be operated as slowly as possible. The drum should be tilted so that the position is between the vertical and horizontal. Composition of the aggregate and emulsion shall be predetermined by the engineer or specified in the technical specification. Usually, the proportion of bituminous emulsion should be 8.5-9.5% of the mass of the asphalt.

Note: The aggregate being mixed must be maintained below 1/3 of the volume of the mixer drum.

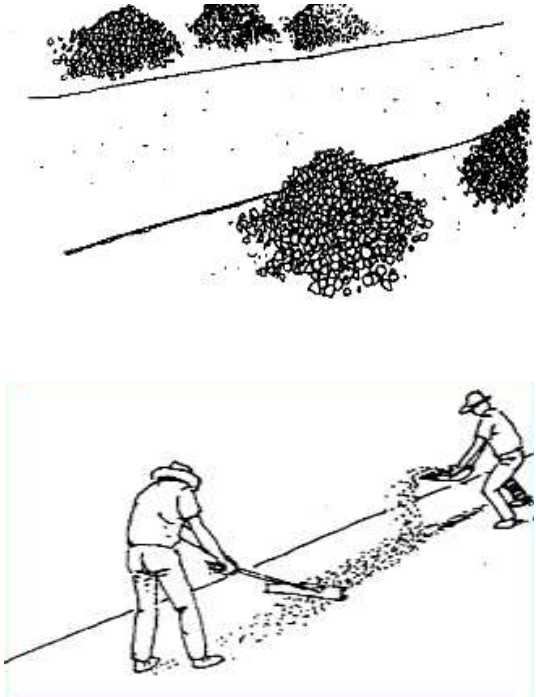
- Immediate after the mixing, the asphalt should be discharged to wheel barrows and hauled to the prepared road base which has been tack coated and is ready for spreading. Wheelbarrows should not be loaded more than half of its capacity. The hauling distance when using wheel barrows should not be more than 200m.
- Space for unloading the asphalt from sequential wheelbarrows should be known and marked before unloading the asphalt. The spacing should be calculated base on quantity of the mixed asphalt in each wheel barrow and the thickness and width of the asphalt area to be covered. The asphalt should be unloaded in middle between the two guide rails.
- Spreading shall be commenced immediately after unloading the asphalt from the wheel barrows. The spreading commenced from heap of the asphalt toward the guide rails. Ensure the spreading level of the asphalt occurs at the same level of the guide rails. The area adjacent to the guide rails is to be filled by asphalt. Screeding will follow the spreading to ensure level of the spread asphalt is as smooth as possible.
- Once the screeding has been completed, the guide rails shall be removed to allow commencing of compaction. Rolling with a 3-5 tons roller can then commence at a low speed of less than 5 km per hour. The wheel of the roller shall be wet with water to avoid sticky by asphalt. Compaction should be carried out for 6-8 passes. It is recommended that, rolling of first 2 passes should be done in static mod. Vibrating mod can be started from 3 pass until completed.

Cleaning equipment:



• All hand tools for spreading the asphalt are continuously cleaned by using kerosene. • Cleaning the mixer is recommended for every 2-3 mixes and before taking a break. The cleaning of mixture can be done by using shovel with round blade to clean all fine asphalt stuck in the mixer. Use kerosene if necessary when the stuck material is too hard to remove.						
						
Manpower: • 1 supervisor (part time) • 1 mixture operator • 1 tack coating worker (part time) • 1 part time worker for setting out guide rails. • 1 work gang for hauling crushed aggregate and measure for mixing (size of the gang depend on demand progress of work) • 3-6 workers for hauling the mixed asphalt (number of workers depend on demand progress of work) • 1 work gang for spreading and screeding asphalt (size of the gang depend on demand progress of work) • 1 roller operator.	Tools + Equipment: • Tape Measures, 30 m and 5m • Guide rails (hollow steel box 20mm x 20mm) • Hammers • Hand broom • Spreaders • Baskets • Wheel barrows • Buckets • Concrete mixture • Roller. • Shovels • steel box 30mmx50mm for screeding • Measuring cans • High visibility vests and protective clothing • First aid kit.	Material: • Bituminous Emulsion bituminous for tack coat 60% CSS 1 s or 1 h • Bituminous for asphalt 65% CMS 2 h (company code E-71) • Kerosene • Crushed Aggregate.				
Quality Control: <table><tr><td>Before activity is carried out:</td><td> ✓ Check if the equipment: mixture and hand tools are functioning ✓ Check guide rails are in placed correctly. ✓ Check aggregates are clean. ✓ Check type/spec of bituminous emulsion. ✓ Check the temperature of the emulsion is in range of 45-60°C ✓ Check all OSH measures are in place. </td></tr><tr><td>While activity is carried out:</td><td> ✓ Check mixing proportion(water, emulsion, aggregate) are correct ✓ Check asphalt spreading to level of guide rails and no waving on the completed surface. In any places where low spots appear, asphalt shall be used for filling the spots before commencing compaction. ✓ Check that compaction activities are undertaken as soon as material has </td></tr></table>			Before activity is carried out:	✓ Check if the equipment: mixture and hand tools are functioning ✓ Check guide rails are in placed correctly. ✓ Check aggregates are clean. ✓ Check type/spec of bituminous emulsion. ✓ Check the temperature of the emulsion is in range of 45-60°C ✓ Check all OSH measures are in place.	While activity is carried out:	✓ Check mixing proportion(water, emulsion, aggregate) are correct ✓ Check asphalt spreading to level of guide rails and no waving on the completed surface. In any places where low spots appear, asphalt shall be used for filling the spots before commencing compaction. ✓ Check that compaction activities are undertaken as soon as material has
Before activity is carried out:	✓ Check if the equipment: mixture and hand tools are functioning ✓ Check guide rails are in placed correctly. ✓ Check aggregates are clean. ✓ Check type/spec of bituminous emulsion. ✓ Check the temperature of the emulsion is in range of 45-60°C ✓ Check all OSH measures are in place.					
While activity is carried out:	✓ Check mixing proportion(water, emulsion, aggregate) are correct ✓ Check asphalt spreading to level of guide rails and no waving on the completed surface. In any places where low spots appear, asphalt shall be used for filling the spots before commencing compaction. ✓ Check that compaction activities are undertaken as soon as material has					

	✓	been spread and control passes of the rolling.
	✓	Check compaction is uniform in rolling pattern and number of passes.
	✓	Ensure that there is always a lateral overlap of at least 20 cm from pass to pass.
Final check after construction:	✓	Make sure all tools and equipment have been cleaned after using
	✓	Check all guide rails have been removed and cleaned for reuse
	✓	Make sure any excess aggregate and sand have been removed for reuse elsewhere
	✓	Remove and dispose of any surplus asphalt.

ERA Enhancing Rural Access	WORK SHEET
Item: Penetration Macadam (Pen-Mac) Pavement	WS-PMP
Specification: The penetration macadam pavement is commonly used as surface layer on roads in Indonesia and worldwide. The work consists of providing bitumen stabilized aggregate over a new or repaired base course layer. The penetration macadam surface constitutes a 50 mm consolidated thickness, obtained by two or three application of hot bitumen, alternated with three applied layers of aggregates.	
Work Method: • Set out road level and camber of 4% cross fall using pegs and strings. Pegs are to be set at road centre line and road edges with 10 m distance intervals between the pegs. Mark the designated level on the pegs and locate and tie the string line. • The different grades of crushed aggregate to be used for the penetration macadam surface shall be placed along the road in orderly arranged heaps. • After spraying the prime coat, apply the first layer of crushed aggregate in sizes 3-5 cm, inter locked with aggregate in sizes 2-3 cm at a rate of about 80-100 kg/m². Apply compaction immediately using an 8-10 ton steel wheel roller for a minimum of 10 passes at a speed of not more than 5 km/h.	 The top part of the image is a line drawing showing a road layout with several piles of aggregate material. A string line is stretched across the road, supported by pegs. The bottom part is a sketch of two workers on a road. One worker is using a tool to spread material, while the other is further ahead, also working on the road surface.
• Spray heated bitumen on the compacted coarse aggregates. Application rate shall be a minimum of 4.5 litres/m², applied as uniformly as possible at the temperature stated in the specification.	 A photograph showing a worker in a yellow hard hat and dark clothing using a spray nozzle to apply a dark liquid (bitumen) onto a road surface. The road is partially covered with a dark layer of bitumen. In the background, another worker is visible, and there are trees and a fence along the side of the road.

While the first application of bituminous material is still warm and plastic, the second layer of aggregate in sizes 1-2 cm shall be spread at a rate of about 25 kg/m². Apply compaction immediately using an 8-10 ton steel wheel roller for a minimum of 10 passes at a speed of not more than 5 km/h.		
- The next layer of bitumen is then applied, sprayed at a minimum rate of 1.5 litres/m² over the previous compacted aggregate layer at the temperatures stated in the specification. - While the bituminous material is still warm and sticky, the third layer of fine aggregate or coat sand in sizes 0-0.5mm (or aggregate chippings) shall be spread at an amount rate of about 8-10 kg/m². Apply compaction immediately using an 8-10 ton steel wheel roller for a minimum of 10 passes at a speed of not more than 5 km/h. The final passes shall make sure the final surface is smooth and even.	 	
Manpower: 1 Supervisor (part time) 1 Worker heating and maintaining temperature of bitumen - Skilled worker(s) spraying bitumen 1 Work gang carrying bitumen 1 Work gang spreading aggregate	Tools + Equipment: - Bitumen sprayer or (if not available) local product spraying bucket - Measuring bucket for measuring hot bitumen - Measuring tapes 30 m and 5 m - Baskets - String line and pegs - Spreader - Shovel - Roller - Bitumen thermometer - High visibility jackets - Protective gear, gloves, etc. - Water for washing potential burns - First aid kit.	Material: - Crushed aggregate: - size:3-5 cm - size 2-3 cm - size 1-2 cm - size 0-0.5cm or coat sand - Bitumen - Fire wood. Remarks: all material shall be applied to specification

Quality Control:

Before activity is carried out:

- ✓ Check setting out done correctly?
- ✓ Check pegs and string line placed correctly?
- ✓ Check camber board used?
- ✓ Check aggregate of correct properties is used, and that aggregate/coat sand is free from dust, dirt and clay.
- ✓ Check correct type and quantity of bitumen is used.
- ✓ Check workers briefed on risks and dangers of working with hot bitumen and emulsions

While activity is carried out:

- ✓ Make sure all heated bitumen is used not more than 1 day.
- ✓ Check all OSH measures are in place
- ✓ Make sure the bitumen is heated at correct temperature as per specification.
- ✓ Make sure the heated bitumen is sprayed uniformly.
- ✓ Make sure crushed aggregate is spread uniformly, and that the correct size of aggregate and thickness of each layer is controlled.
- ✓ Make sure that compaction activities are completed as soon as material has been spread.
- ✓ Make sure all three layers are completed within a maximum of 2 to 3 days.

Final check:

- ✓ Keep children and bystanders clear of work site and bitumen activities
- ✓ Make sure the road surface is even after compaction.
- ✓ Make sure the total surface is covered by the last layer material (sand).

ERA Enhancing Rural Access	WORK SHEET
Item: Bitumen and Emulsion Seals	WS- ESP
Specification: Bitumen emulsion surface dressings consist of a spray of bituminous emulsion binder followed by the application of a layer of aggregate or stone chippings. The binder acts as a waterproofing seal preventing entry of surface water into the road structure while the chippings protect this film from damage by vehicle tyres. Surface Dressings are also called Chip Seals or Surface Treatments in different countries. Surface Dressings can be used for a number of purposes, including: • New construction (normally Double Surface Dressings only); • Temporary by-passes (normally Single Surface Dressings); • Maintenance resealing (normally Single Surface Dressing). The bitumen emulsions can be applied under labour-based arrangements using motorised hand sprayers and hand spray cans, or under equipment based activities using bitumen tankers and spray bars. This training manual covers both methods of application.	
Safety Requirements Contractors must be aware of the risks and dangers of construction using hot bitumen and emulsion products and should be familiar with the related provisions in the Bituminous Treatments Training Manual and the Work Sheet outlining the Safe methods for handling hot bituminous products. Materials The materials required for construction of Surface Dressings by labour based and equipment based methods are: • Surfacing aggregate of the specified size (obtained from a commercial source/quarry) • Bituminous binder in the form of a bitumen emulsion, either Anionic spray grade emulsion RS60 or Cationic spray grade emulsion CRS 65 or CRS 70. Cationic emulsion is preferred because it has better flow properties (higher viscosity). Aggregate quality The chippings must have a maximum Los Angeles Abrasion (LAA) value of 30 after 500 revolutions. The aggregate crushing value (ACV) is an indication of chipping strength and allowable values usually lie in the range of 20 to 35. Medium to heavily trafficked roads must have chippings with a maximum ACV of 20. On lightly trafficked roads it may be acceptable to have an ACV up to 35 but it is	 

preferable to have chippings with a maximum ACV of 20.

Aggregate size and grading

For a Double Surface Dressing typically 12 mm and 8 mm aggregates are used for the first and second layer respectively. All sealing chips shall be clean, hard, dry, tough, sound, crushed stone or crushed gravel of uniform quality free from dust, clay or organic matter. Nominal size of stone shall be 12 mm, 100% Passing 20 mm sieve and retained on 10 mm sieve. The aggregate for the second coat shall be 8 mm, 100% Passing 12.5 mm sieve and retained on 6.3 mm sieve.

The application rate for the aggregate shall be:

- First layer: nominal stone size 12 mm at $0.015 \text{ m}^3 \text{ per m}^2$;
- Second layer: nominal stone size 12 mm $0.008 \text{ m}^3 \text{ per m}^2$.

Method

Applying the tack coat

Because of the low viscosity of the emulsion it is not possible to spray emulsion at more than $0.6 - 0.7 \text{ ltr/m}^2$ without the binder tending to flow. To overcome this problem, the tack coat is sprayed at $0.6 - 0.7 \text{ ltr/m}^2$, and the balance of the calculated tack coat application is applied as the penetration spray, where the aggregate will inhibit any untoward flow of the binder.

Application of Aggregate

The application of aggregate should follow close after the application of binder, but must only commence after approximately 4m of road has been sprayed to avoid aggregate falling on unsprayed road.

There are two methods of applying the aggregate:

- Spotting of aggregate and spreading by hand;
- Application of aggregate by mechanical chip spreader.

For manual spreading when the aggregates are placed alongside the sprayed surface, a shovel of aggregate is taken and pitched into the air and in the process the shovel twisted rapidly. In so doing the chips are sprayed uniformly over the area to be covered and the stones will fall onto the wet tack coat while the dust, if any, will fall onto the top of the stone or, if there is a breeze, will be blown across the road away from the surface.



Once sufficient stones have been applied so that one can walk on the surface without coming into contact with the wet binder, the bare spaces are filled with additional aggregates. Gently broom the surface to distribute the aggregate uniformly.

Rolling

As soon as the surface has been covered with the aggregate without bare patches of binder showing, rolling, with a suitable 3-5 ton roller can commence. After the surface has been rolled once (i.e. a complete coverage of the roller) attention must be given again to covering bare patches. The first roll must be done without vibration but subsequent rolling, when the aggregate is properly placed with full coverage obtained, can be done with the intermediate vibration of the roller. The rolling carried out in straight lines parallel to the centre line or edges of the road. Typically three passes should be sufficient to seat the aggregate.

Applying the penetration spray

The remainder of the bitumen emulsion that was not applied in the tack coat is now sprayed as a penetration spray. After the application of the penetration spray, crusher dust or sand should be applied to prevent the roller and vehicles from picking up bitumen.

Constructing a Double Surface Dressing

Double surface dressings are robust and should be used when:

- A new road base is surface dressed;
- Extra 'cover' is required on an existing bituminous road surface because of its condition (e.g. when the surface is slightly cracked or patched);
- There is a requirement to maximise durability and minimise the frequency of maintenance and resealing operations.

The quality of a double surface dressing will be greatly enhanced if traffic is allowed to run on the first dressing for a minimum period of 2-3 weeks before the second dressing is applied. This allows the chippings of the first dressing to adopt a stable interlocking mosaic which provides a firm foundation for the second dressing.

Applying the second spray

When a Double Surface Dressing is constructed it should be possible to apply sufficient binder in the



second spray to give the required total rate of spray for the finished dressing since the first layer of aggregates will prevent run-off of the binder.

Applying the second layer of aggregates

The same procedures are followed as for the first layer

Weather constraints

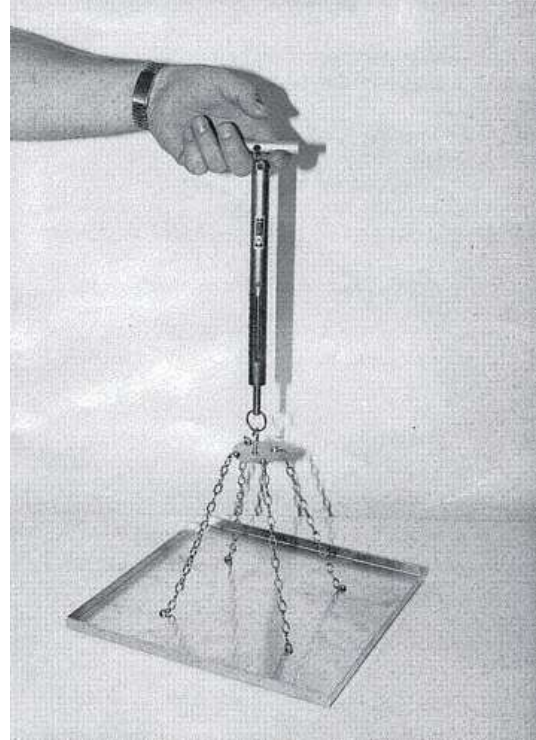
Spray applications should only be applied during the day and only in good weather conditions and when rain is not imminent. The road surface temperature should be above 10°C. Care should be taken when spraying on a windy day as the spray may be carried some distance and damage property or passing vehicles down-wind of the operation.

Application of Chippings

The application of stone chippings is measured by placing a 300 x 300 mm pan or reinforced paper square on the area where the chip is being placed. The chippings are weighed to compare with the specified overage.

Application of bitumen emulsion

The application of the bitumen emulsion shall be measures by dipping the drums or tankers depending upon the application method, to calculate the quantity applied in litres per m² and then comparison of this against the specified application rate. Similar to the measurement of the application of the sealing chips 300 x 300 mm square paper pads can be placed under the spray run, and the weight of the emulsion measures and prorated to indicate the weight (and litres) per m².



Useful equipment can be obtained for control of aggregate spread rate.

Equipment Based Emulsion Seals – methodology indicated by following photographs



Even application from all spray nozzles



Spray run marked with guide for driver



Stone chipping (aggregate) applied uniformly after bitumen spray



Sweep stone chippings or broadcast additional for even coverage



Rolling follows immediately after placement of stone chippings



Mechanical spreader and speed of truck governs application



Pneumatic tyre or smooth wheel tandem roll



Bitumen run about to start with placement of stone chipping and rolling immediately following application of bitumen binder

Manpower:

- Supervisor;
- Trained and knowledgeable workers aware of hazards from hot bitumen and bitumen related products and work activities;
- Experienced bitumen tanker operator and assistants (2);

Construction Plant and Equipment:

The following equipment is recommended to promote the construction of the single or double emulsion seal surfacing by labour or equipment-based methods.

- Shovels;
- Pneumatic tyre roller;

Material:

- Bitumen
- Aggregate (sealing chips)

• Truck drivers experienced in the spreading of aggregate and assistant to control application (one); • Experienced roller driver; • Workers trained in the construction of hot bitumen sprayed surface treatments; • Road flagmen to control traffic through site and protect road users.	• Smooth wheel tandem vibrating roller; • Brooms; • Builders' wheelbarrows (capacity $\pm 65 - 67$ litres); • Hammers; • Reinforced paper, 4 rolls x 1 metre wide; • Steel pegs, 300 mm x 9 mm; • Chalk-line equipment; • Steel tape, 50 m; • 105 litre drums (cleaning hand tools and equipment); • Items identified in Bitumen safety work sheet. • And for Equipment-Based method • Bitumen tanker with heater, bitumen pump and spray bar; • Trucks with aggregate spreader.																																					
Quality Control: <table border="0"> <tr> <td data-bbox="204 981 496 1048">Before activity is carried out:</td><td data-bbox="533 981 560 1010">✓</td><td data-bbox="592 981 1412 1048">Understanding of the risks with the handling and application of hot bitumen.</td></tr> <tr> <td></td><td>✓</td><td>Brief work site personnel on the risks and safety requirements, and emergency actions in the case of burns or scalds?</td></tr> <tr> <td></td><td>✓</td><td>Ensure burn cards are available in the Tetum language?</td></tr> <tr> <td></td><td>✓</td><td>Understanding of the application rates for the bitumen and aggregate?</td></tr> <tr> <td data-bbox="204 1272 496 1339">While activity is carried out:</td><td>✓</td><td>Site marked out and work planned in advance?</td></tr> <tr> <td></td><td>✓</td><td>Management the work site to avoid risk to workers and the public. Ensure availability of fire extinguishers with supplier's tanker, or provided by contractor.</td></tr> <tr> <td></td><td>✓</td><td>Check bitumen and aggregate application rates at regular intervals, using a square plate/pad placed under the spray bar of the moving sprayer, or the aggregate spreader, respectively and measuring the weight of each applied</td></tr> <tr> <td></td><td>✓</td><td>Ensure workers have required safety clothing and equipment and that no-smoking requirement is observed.</td></tr> <tr> <td></td><td>✓</td><td>Keep children and public away from work site and vicinity of bitumen spraying and associated plant.</td></tr> <tr> <td data-bbox="204 1664 347 1693">Final check:</td><td>✓</td><td>Review work and safety measures throughout the bitumen application and seal work.</td></tr> <tr> <td></td><td>✓</td><td>Stop work if a risk is evident and adjust the site management and safety precautions</td></tr> <tr> <td></td><td>✓</td><td>Hold debriefing to review safety precautions following completion of work.</td></tr> </table>			Before activity is carried out:	✓	Understanding of the risks with the handling and application of hot bitumen.		✓	Brief work site personnel on the risks and safety requirements, and emergency actions in the case of burns or scalds?		✓	Ensure burn cards are available in the Tetum language?		✓	Understanding of the application rates for the bitumen and aggregate?	While activity is carried out:	✓	Site marked out and work planned in advance?		✓	Management the work site to avoid risk to workers and the public. Ensure availability of fire extinguishers with supplier's tanker, or provided by contractor.		✓	Check bitumen and aggregate application rates at regular intervals, using a square plate/pad placed under the spray bar of the moving sprayer, or the aggregate spreader, respectively and measuring the weight of each applied		✓	Ensure workers have required safety clothing and equipment and that no-smoking requirement is observed.		✓	Keep children and public away from work site and vicinity of bitumen spraying and associated plant.	Final check:	✓	Review work and safety measures throughout the bitumen application and seal work.		✓	Stop work if a risk is evident and adjust the site management and safety precautions		✓	Hold debriefing to review safety precautions following completion of work.
Before activity is carried out:	✓	Understanding of the risks with the handling and application of hot bitumen.																																				
	✓	Brief work site personnel on the risks and safety requirements, and emergency actions in the case of burns or scalds?																																				
	✓	Ensure burn cards are available in the Tetum language?																																				
	✓	Understanding of the application rates for the bitumen and aggregate?																																				
While activity is carried out:	✓	Site marked out and work planned in advance?																																				
	✓	Management the work site to avoid risk to workers and the public. Ensure availability of fire extinguishers with supplier's tanker, or provided by contractor.																																				
	✓	Check bitumen and aggregate application rates at regular intervals, using a square plate/pad placed under the spray bar of the moving sprayer, or the aggregate spreader, respectively and measuring the weight of each applied																																				
	✓	Ensure workers have required safety clothing and equipment and that no-smoking requirement is observed.																																				
	✓	Keep children and public away from work site and vicinity of bitumen spraying and associated plant.																																				
Final check:	✓	Review work and safety measures throughout the bitumen application and seal work.																																				
	✓	Stop work if a risk is evident and adjust the site management and safety precautions																																				
	✓	Hold debriefing to review safety precautions following completion of work.																																				

Labour-based rural road work manuals for training provided by Don Bosco Training Center



International
Labour
Organization



Training modules developed through the Enhancing Rural Access Project, with technical support from the ILO and funding from the European Union and the Government of New Zealand