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Manual for the labour-based construction of bituminous surfacing on low-volume roads

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1 Introduction

This manual is a guide to the construction of new bituminous surfacings on unpaved low trafficked roads in tropical countries using labour-based methods. It is aimed at local government officials and their staff, and small-scale contractors who are responsible for carrying out the work employing mainly local labour.

To achieve the desired results it is essential that works supervisors be trained by means of short training courses and field trials to deliver the required standard of workmanship. This manual can also be used to assist with this training.

Labour-based construction of bituminous surfacings can be very effective providing there is good roadside drainage and the underlying road surface is sufficiently stable and the workmanship is to a good standard. It is therefore stressed that the preparation of the existing road and materials used must meet the particular country and ministry design specifications before any sealing work is undertaken.

Road construction in rural areas is increasingly being focused on provision of access and poverty alleviation. When access is treated as a priority, it is likely that there will be an increased use of spot improvement techniques. The decision to surface a road with a bituminous seal may be made because the existing gravel pavement requires too much maintenance or because suitable regravelling materials are scarce and in some cases sealing roads, which carry traffic as low as 30 vpd, may be justified. The upgrading of short sections of road for which the use of conventional large road construction equipment is prohibitively expensive make the methods described here most suitable.

The techniques described in this manual, use low cost plant that can either be manufactured locally or be bought or hired by small local contractors. However, there are situations where traffic levels will be at the limit of the 'low-volume' category and in these cases the use of bitumen heating and spraying tanks if appropriate, should be used. Any additional equipment that may be required should be relatively cheap and within the range of the capital investment expected by small-scale contractors.

2 Choice of surfacing

Several types of bituminous surfacings can be constructed by labour-based methods using small, affordable plant such as tractors, trailers, hand sprayers, concrete mixers and pedestrian rollers. Some can be constructed to acceptable standards using the simplest of hand tools and materials. Although cold bitumen emulsion is the ideal binder for labour-based construction, if

equipment is available for the safe handling of hot binders, then they may be used if emulsions are not suitable. Selection of an appropriate bituminous surfacing will depend on the materials to be used, the site characteristics such as steep gradients and the equipment that is available for construction. A guide to the selection of the surface treatments is given in Table 1 and Figure 1.

2.1 Surface treatments

Sand seal

This seal consists of first a prime coat, a film of binder (cutback bitumen, emulsion) followed by graded sand (3-5 mm) which must then be compacted.

Table 1 Suitability for labour-based construction of bituminous surfacings on low volume roads

<i>Surface treatment</i>	<i>Cold emulsion</i>	<i>Hot bitumen¹</i>	<i>Minimum local maintenance capacity</i>	<i>Steep gradient</i>	<i>Poor surface drainage</i>	<i>Junction or turning trucks</i>
Priming	Good ²	Good				
Sand seal	Good	Good	No	No	No	No
Slurry seal	Good	Not used	10 mm layer	No	Yes	10 mm layer
Single Otta	Good ⁵	Fair ³	Yes	No	Yes	No
Double Otta	Good ⁵	Fair ³	Yes	Yes	Yes	Yes
Single Otta with sand seal	Good ⁵	Fair ³	Yes	No	Yes	No
Single surface dressing	Good	Good	No	No	No	No
Double surface dressing	Good	Good	Yes	Yes	Yes	Yes ⁴
Pre-mix bitumen and gravel	Good	Not used	Yes	Yes	Yes	Yes
Penetration macadam	Good	Not used	Yes	Yes	Yes	Yes

¹ A safe method of heating is essential.

² Invert emulsion only.

³ Good if adequate compaction can be achieved.

⁴ With third seal, fine aggregate is added to reduce damaging action on chippings.

⁵ Emulsion must be HFMS-2s grade (minimum 200 Pen base bitumen).

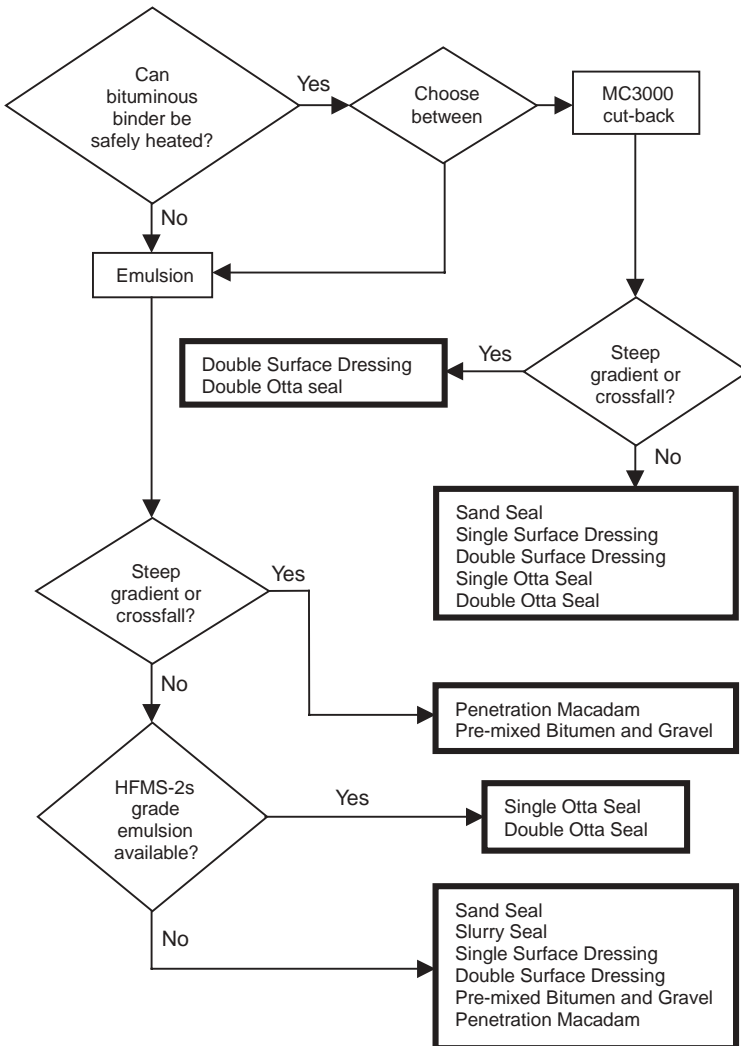


Figure 1 Basic selection of bituminous surfacings

Performance can be improved if a second seal is applied after 3 months. A life of 4-5 years can be expected. It is primarily a temporary surfacing, or for application on top of other seals. It is especially useful if good aggregate is hard to find, in deserts for example, and is suitable for labour-based construction, especially where emulsions are used.

Slurry seal

Slurry seals are laid cold and are a mixture of fine aggregates, Portland cement filler, binder emulsion and additional water. When freshly mixed they have a thick creamy consistency and can be spread to a thickness of 5 to 10 mm. This method of surfacing is not normally used for new construction because it is more expensive than surface dressing and is not as durable as a properly designed and constructed surface dressing. On large-scale projects, slurry mixes are made and spread by purpose made machines. However, on low volume roads and on short sections, they can be suitable for labour-based construction using portable concrete mixers.

Otta seal

An Otta seal consists of a layer of binder followed by a layer of aggregate that is rolled into the binder using a pneumatic tyred roller or loaded trucks. It is different to surface dressing in that a graded gravel or crushed aggregate containing all sizes, is used instead of single sized chippings. It depends for its success on the binder being squeezed up through the aggregate by the action of extensive rolling. Due to the fines in the aggregate, 2 to 3 days of pneumatic-tyred compaction (rollers or traffic) are required to fully coat all the particles. An Otta seal may be applied in a single or double layer. Evidence on the performance of these types of seal constructed by conventional plant methods has shown them satisfactory for over 12 years on roads carrying up to 500 vehicles per day. Otta seals have a tolerant and forgiving design and are well suited to labour-based construction methods.

Binder and aggregate design is by judgement and must be established through trials. Inadequate trials can give poor results and a loss of confidence in the construction technique. Normally a cut-back bitumen, MC3000 or 150/200 penetration grade bitumen is used with either a fine or coarse aggregate cover depending on the level of traffic. Hard grade binders such as 80/100 cannot be used, as it is too viscous. Ordinary grade emulsions also, should not be used in the construction of Otta seals. However, emulsions with a base bitumen penetration of 200 such as HFMS-2s grade can be used. A wide range of aggregate sources and types can be used.

Surface dressing

Untreated road surfaces that are to be surface dressed must first be primed. The surface dressing comprises a thin film of binder sprayed onto the previously primed surface and then covered with a layer of stone chippings. The thin film of binder acts as a waterproofing layer preventing the entry of surface water into the road structure. The stone chippings protect this film of binder from damage by vehicle tyres, and form a durable, skid-resistant and

dust-free wearing surface. It can provide an effective and economical running surface for newly constructed road pavements. Roads carrying up to 1000 vehicles/lane/day are successfully surfaced with multiple surface dressings, but typically, the process is reserved for surfacing more lightly trafficked roads, carrying up to 500 vehicles/lane/day. Double surface dressings are usually used to seal an unpaved surface with single surface dressings normally being used as a maintenance treatment for existing bituminous sealed roads. A correctly designed and constructed surface dressing should last at least 5 years and longer on very lightly trafficked roads, before resealing with another surface dressing becomes necessary. Surface dressings can be constructed in a number of ways to suit site conditions, the most common being a single or double seal.

Surface dressings are less tolerant of labour-based methods compared to Otta seals, as they require accurate rates of spread of both binder and surfacing aggregate. However, they can be successful if hand spraying of the binder is done carefully by suitably trained operators. With this in mind and considering the safety to the workforce and environmental aspects, emulsions are best suited to labour based methods.

The single and double surface dressing methods described in this manual are based on a full design method summarised in Appendix B.

Pre-mixed bitumen and gravel

This type of surfacing is made by mixing gravel with a stable slow breaking emulsion either by hand or in a small drum mixer such as a portable cement mixer. The aggregate gravel specification is the same as for an Otta seal. After mixing, the material is spread on a primed roadbase and rolled. The surfacing is comparable to an Otta seal after some months of trafficking.

Penetration macadam

After trafficking, Penetration Macadam is effectively similar to asphalt. It is constructed to be at least 50 mm thick and is very robust compared to thin seal coats. This type of surfacing is, therefore, likely to be the best solution for sites where traffic and road geometry is severe. The cost of this surfacing will be relatively high because screened crushed rock aggregate is required together with a high rate of application of binder. However, cold emulsion is suitable for this process and this makes it one of the surfacings best suited to labour-based construction.

Crushed aggregate is normally used because this material helps to generate a stable interlocking layer after it has been compacted. A heavy (8 Tonne) roller

is needed and the road base must be strong enough to resist the aggregate punching in. Uncrushed gravel materials can be used if the aggregate particles have some surface texture and traffic is light. Suitable aggregates can also be produced by hand-knapping if necessary.

3 Materials for bituminous surfacings

Safety considerations must be taken into account when selecting bitumen for labour-based work. The application of hot binders require the use of purpose made towable heater tanks with a built in spray bar or an attached hand lance.

3.1 Cut-back bitumens

These binders must be heated before they can be applied. Application temperatures are lower for bitumens cut-back with more solvent (kerosene type material) but the risk of fire increases. Typical spraying temperatures for cut-back bitumens for hand lance spraying are given in Table 2.

Table 2 Spraying temperatures for cut-back bitumens

<i>Bitumen type</i>	<i>Slotted jets</i>	
	<i>Min°C</i>	<i>Max°C</i>
<i>Cutback grades</i>		
MC30 (Prime)	40	50
MC70 (Prime)	55	70
MC3000	120	130

3.2 Bitumen emulsions

Bitumen emulsion is commercially available in different types and grades. Inverted emulsions (i.e. water suspended in bitumen) are available and are used as primes whilst anionic and cationic emulsions are suitable for different types of aggregates and uses.

Emulsions containing less than 70 per cent bitumen can be sprayed and mixed at ambient temperatures. Emulsions that contain greater than 70 per cent bitumen require heating to approximately 70°C.

Anionic emulsions can give poor adhesion with acidic rocks (such as granite and quartzite) but good adhesion with basic rocks (such as basalt) and with limestone. Cationic emulsions are suitable for use with both rock types. The

addition of small percentages of fresh hydrated lime, or sometimes Portland cement, to the aggregate will improve adhesion of anionic emulsion to acidic rocks.

There are three grades of anionic and cationic emulsions; Rapid, Medium, or Slow setting and normally contain between 40 and 70 per cent bitumen, 65 per cent being the best for most labour-based work.

The main uses of bitumen emulsions are given in Table 3.

Table 3 Uses of common bitumen emulsions

<i>Grade of emulsion</i>		<i>Appropriate uses</i>
Rapid setting	RS	Sand seals. Surface dressing. Penetration macadam.
Medium setting	MS	Pre-mixed bitumen and gravel (coarse grading).
Slow setting	SS	Otta seal ¹ . Pre-mixed bitumen and gravel (fine grading). Slurry seal.

¹ Minimum 200 penetration grade based bitumen (e.g. HFMS-2s)

Some emulsions such as slow setting grades can be diluted with water if necessary but a test on a small quantity of emulsion and water should be carried out to confirm that the quality of the water is satisfactory. If the bitumen coagulates then a new source of water must be found.

3.3 Aggregates

Clean crushed rock that can be produced by handknapping and screening should be used for penetration macadam.

Clean single sized crushed gravel or rock should be used for surface dressings. The chippings that are available to the contractor may be of varying quality, but generally, they will be able to be classified into three types. They are:

- *Rounded* Worn round by the action of water and friction.
- *Angular* Having easily seen edges and roughly cubical in shape.
- *Flaky* Thickness less than approximately half the length or width.

Single sized chippings should be produced by screening. A simple screening frame is shown in use in Plate 1.



Plate 1 Screening frame

Clean gravel with little fine material or crushed rock can be used for Otta seals and pre-mixed bitumen and gravel. Oversize aggregate greater than 16 mm should be screened out.

4 Tools and equipment

Labour-based construction methods require an adequate number of hand tools and equipment to successfully carry out the task. Most are relatively inexpensive, either already in the possession of the local labour force or are easily obtained. In addition, small mechanised plant that a contractor may have should be employed whenever possible. The plant will provide the means to more accurately meet construction requirements and speed up the work. The tools and equipment that are thought essential for various types of labour-based work are listed below. The numbers of each item required will depend on the nature of the surface treatment and the size of the construction project.

- Shovels.
- Pickaxes.
- Hoes.
- Brooms.

- Rakes.
- Buckets.
- Watering cans.
- Measuring containers of known volume.
- Steel measuring tape (50 metre).
- String.
- Hand tampers or rammers.
- Steel pegs or nails.
- Balance or scales, 20 kg minimum capacity.
- Large clock.

Particular plant required for labour-based construction can include those described in Plates 2 - 7.



Plate 2 Stand for drum of bituminous binder.

(Photograph courtesy of South African National Roads Agency)

To discharge the bituminous binder (usually emulsions) into smaller measuring containers an easily removable gate valve/tap must be used. This will help to keep a clean operation without undue wastage. The drum must be rolled up a ramp onto a stand that can be made locally. The stand must be high enough to clear the containers beneath.



Plate 3 Open top and bottom drum.

(Photograph courtesy of South African National Roads Agency)

Half of a 210 litre drum with the top and bottom open and with metal handles attached is light, economical and can be made locally. It is used for placing heaps of aggregate along the length of the road surface to be treated.



Plate 4 Portable concrete mixer.

(Photograph courtesy of South African National Roads Agency)

Although small quantities may be mixed by hand, a portable concrete mixer of approximately 200 litres capacity can be used to efficiently mix aggregate and emulsions to produce slurries and premix gravels.



Plate 5 Pedestrian roller.

(Photograph courtesy of South African National Roads Agency)

Compaction of surfaces can be achieved with the use of small pedestrian rollers.



Plate 6 Lorry wheel compaction

Compaction of surfacings can also be carried out using a heavily loaded lorry. This method is especially suitable for the rolling of Otta seals.



Plate 7 Motor powered pump and hand-lance sprayer

The pump and lance are fitted to a four-wheeled trolley that carries a drum of bituminous binder, usually emulsion or prime that can be sprayed at ambient temperature.

4.1 Spraying by hand lance

A hand lance is fitted with a motor driven pump that operates at constant speed. Adjusting the setting on the pump by-pass system controls the pressure at two hand lance jets.

During spraying the lance must be held at a height that gives a 50 per cent overlap of the spray from each jet as shown in Figure 2. It is then possible to time a pass across a lane width, perpendicular to the centre-line of the road, to provide the correct application rate of bitumen.

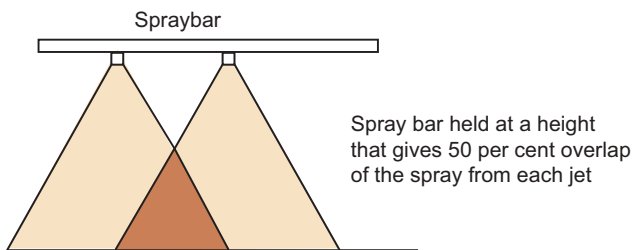


Figure 2 Overlap of spray from hand lance sprayer

The bituminous binder should be applied as the operator and trolley move backwards along the road. The spray pattern on one pass results in one third of the area receiving half the output of the trailing jet, one third receiving half the output of both jets and the final third receiving half the output of the leading jet. The first pass should be made with the trailing half spray being made on loose sand (a paper strip could be used) and the subsequent passes overlapped to ensure that all of the road surface receives half the output from each jet. This is illustrated in Figure 3.

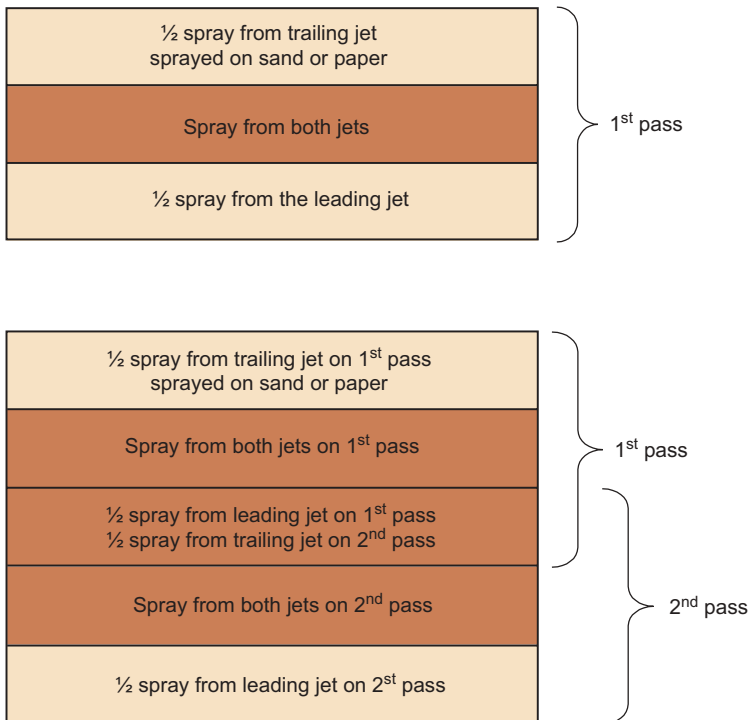


Figure 3 Spray coverage of the road surface

At the end of each pass, the lance has to be pulled back sharply to the new spraying position to avoid applying too much binder at the centre-line and road edge.

Large cut-off boards or screens can be used to ensure that a clean cut off in the bitumen is produced along the centre-line of the road and at the road edge. However, the nature of the spray produced by the lance and the method in

which it is used must be considered if cut-off boards are used. The skin and eyes of people holding the boards and all other operatives should be protected from contact with sprayed binder and from any fumes that may be produced. Rubber gloves, safety glasses and facemasks are considered suitable for this purpose.

It is important that operators of the hand sprayers are fully trained beforehand in its use. The training and practice in the use of hand sprayers should be carried out on ground away from the road to be treated. A good way to begin training is to use water as the sprayed liquid. In this way there will be no damage to the surrounding environment.

5 Health and safety

All of the bituminous surfacings described in this manual involve the use of bituminous binders during construction. Depending on the particular surfacing or the availability of binder, they may be hot cut-back bitumens or bituminous emulsions that are applied cold.

Emulsions that can be sprayed at ambient temperature or need only slight heating in a towable 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 minimise the chance of skin sensitisation. 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. Solvents such as kerosene should not be used as they in themselves may cause skin irritation. 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 presents hazards for the labour force and the availability of heating fuel may be limited or its use environmentally undesirable. 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. No attempt should be made to remove any binder that has stuck to the skin. The binder will gradually lift from the skin by itself after a few days. To minimise the risk of burns, protective heat resistant gloves and footwear should be worn. The heating of bitumens can generate large volumes of fumes that must not be inhaled.

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 concrete mixers and hand sprayers must be fully trained and familiar with their use.

6 Project organisation

6.1 Planning

It is important that preparation of the surface to be treated and application of the materials used in the construction of all the surfacings be carried out in an organised way to ensure the correct stages take place at the right time.

Before any bituminous surfacing is constructed, the existing unpaved surfaced road must be prepared if necessary by reshaping, compacting and providing drainage.

Some basic steps and decisions must be made. A list should be made itemising:

- Number of workers needed.
- Tools and equipment needed.
- Type and quantity of materials needed.
- Transport of the workers, materials and equipment to the road site.

During construction of the bituminous surfacings, methods of measuring aggregate and bitumen quantities will be required. This can be done using relatively inexpensive containers. Examples that may be used are:

- Buckets (10 litre).
- Watering cans (10 litre).
- Empty drink (soft drink and water) bottles (2 litre and 1 litre).
- Empty fuel cans (25 litre).
- Empty paint containers (5 litre and 2½ litre).
- Any empty container where the volume is known or can be measured and is between 2 and 25 litres.

Special use can be made of an empty 210-litre drum. It should be cut in half with the bottom also removed. This will make a cylinder open at the top and bottom. Set amounts of sand, chippings or gravel can then be transferred from

wheelbarrows into the drum until it is full. Lifting away the drum at points along the road then places the material where it is needed to be spread from. See Plate 3.

Immediately prior to any construction, the surface of the road must be swept clear of loose material and mud. Repairs must be made to potholes or any depressions that may have formed since the reshaping of the road. It is recommended that a light spray of water be applied prior to priming of the surface the day before the construction of the surfacing.

Before construction can take place the spread rate of aggregates must be established. Typical spread rates are given in Table 4. Sufficient aggregate will need to be prepared and stockpiled along the road.

Table 4 Sand / aggregate / chipping spread rates and coverage

<i>Treatment</i>	<i>Spread rate</i>	<i>Approximate area half drum will cover (m²)</i>
Sand seal	13 - 19 kg/m ²	17.5
Otta seal	0.013 - 0.016 m ³ /m ²	7.5
Single surface dressing	12.5 ¹ kg/m ²	11.5 ¹
Double surface dressing <i>1st layer</i>	12.5 ¹ kg/m ²	11.5 ¹
Double surface dressing <i>2nd layer</i>	4.0 ² kg/m ²	35 ²

¹ 14 mm chippings.

² 6 mm chippings.

The sealing operation must be carried out in dry weather and must not begin if there is a threat of rain or if a strong wind is blowing. Construction should begin with the setting out of the area that can be treated in one day. Stockpiles of sufficient chippings or aggregate should be placed along the roadside, at intervals shown in Table 5, ready to be spread by hand after application of the binder.

The application of primer to the existing gravel surface and the subsequent application of the bituminous binder can be carried out either by a hand pumped sprayer or watering cans. The area of the surface that can be covered by one watering can must first be marked into smaller areas (for example 1 metre wide). This will help in the even distribution of the binder. More reliable and accurate spray rates can be achieved using the hand sprayer method but the rate of delivery of the sprayer must be known. This can be

Table 5 Approximate interval between aggregate placement (to the nearest 0.5 metre)

	<i>Width of area to be treated (metres)</i>											
	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	
<i>Treatment</i>	<i>Approximate aggregate spacing (metres)</i>											
Sand seal	9.0	8.0	7.0	7.0	6.0	6.0	5.5	5.0	5.0	4.5	4.5	
Otta seal	3.5	3.5	3.0	2.5	2.5	2.5	2.5	2.0	2.0	2.0	2.0	
Single surface dressing ¹	6.0	5.0	5.0	4.5	4.0	4.0	3.5	3.5	3.0	3.0	3.0	
Double surface dressing <i>1st layer</i> ¹	6.0	5.0	5.0	4.5	4.0	4.0	3.5	3.5	3.0	3.0	3.0	
Double surface dressing <i>2nd layer</i> ²	17.5	16.0	15.0	13.5	12.5	11.5	11.0	10.0	9.5	9.0	9.0	

¹ 14 mm chippings.

² 6 mm chippings.

determined easily by timing how long it takes to fill a container of known volume. It is important that operators of the hand sprayers are fully trained beforehand in its use. The rates of delivery calculated using 10 and 5 litre containers are shown in Appendix C.

It is essential that sufficient time is given well before any construction takes place to ensuring hand lance operatives are well trained in the use of the equipment and can deliver the correct rates of spray.

6.2 Workforce

The size and makeup of the workforce will vary with the size of the project undertaken. A supervisor with some experience and practical knowledge of road construction should be appointed to be in charge of 3 or 4 teams. The supervisor must be responsible for taking charge of everyday organisational and technical problems, be competent in the methods of construction to be used and have the authority to give instructions on-site to the team leaders and workforce. For most construction work, a basic team of 20 - 25 labourers under the direction of one team leader can be employed. The team leader should be experienced and have the confidence and respect of his team. Team leaders and the workforce need not have had any formal training in road construction. If the workforce is inexperienced then training must be received during the course of construction through practical demonstrations and instructions from the supervisor.

7 Preparation of existing road surface

The performance and success of any bituminous surfacing will depend on the condition and strength of the existing surface that it is to be constructed upon and the provision of drainage. There will normally be some need to prepare the road surface. How this is carried out and to what specifications will be dependent on local circumstances but a summary of what should be considered and actions to take is shown in Figure 4.

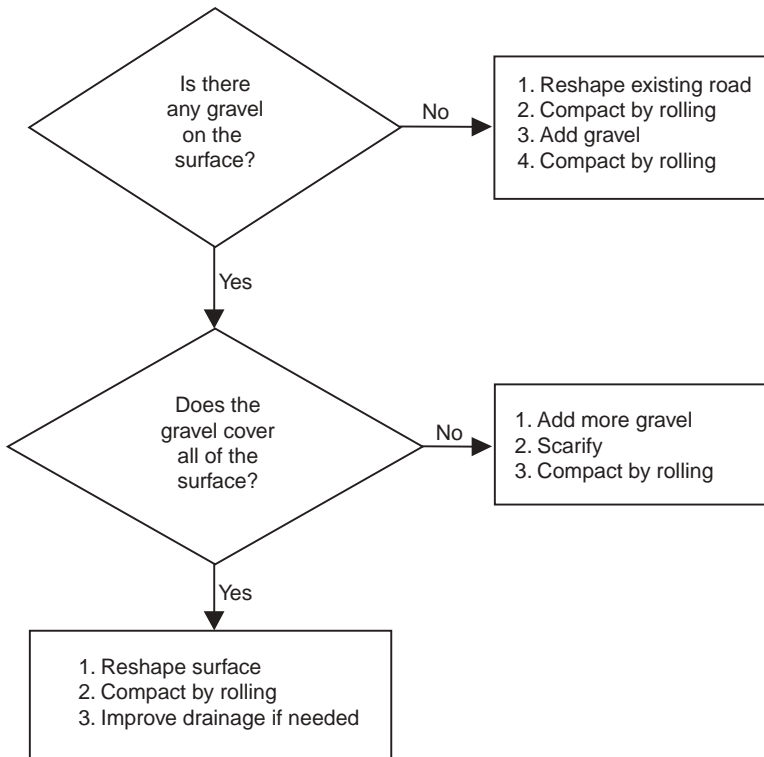


Figure 4 Surface preparation plan

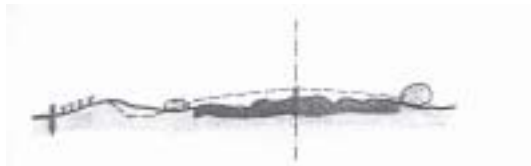
One of the most important aspects of the design of a road is the provision made for protecting the road from surface water or ground water. The road surface must be constructed so that it drains rainwater away quickly to drainage ditches. The formation of the road must be raised above the level of the local water table to prevent it being soaked by ground water.

A road that is flat or dished will collect water and this will cause the surface to deteriorate rapidly. Therefore, the road should be shaped so that the surface falls away either side of the centre line of the road (crossfall). This can be done by loosening the existing surface, adding and mixing in more material as necessary, returning material from the road edges towards the centre of the road, and recompacting as directed in Table 6.

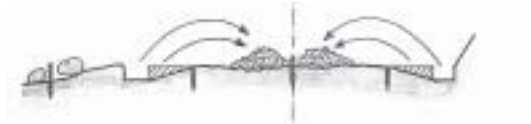
Table 6 Reshaping of road surface

Procedure

- 1 Mark the centre line of the road with pegs every 10 metres.



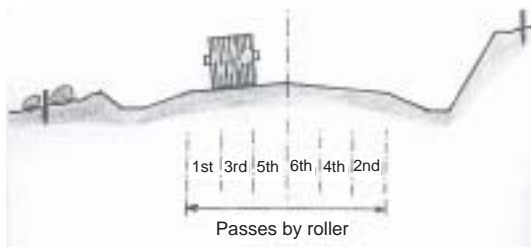
- 2 Set out the pegs for the road edges and gutters using tape measure and camber board.



- 3 Material may be dug from a backslope or beyond the gutter.



- 4 Compact the fill material to the required camber using a motorised pedestrian roller or hand, animal or tractor drawn roller. See Plate 9.



The crossfall on bituminous surfaced roads should normally be between 1 in 40 (2.5%) and 1 in 33 (3%). When bituminous emulsion is to be used, the shallower slope should be used. The final shape of the road surface ready for bituminous surfacing is shown in Figure 5. It should be checked using a simple camber board, such as that illustrated in Plate 8 and in Figure 6. Use of the camber board is illustrated in Figure 7. It should be placed on its edge across the road with its narrower end pointing towards the centre line. If the level bubble is central, then the camber is correct. Checks should be made at approximately 10 metre intervals along the road and if the camber is too steep or too flat, then the road must be graded again.

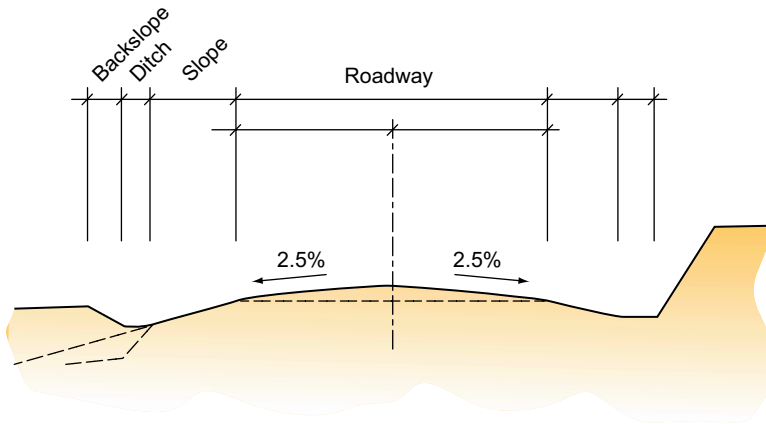


Figure 5 The road shaped ready for bituminous treatment



Plate 8 Camber board



Plate 9 Hand drawn roller

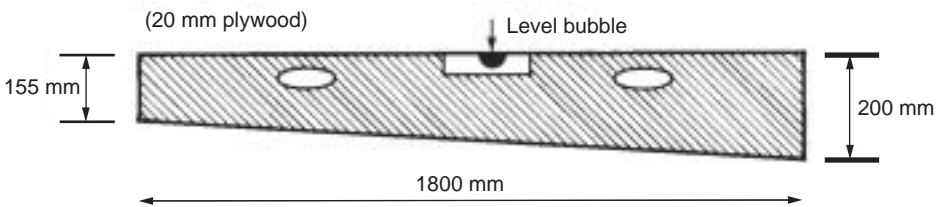


Figure 6 2.5% camber board

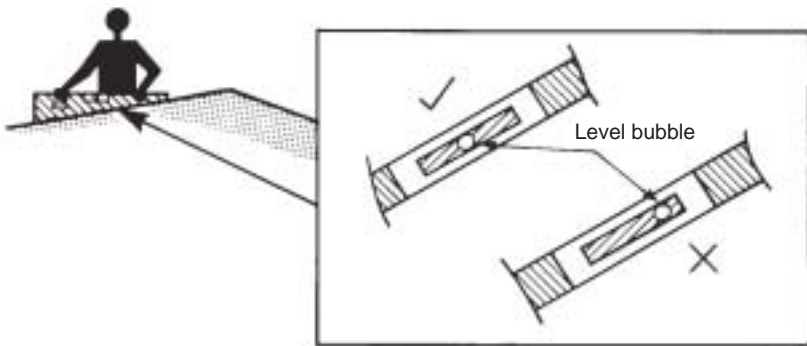


Figure 7 Use of camber board

7.1 Methods of preparation

The principal operations in preparing unpaved roads before the construction of a bituminous surface are grading, with the addition of gravel and compaction of the surface by some means of rolling.

7.1.1 Grading

Grading is used to reshape the road to the correct camber or crossfall and to provide a surface suitable to apply a bituminous layer. Light grading is a light trimming of the surface of the road. In the dry season, loose material should be bladed towards the edge of the road. In the wet season, material should be graded towards the centre of the road. Motor graders may carry out light grading, but a more cost-effective technique is to use tractor-towed graders that are capable of sufficient outputs and standard of work.

Heavy grading consists of scarifying as shown in Plates 10 and 11 and cutting to the bottom of deformations and then reshaping the surface. It usually requires the use of a 135 horse power motor grader but, in some cases, a tractor-towed grader could also be utilised. When possible, it should be carried out at the end of the wet season when the moisture content of the surfacing material is still high enough to achieve recompaction. This is particularly important when heavy grading is needed to remove ruts and potholes. Scarifying to the depth required to remove these will result in the production of a considerable depth of loose materials and, in the dry season, this cannot be recompacted unless water is added.

Grader operation

The quality of workmanship in preparing the road surface for bituminous treatments depends largely on the skill and judgement of the individual grader operator. Careless operation can cause extensive damage to a road, for example by flattening the crown so that rainwater is not discharged, by cutting too deeply in dry weather or by blading plastic material from side drains onto the carriageway.

For heavy grading, the grader works on one side of the road at a time, if possible, and works in passes of about 200 metres in length. On straight stretches of road, the operator should aim to develop a crown on the road. The surface should be cambered to fall away from the crown with a slope of 2.5-3 per cent. The shape of the road must be maintained across culverts but, on sharp bends, the surface must be super elevated and must be flat from shoulder to shoulder with the outer shoulder higher. Any crown on a bend can be very dangerous to traffic. On the transition from bends in the road to straight



Plate 10 Tractor towed scarification



Plate 11 Scarification

sections, the camber on the outside lane should be gradually reduced until the normal cross-section shape is obtained again (see Figure 8).

For heavy grading, it is important to cut to the bottom of surface defects and, if the road surface is hard, the grader's rippers should be used to loosen the material. The grader should start from the edge of the road and work towards the centre. The first and second passes cut to the bottom of the surface irregularity and deposit a windrow just beyond the centre line. The windrow is then spread back across the road depositing all the material on the carriageway to give the correct camber. The material may need to be sprayed again with water during this operation. After the camber has been checked, the other side

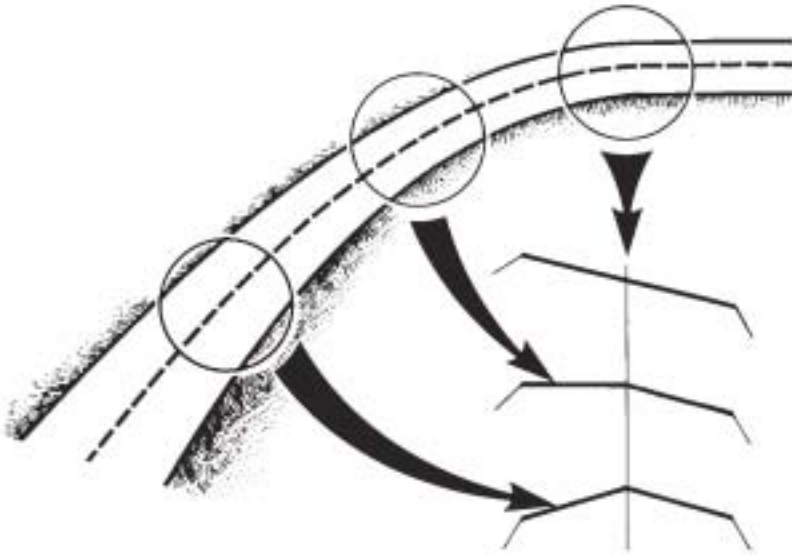


Figure 8 Camber on approach to bends

of the carriageway is graded in a similar way to complete the work and leave a smooth even surface. This is illustrated in Figure 9.

It is important that the grader does not make a final pass down the centre of the road with the blade horizontal. This flattens the centre of the road and causes water to pond.

7.1.2 Regravelling

Some roads that are to be treated with a bituminous surfacing may be damaged to the extent where regravelling to a compacted layer depth of 100 mm is required. Before regravelling work is carried out, it is important to make any necessary repairs or improvements to the drainage system of the road including the clearance of blocked culverts.

Quality of gravel

In practice, what gravel is used will depend largely on what is available, and it may be necessary to use lower-grade material than is commonly specified. The fines of the gravel should ideally be non-plastic but should normally not exceed a Plasticity Index (PI) of 6. However in arid and semi-arid areas,

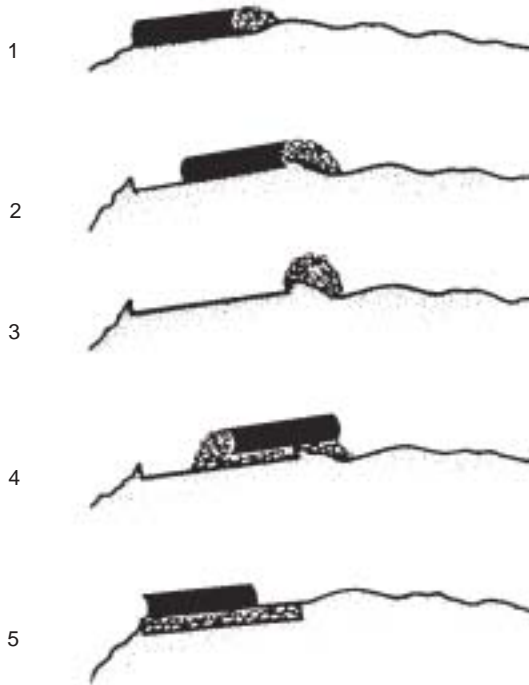


Figure 9 Grading

material with PI of up to 30 can be used. The facilities of a materials laboratory to measure such variables as plasticity will rarely be available and the following methods may be used to assess the gravel material.

Crumble a dry sample of the gravel material in the hands. About half by volume of the particles should be larger than 2 mm in diameter. Attempt to crumble the large particles in the hand by lightly tapping with a hammer. If the lumps disintegrate completely into sand size particles, the material will not be suitable for gravelling.

The ability of the gravel material to bind together is dependent on the presence of cohesive fine material. These can be checked for by moulding a damp sample of the gravel into a ball. If cohesive fines are present, the material will stick together when gently placed on a flat surface.

Good gravel should have a mixture of stones, sand and clay roughly in the following proportions:

Stone (> 2 mm)	50 per cent
Sand	40 per cent
Clay	10 per cent

Placing a sample of material in a glass jar and adding some water can check the proportions. The jar and contents should be shaken vigorously and left to stand for some hours. The approximate quantities of each size of particle can be seen as layers in the sample with the finer material being of a different colour.

7.1.3 Compaction

Compaction rollers must follow up closely behind the grader but must only work on sections where grading has been completed to avoid interference with the grading operation. Rolling should start at the edge of the road and work towards the middle and be repeated by a number of passes until full compaction has been achieved. The number of passes required will depend on the type and weight of the roller used. Table 7 gives a guide to the number of passes to be made to adequately compact a 100 mm gravel layer with typical kinds of roller used in labour-based construction. Providing the work is carried out in the wet season, little watering of the road will be necessary before rolling. Otherwise, water should be added as required, during the rolling operation.

Table 7 Roller compaction and number of passes required

<i>Roller type</i>	<i>Number of passes</i>	<i>Operating speed (km/h)</i>	<i>Width compacted (m)</i>
Smooth wheeled 8 tonne tandem	8	2.5	1.3
Pedestrian vibratory 600 kg	16 ¹	5	0.6
Vibratory plate compactor 700 kg	6	1	0.7
Manual roller 700kg	12	–	0.9

¹ Compacted in two lifts of 50mm.

8 Priming

Description of treatment

Where a bituminous surfacing is to be applied to an untreated road surface it is important that the surface should be dry, clean and as dust-free as possible. A prime coat of bitumen ensures that these conditions are met.

Priming helps maintain adhesion between the roadbase and the bituminous surfacing and seals surface pores in the roadbase. It helps to strengthen the roadbase near its surface and if the surfacing construction is delayed it provides the roadbase with a temporary protection against rainfall and light traffic until the surfacing can be laid. The surface should be lightly sprayed with water before applying the prime coat as this helps to suppress dust and allows the primer to spread more easily over the surface and to penetrate the roadbase. Cutback bitumens such as MC30 that need no heating are applied at a typical application rate of 1.0 l/m². A good alternative prime to apply is an invert emulsion that can be applied with no heating. The typical application spray rate is 1.2 l/m².

The depth of penetration of the prime should be 3-10 mm and the quantity sprayed should be such that the surface is dry within a few hours but normally a prime is applied 24 hours before the construction of a surface treatment.

<i>Bituminous binder</i>	<i>Spray rates</i>
MC30 cut-back	1.0 l/m ²
Invert emulsion	1.2 l/m ²

Equipment and tools

- Measuring tape of minimum 10 metre length.
- Ball of string.
- Brooms.
- Cut off boards 2m × 1m.
- Clock or watch.
- Motor powered pump and hand lance sprayer.

Materials

- Water.
- MC30 cut-back bitumen or invert emulsion.

PRIMING

<i>Preparation</i>	<i>Notes</i>
1 Priming must be carried out 24 hours before the construction of other bituminous surface treatments.	
2 Sweep the roadbase from the centre of the road to the road edges.	Remove all loose material such as large stones and vegetation.
3 Measure out the area of the road to be primed into sections.	Mark out the area with string.
4 Lightly spray water on to the roadbase surface.	This may be carried out using watering cans that deliver a fine spray.
<i>Construction</i>	<i>Notes</i>
1 Test the hand lance sprayer is working correctly.	Test on waste ground.
2 Begin spraying the primer.	Spraying begins at the signal of the person keeping time.
3 The hand lance operative must spray each marked section in the prearranged set time to give the correct spray rate.	The timekeeper must shout out the time elapsed in seconds to guide the hand lance operatives progress.
4 Move the cut off boards positioned at the edges of the road as the hand lance operative moves down the road.	The boards are held vertically to prevent overspray onto surface areas outside those areas being primed. Two people to each cut off board.
5 Continue until all of the roadbase has been primed.	

9 Sand seal

Description of treatment

A bituminous binder and a graded sand are applied to a primed base course to seal the surface as a light wearing course. Single sand seals are not very durable. Application of a second seal after 3 months should give a life of 4-5 years. They may also be applied as a final layer on other types of seals.

Sand seals are suitable for labour-based construction on roads carrying up to 100 vpd where natural sand is plentiful. Cationic emulsion or hot bitumen is suitable for these seals. The design is based on experience of the performance of materials and climate effects in the particular location.

Bituminous binder

MC3000 cut-back bitumen

Spray rates

1.4 l/m² Best applied with tractor towed heating tank with spray bar or hand lance.

Emulsion, 60% cationic

1.6 l/m²

Sand

Spread rate

13 - 19 kg/m²

Equipment and tools

- Measuring tape of minimum 10 metre length.
- Ball of string.
- Shovels.
- Rakes.
- Brooms.
- Hand sprayer or watering cans for unheated emulsions.
- Tamping tool.
- Squeegees.
- Pedestrian roller or tractor or truck.

Materials

- Water.
- MC30 cut-back bitumen or invert emulsion for prime.
- Cut-back bitumen or emulsion.
- Screened river sand or crusher dust (no material greater than 6.3 mm).

SAND SEAL

<i>Preparation</i>	<i>Notes</i>
1 Broom and roll the surface.	
2 Water the surface to be sand sealed.	
3 Continue 1 and 2 until the surface is very smooth and well compacted.	
4 Prime the surface.	Twenty four hours before sand seal construction.
<i>Construction</i>	<i>Notes</i>
1 Sweep the base clear of loose material.	Clay particles, animal droppings.
2 Apply the bituminous binder at the correct spray rate.	Spray rate, see page 30.
3 Apply sand to the binder immediately after spraying.	Spread rate, see page 30. If the binder used is emulsion, wait until the emulsion has started to break (changing from brown to black in colour) before applying sand.
4 Roll the treated surface with a pedestrian roller or lightly loaded truck.	
5 Sweep loose sand back into the wheelpaths.	For one or two weeks, continue this process from time to time.
6 A second seal may be constructed.	Allow 12 weeks of trafficking on the first seal.
7 Repeat 3 - 6 of the above method of construction.	Sweep clear any loose sand remaining on the first seal before applying binder.

10 Slurry seal

Description of treatment

A mixture of fine aggregates, cement filler, binder emulsion and additional water. This type of surfacing is relatively expensive and works best when laid on an existing bituminous surfacing or a crushed stone roadbase. However, it can be used on low volume roads. As a first surfacing, it should be applied in two layers each being of 5-10 mm thick.

Material quantities

The quantities of the material needed for one mix are calculated from knowing the size or volume of the mixer. The calculations are as follows:

Crusher dust = Mixer volume \times 0.69 litres

Emulsion = Mixer volume \times 0.17 litres

Water = Mixer volume \times 0.11 litres

Cement = Mixer volume \times 0.02 litres

Equipment and tools

- Concrete mixer.
- Wheel barrows.
- Measuring tape of minimum 10 metre length.
- Ball of string.
- Shovels.
- Rakes.
- Brooms.
- Buckets.
- Containers 25, 2, 1 litres.
- Rope.
- 10 mm thick metal rails or wooden batons.
- Spreader rail.
- Wide rubber squeegees.
- Rubber boots.
- Diesel/petrol/oil for mixer.
- Clean water.

SLURRY SEAL

<i>General</i>	<i>Notes</i>
1 Prime the roadbase surface.	Twenty four hours before slurry seal construction is to begin.
2 The area where the concrete mixer is operating must be have a good surface and be kept clean.	Dirt and mud must not be carried by the wheelbarrows onto the surface to be treated.
3 Crusher dust must be dumped close to the mixing site.	Mid-point of the section of road to be treated to the side of the road.
4 The concrete mixer must be checked for oil and fuel.	Concrete mixer operator is responsible.
5 At the end of the work day, the mixer must be cleaned out with water.	Concrete mixer operator is responsible.
6 The mixing and road works site must be kept clean of slurry spillage or contaminants such as mud.	Wheelbarrow operators responsible.
<i>Mixing</i>	<i>Notes</i>
1 Start the mixer and set turning.	The volume of the mixer must be known for material quantities. Material quantities, See page 32.
2 Use measuring containers to add the correct amount of aggregate.	Supervisor of mixing operation is responsible.
3 Slowly add the cement to the aggregate.	Make sure the aggregate and cement are well mixed.
4 Add a small amount of water.	
5 Slowly add the emulsion.	A little at a time to prevent splashing.
6 Carefully add the rest of the water.	2.5 litres at a time and allow time for complete mixing. Inspect the mixture after each addition of water to decide if the full amount of water is required to get the correct creamy appearance.

Continued

SLURRY SEAL (Continued)

<i>Spreading and placing</i>	<i>Notes</i>
1 The surface of the road should be checked for loose materials.	Sweep clear.
2 Mark the lines for the metal rails with a string line and place the rails.	<p>The distance between the rails should be so the minimum amount of discharge and spreading is needed.</p> <p>The rails gauge the depth of the wet slurry. 10 mm depth rails ensure a final minimum depth of 6 mm.</p>
3 Lightly sprinkle water over the area to be treated.	No slurry should be placed on a dry surface. Ensure no free standing water on surface.
4 Wheelbarrows are needed to transport slurry from the concrete mixer to the road.	
5 Discharge the slurry mixture into wheelbarrows in half barrow loads.	The concrete mixer operator is in charge of the transfer of slurry from mixer to wheelbarrow. The operator should ensure the mixture falls into the bowl of the barrow without any wastage.
6 Transfer the half barrow loads of slurry between the rails or batons using shovels.	During this operation the shovels must be dipped into water and wiped with a wet cloth.
7 Spread the slurry over the surface between the rails with rubber squeegees.	
8 Ensure consistent depth.	Two operators to work a spreader rail back and forth at right angles across the rails.
9 The spreader rail and all hand tools should be kept clean.	Water for cleaning may be kept in a half drum near the place of work by transporting it in a barrow.
10 Wipe out empty barrows with a wet cloth to remove any slurry remaining stuck to the bottom of the barrow.	<p>Wheelbarrow operators responsible.</p> <p>No traffic is to be allowed on the surface until the emulsion has broken and set.</p> <p>Stable grade anionic emulsion can take 2 to 3 hours for breaking to happen.</p>
11 Apply a second layer.	The procedure follows that for the first layer. The first layer must be dry and have been open to traffic for 24 hours.

11 Single surface dressing

Description of treatment

On a gravel road, one layer of bituminous binder is sprayed onto the road surface followed by a layer of chippings and finished with a sand seal.

A surface dressing can be successfully constructed using either hot cut-back bitumen such as MC 3000 or a rapid breaking cationic emulsion such as K1-60 that requires no heating. The physical characteristics of the site and the ability to safely heat binder will determine which is used. Generally, on road surfaces with no steep crossfalls or gradients, it is advisable to use an emulsion as the binder.

Bituminous binder

MC3000 cut-back

Emulsion, 60% cationic

Chipping spread rate

Spray rate

See Tables 8 - 10

See Tables 11 - 13

See Tables 14

The full surface dressing design for these and other conditions can be found in Appendix B.

Equipment and tools

- Measuring tape of minimum 10 metre length.
- Vernier gauge.
- String.
- Shovels.
- Rakes.
- Brooms.
- Hand sprayer or watering cans for emulsions only.
- Safe method for the heating of MC3000.
- Buckets.
- Tamping tool.
- Pedestrian roller or tractor or truck.

Materials

- Water.
- MC30 cut-back bitumen or invert emulsion prime.
- MC3000 cut-back bitumen or bituminous emulsion.
- Nominal single size stone chippings.

Table 8 14 mm chippings, MC3000 binder spray rates

<i>Binder spray rate (litres per square metre)</i>						
<i>Climate</i>						
<i>ALD¹ mm</i>	<i>Hot and wet</i>			<i>Hot and dry</i>		
	<i>Type of chippings²</i>			<i>Type of chippings²</i>		
	<i>Rounded</i>	<i>Angular</i>	<i>Flaky</i>	<i>Rounded</i>	<i>Angular</i>	<i>Flaky</i>
8	1.3	1.2	1.2	1.2	1.2	1.1
8.1	1.3	1.2	1.2	1.2	1.2	1.1
8.2	1.3	1.3	1.2	1.3	1.2	1.1
8.3	1.3	1.3	1.2	1.3	1.2	1.1
8.4	1.3	1.3	1.2	1.3	1.2	1.1
8.5	1.3	1.3	1.2	1.3	1.2	1.1
8.6	1.3	1.3	1.2	1.3	1.2	1.1
8.7	1.3	1.3	1.2	1.3	1.2	1.1
8.8	1.3	1.3	1.2	1.3	1.2	1.2
8.9	1.4	1.3	1.2	1.3	1.2	1.2
9	1.4	1.3	1.2	1.3	1.2	1.2
9.1	1.4	1.3	1.2	1.3	1.2	1.2
9.2	1.4	1.3	1.2	1.3	1.2	1.2
9.3	1.4	1.3	1.2	1.3	1.2	1.2
9.4	1.4	1.3	1.2	1.3	1.2	1.2
9.5	1.4	1.3	1.2	1.3	1.2	1.2
9.6	1.4	1.3	1.3	1.3	1.3	1.2
9.7	1.4	1.3	1.3	1.3	1.3	1.2
9.8	1.4	1.3	1.3	1.3	1.3	1.2
9.9	1.4	1.3	1.3	1.3	1.3	1.2
10	1.4	1.3	1.3	1.3	1.3	1.2

¹ *The Average Least Dimension (ALD) is a measure of the average size of chippings and how flaky they are. ALD is obtained by taking a sample of 200 chippings and measuring the least dimension of each chipping with a vernier gauge and calculating the average value.*

² *See Section 3.3, page 7.*

Table 9 10 mm chippings, MC3000 binder spray rates

<i>Binder spray rate (litres per square metre)</i>							
<i>Climate</i>							
<i>Hot and wet</i>				<i>Hot and dry</i>			
<i>Type of chippings</i>				<i>Type of chippings</i>			
<i>ALD mm</i>	<i>Rounded</i>	<i>Angular</i>	<i>Flaky</i>	<i>Rounded</i>	<i>Angular</i>	<i>Flaky</i>	
5	1.2	1.1	1.0	1.1	1.0	1.0	
5.1	1.2	1.1	1.0	1.1	1.0	1.0	
5.2	1.2	1.1	1.0	1.1	1.0	1.0	
5.3	1.2	1.1	1.1	1.1	1.1	1.0	
5.4	1.2	1.1	1.1	1.1	1.1	1.0	
5.5	1.2	1.1	1.1	1.1	1.1	1.0	
5.6	1.2	1.1	1.1	1.1	1.1	1.0	
5.7	1.2	1.1	1.1	1.1	1.1	1.0	
5.8	1.2	1.1	1.1	1.1	1.1	1.0	
5.9	1.2	1.1	1.1	1.1	1.1	1.0	
6	1.2	1.1	1.1	1.1	1.1	1.0	
6.1	1.2	1.2	1.1	1.2	1.1	1.0	
6.2	1.2	1.2	1.1	1.2	1.1	1.0	
6.3	1.2	1.2	1.1	1.2	1.1	1.0	
6.4	1.2	1.2	1.1	1.2	1.1	1.0	
6.5	1.2	1.2	1.1	1.2	1.1	1.0	
6.6	1.2	1.2	1.1	1.2	1.1	1.1	
6.7	1.2	1.2	1.1	1.2	1.1	1.1	
6.8	1.2	1.2	1.1	1.2	1.1	1.1	
6.9	1.3	1.2	1.1	1.2	1.1	1.1	
7	1.3	1.2	1.1	1.2	1.1	1.1	

Table 10 6 mm chippings, MC3000 binder spray rates

<i>Binder spray rate (litres per square metre)</i>						
<i>Climate</i>						
<i>Hot and wet</i>				<i>Hot and dry</i>		
<i>Type of chippings</i>				<i>Type of chippings</i>		
<i>ALD mm</i>	<i>Rounded</i>	<i>Angular</i>	<i>Flaky</i>	<i>Rounded</i>	<i>Angular</i>	<i>Flaky</i>
2	1.0	1.0	0.9	1.0	0.9	0.9
2.1	1.0	1.0	0.9	1.0	0.9	0.9
2.2	1.0	1.0	0.9	1.0	0.9	0.9
2.3	1.0	1.0	0.9	1.0	0.9	0.9
2.4	1.0	1.0	0.9	1.0	0.9	0.9
2.5	1.0	1.0	0.9	1.0	0.9	0.9
2.6	1.0	1.0	0.9	1.0	0.9	0.9
2.7	1.0	1.0	0.9	1.0	0.9	0.9
2.8	1.0	1.0	0.9	1.0	0.9	0.9
2.9	1.0	1.0	0.9	1.0	0.9	0.9
3	1.1	1.0	0.9	1.0	0.9	0.9
3.1	1.1	1.0	1.0	1.0	1.0	0.9
3.2	1.1	1.0	1.0	1.0	1.0	0.9
3.3	1.1	1.0	1.0	1.0	1.0	0.9
3.4	1.1	1.0	1.0	1.0	1.0	0.9
3.5	1.1	1.0	1.0	1.0	1.0	0.9
3.6	1.1	1.0	1.0	1.0	1.0	0.9
3.7	1.1	1.0	1.0	1.0	1.0	0.9
3.8	1.1	1.0	1.0	1.0	1.0	0.9
3.9	1.1	1.0	1.0	1.0	1.0	0.9
4	1.1	1.0	1.0	1.0	1.0	0.9

Table 11 14 mm chippings, Emulsion 60% cationic spray rates

<i>Binder spray rate (litres per square metre)</i>						
<i>Climate</i>						
<i>ALD mm</i>	<i>Hot and wet</i>			<i>Hot and dry</i>		
	<i>Type of chippings</i>			<i>Type of chippings</i>		
	<i>Rounded</i>	<i>Angular</i>	<i>Flaky</i>	<i>Rounded</i>	<i>Angular</i>	<i>Flaky</i>
8	2.0	1.9	1.8	1.9	1.8	1.7
8.1	2.0	1.9	1.8	1.9	1.8	1.7
8.2	2.0	1.9	1.8	1.9	1.8	1.7
8.3	2.0	1.9	1.8	1.9	1.8	1.7
8.4	2.0	1.9	1.8	1.9	1.8	1.7
8.5	2.0	1.9	1.8	1.9	1.8	1.7
8.6	2.0	1.9	1.8	1.9	1.8	1.7
8.7	2.0	1.9	1.8	1.9	1.8	1.7
8.8	2.0	1.9	1.8	1.9	1.8	1.7
8.9	2.0	1.9	1.8	1.9	1.8	1.7
9	2.0	1.9	1.8	1.9	1.8	1.7
9.1	2.0	1.9	1.8	1.9	1.8	1.7
9.2	2.1	2.0	1.9	2.0	1.9	1.8
9.3	2.1	2.0	1.9	2.0	1.9	1.8
9.4	2.1	2.0	1.9	2.0	1.9	1.8
9.5	2.1	2.0	1.9	2.0	1.9	1.8
9.6	2.1	2.0	1.9	2.0	1.9	1.8
9.7	2.1	2.0	1.9	2.0	1.9	1.8
9.8	2.1	2.0	1.9	2.0	1.9	1.8
9.9	2.1	2.0	1.9	2.0	1.9	1.8
10	2.1	2.0	1.9	2.0	1.9	1.8

Table 12 10 mm chippings, Emulsion 60% cationic spray rates

<i>ALD mm</i>	<i>Binder spray rate (litres per square metre)</i>					
	<i>Climate</i>					
	<i>Hot and wet</i>			<i>Hot and dry</i>		
	<i>Type of chippings</i>			<i>Type of chippings</i>		
	<i>Rounded</i>	<i>Angular</i>	<i>Flaky</i>	<i>Rounded</i>	<i>Angular</i>	<i>Flaky</i>
5	1.7	1.6	1.6	1.6	1.6	1.5
5.1	1.7	1.7	1.6	1.7	1.6	1.5
5.2	1.7	1.7	1.6	1.7	1.6	1.5
5.3	1.8	1.7	1.6	1.7	1.6	1.5
5.4	1.8	1.7	1.6	1.7	1.6	1.5
5.5	1.8	1.7	1.6	1.7	1.6	1.5
5.6	1.8	1.7	1.6	1.7	1.6	1.5
5.7	1.8	1.7	1.6	1.7	1.6	1.5
5.8	1.8	1.7	1.6	1.7	1.6	1.5
5.9	1.8	1.7	1.6	1.7	1.6	1.5
6	1.8	1.7	1.6	1.7	1.6	1.5
6.1	1.8	1.7	1.6	1.7	1.6	1.5
6.2	1.8	1.7	1.6	1.7	1.6	1.6
6.3	1.8	1.7	1.7	1.7	1.7	1.6
6.4	1.8	1.7	1.7	1.7	1.7	1.6
6.5	1.8	1.8	1.7	1.8	1.7	1.6
6.6	1.9	1.8	1.7	1.8	1.7	1.6
6.7	1.9	1.8	1.7	1.8	1.7	1.6
6.8	1.9	1.8	1.7	1.8	1.7	1.6
6.9	1.9	1.8	1.7	1.8	1.7	1.6
7	1.9	1.8	1.7	1.8	1.7	1.6

Table 13 6 mm chippings, Emulsion 60% cationic spray rates

<i>Binder spray rate (litres per square metre)</i>							
<i>Climate</i>							
<i>Hot and wet</i>				<i>Hot and dry</i>			
<i>Type of chippings</i>				<i>Type of chippings</i>			
<i>ALD mm</i>	<i>Rounded</i>	<i>Angular</i>	<i>Flaky</i>	<i>Rounded</i>	<i>Angular</i>	<i>Flaky</i>	
2	1.5	1.4	1.4	1.4	1.4	1.3	
2.1	1.5	1.4	1.4	1.4	1.4	1.3	
2.2	1.5	1.4	1.4	1.4	1.4	1.3	
2.3	1.5	1.4	1.4	1.4	1.4	1.3	
2.4	1.5	1.5	1.4	1.5	1.4	1.3	
2.5	1.5	1.5	1.4	1.5	1.4	1.3	
2.6	1.5	1.5	1.4	1.5	1.4	1.3	
2.7	1.6	1.5	1.4	1.5	1.4	1.3	
2.8	1.6	1.5	1.4	1.5	1.4	1.3	
2.9	1.6	1.5	1.4	1.5	1.4	1.3	
3	1.6	1.5	1.4	1.5	1.4	1.3	
3.1	1.6	1.5	1.4	1.5	1.4	1.3	
3.2	1.6	1.5	1.4	1.5	1.4	1.4	
3.3	1.6	1.5	1.4	1.5	1.4	1.4	
3.4	1.6	1.5	1.4	1.5	1.4	1.4	
3.5	1.6	1.5	1.5	1.5	1.5	1.4	
3.6	1.6	1.5	1.5	1.5	1.5	1.4	
3.7	1.6	1.6	1.5	1.6	1.5	1.4	
3.8	1.6	1.6	1.5	1.6	1.5	1.4	
3.9	1.6	1.6	1.5	1.6	1.5	1.4	
4	1.7	1.6	1.5	1.6	1.5	1.4	

Table 14 Spread rate and coverage of chippings

<i>ALD</i> <i>mm</i>	<i>Spread</i> <i>rate</i> <i>kg/m²</i>	<i>Area</i> <i>covered</i> <i>by one</i> <i>'spot' of</i> <i>chippings</i> <i>m²</i>	<i>ALD</i> <i>mm</i>	<i>Spread</i> <i>rate</i> <i>kg/m²</i>	<i>Area</i> <i>covered</i> <i>by one</i> <i>'spot' of</i> <i>chippings</i> <i>m²</i>	<i>ALD</i> <i>mm</i>	<i>kg/m²</i>	<i>Area</i> <i>covered</i> <i>by one</i> <i>'spot' of</i> <i>chippings</i> <i>m²</i>	<i>ALD</i> <i>mm</i>	<i>kg/m²</i>	<i>Area</i> <i>covered</i> <i>by one</i> <i>'spot' of</i> <i>chippings</i> <i>m²</i>
10	13.6	10.4	8	10.9	13	6	8.2	17.3	4	5.5	25.8
9.9	13.5	10.5	7.9	10.8	13.1	5.9	8	17.7	3.9	5.3	26.7
9.8	13.4	10.6	7.8	10.6	13.4	5.8	7.9	17.9	3.8	5.2	27.3
9.7	13.2	10.7	7.7	10.5	13.5	5.7	7.8	18.2	3.7	5	28.4
9.6	13.1	10.8	7.6	10.4	13.6	5.6	7.6	18.7	3.6	4.9	28.9
9.5	13	10.9	7.5	10.2	13.9	5.5	7.5	18.9	3.5	4.8	29.5
9.4	12.8	11.1	7.4	10.1	14	5.4	7.4	19.2	3.4	4.6	30.8
9.3	12.7	11.2	7.3	10	14.2	5.3	7.2	19.7	3.3	4.5	31.5
9.2	12.5	11.3	7.2	9.8	14.5	5.2	7.1	20	3.2	4.4	32.2
9.1	12.4	11.4	7.1	9.7	14.6	5.1	7	20.3	3.1	4.2	33.8
9	12.3	11.5	7	9.5	14.9	5	6.8	20.8	3	4.1	34.6
8.9	12.1	11.7	6.9	9.4	15.1	4.9	6.7	21.2	2.9	4	35.4
8.8	12	11.8	6.8	9.3	15.2	4.8	6.5	21.7	2.8	3.8	37.3
8.7	11.9	11.9	6.7	9.1	15.6	4.7	6.4	22.1	2.7	3.7	38.3
8.6	11.7	12.1	6.6	9	15.8	4.6	6.3	22.6	2.6	3.5	40.5
8.5	11.6	12.2	6.5	8.9	15.9	4.5	6.1	23.1	2.5	3.4	41.7
8.4	11.5	12.3	6.4	8.7	16.3	4.4	6.0	23.6	2.4	3.3	43
8.3	11.3	12.5	6.3	8.6	16.5	4.3	5.9	24.2	2.3	3.1	45.7
8.2	11.2	12.7	6.2	8.5	16.7	4.2	5.7	24.7	2.2	3	47.3
8.1	11	12.9	6.1	8.3	17.1	4.1	5.6	25.3	2.1	2.9	48.9

SINGLE SURFACE DRESSING

<i>Preparation</i>	<i>Notes</i>
1 Calculate area of section to be treated.	Area = section length × section width
2 Decide area of surface to be prepared that day.	
3 Sweep clear loose material and excess dust.	
4 Fill in depressions and holes in surface with gravel and compact.	
5 Sweep clear repaired areas.	
6 Lightly apply water to prepared surface area.	Watering cans may be used.
7 Prime surface to be treated.	Apply prime by hand sprayer.
<i>Construction</i>	<i>Notes</i>
1 Mark out area of road surface to be treated in one day into sections.	Use a string line.
2 Place chippings at set intervals along either side of the road to be treated using half 210 litre drums with the bottom of the drum removed.	See Table 14.
3 Construct a small windrow along the edges of road to mark the limit of the area of surface to be sprayed and to contain any runoff of emulsion.	Sand and gravel or rope may be used.
4 If it is to be used as the binder, arrange for the heating of MC3000 cut-back bitumen. Heat to 155 °C or if a thermometer is not available, until the binder steams and flows very easily.	The heating of MC3000 must be done in a tractor drawn heater tank fitted with a diesel fuelled burner and a hand lance sprayer fitted.
5 If watering cans are to be used with emulsion, measure the volume of watering cans.	

Continued

SINGLE SURFACE DRESSING (Continued)

<i>Construction</i>	<i>Notes</i>
<p>6 Apply MC 3000 or emulsion binder to the surface area by hand lance sprayer.</p> <p>or</p>	
<p>7 Emulsion can be applied using watering cans and spread over area with brooms and brushes after application.</p>	<p>Do not attempt to apply MC3000 with watering cans.</p>
<p>8 Immediately after the binder has been spread, apply the chippings using hand shovels.</p>	<p>Prevent traffic or pedestrians entering the construction area until after the binder and chippings have been spread. Use a broom to help ensure even distribution.</p>
<p>9 Roll the surface</p>	<p>Begin as soon as chippings have been applied to binder.</p>
<p>10 Continue 6 - 9 until the area of the road to treat that day has been completed.</p>	<p>Continue rolling for as long as possible. 2 hours minimum as a guide. Very slow moving traffic may be allowed onto the surface during rolling.</p>
<p>11 When the surface is stable, remove excess chippings.</p>	<p>Sweep the surface in the cool of early morning. Retain excess chippings for use elsewhere.</p>
<p>12 Finish the surface treatment by applying a sand seal.</p>	<p>Follow the construction details from page 30.</p>



Plate 12 Brooming of surface



Plate 13 Application of binder using watering can



Plate 14 Pedestrian roller

12 Double surface dressing

Description of treatment

A bituminous seal consisting of two layers of bituminous binder and two layers of single size stone chippings. The size of the second layer of chippings is roughly half that of the first layer. A combination of chipping sizes that would meet this requirement are a first layer of nominal 14 mm chippings followed by a second layer of 6 mm chippings.

Bituminous binder

MC3000 cut-back

Emulsion, 60% cationic

Spray rate

1st layer and 2nd layer

See Tables 8 - 10

See Tables 11 - 13

Chipping spread rate

See Table 14

Equipment and tools

- Measuring tape of minimum 10 metre length.
- String.
- Shovels.
- Rakes.
- Brooms.
- Hand sprayer or watering cans for emulsion only.
- Safe method for the heating of MC3000.
- Buckets.
- Tamping tool.
- Squeegees.
- Pedestrian roller or tractor.

Materials

- Water.
- MC30 cut-back bitumen or invert emulsion prime.
- MC3000 cut-back bitumen or bituminous emulsion.
- Nominal single size stone chippings.

DOUBLE SURFACE DRESSING

<i>Preparation</i>	<i>Notes</i>
1 Calculate area of section to be treated.	Area = section length × section width
2 Decide area of surface to be prepared that day.	
3 Sweep clear loose material and excess dust.	
4 Fill in depressions and holes in surface with gravel and compact.	
5 Sweep repaired areas	
6 Lightly apply water to prepared surface area.	Watering cans may be used.
7 Prime surface to be treated.	Apply prime by hand sprayer.
<i>Construction (1st layer)</i>	<i>Notes</i>
1 Mark out area of road surface to be treated in one day into sections.	Use a string line.
2 Place chippings at set intervals along either side of the road to be treated using half 210 litre drums with the bottom of the drum removed.	See Table 14.
3 Construct a small windrow along the edges of road.	Sand and gravel or rope may be used.
4 If it is to be used as the binder, arrange for the heating of MC3000 cut-back bitumen. Heat to 155°C or if a thermometer is not available, until the binder steams and flows very easily.	The heating of MC3000 must be done in a tractor drawn heater tank fitted with a diesel fuelled burner and a hand lance sprayer fitted.
5 If watering cans are to be used with emulsion, measure the volume of watering cans.	

Continued ...

DOUBLE SURFACE DRESSING (Continued)

<i>Construction (1st layer)</i>	<i>Notes</i>
6 Apply MC3000 or emulsion binder to the surface area by hand lance sprayer. or	
7 Emulsion can be applied using watering cans and spread over area with brooms and brushes after application.	Do not attempt to apply MC3000 with watering cans.
8 Immediately after the binder has been spread, apply chippings onto top of binder using hand shovels.	Prevent traffic or pedestrians entering the construction area until after the binder and chippings have been spread. Use a broom to help ensure even distribution.
9 Roll the surface.	Begin as soon as chippings have been applied to binder.
10 Continue 6 - 9 until the area of the road to treat that day has been completed.	Continue rolling for as long as possible. 2 hours minimum as a guide. Very slow moving traffic may be allowed onto the surface during rolling.
11 When the surface is stable, remove excess chippings.	Sweep the surface in the cool of early morning. Retain excess chippings for elsewhere.
<i>Construction 2nd layer</i>	<i>Notes</i>
1 Prepare the existing chipping layer by sweeping clear any loose material.	2 to 3 months after construction of 1st layer.
2 Mark out area of road surface to be treated in one day into sections.	Use a string line.
3 Continue to follow stages 2 - 11 as before for the construction of the 1st layer.	



Plate 15 Sweeping excess chippings

13 Single Otta seal

Description of treatment

A bituminous surfacing layer approximately 16 mm thick made up of graded aggregate from natural gravel or crushed rock in combination with a soft bituminous binder. It is suitable for roads and tracks carrying less than 500 vehicles per day.

Bituminous binder

MC3000 cut-back.

Minimum 200 penetration grade

bitumen based emulsion, HFMS-2s,

ASTM specification D2397.

Spray rate

2.0 l/m²

2.4 l/m²

Screened gravel spread rate

See Table 4, page 16.

Equipment and tools

- Measuring tape of minimum 10 metre length.
- String.
- Shovels.
- Rakes.
- Brooms.
- Hand lance sprayer.
- Safe method for the heating of MC3000.
- Buckets.
- Tamping tool.
- Squeegees.
- 12 tonne pneumatic roller (if available) or pedestrian roller and heavily loaded lorry.

Materials

- Water.
- MC30 cut-back bitumen or invert emulsion prime.
- MC3000 cut-back bitumen or HFMS-2s emulsion.
- Screened gravel.

SINGLE OTTA SEAL

<i>Preparation</i>	<i>Notes</i>
1 Decide the area of surface to be prepared that day.	Area = section length × section width.
2 Sweep clear loose material and excess dust.	
3 Fill in depressions and holes in surface with gravel and compact.	
4 Sweep repaired areas.	
5 Lightly apply water to prepared surface area.	Use watering cans.
6 Prime surface to be treated.	Apply prime by hand sprayer at rate of 1.0 - 1.2 litres per square metre.
<i>Construction</i>	<i>Notes</i>
1 Mark out area of road surface to be treated in one day with a string line into 5 metre sections.	
2 Calculate area of first 5 metre length section to be treated.	Area (m ²) = 5 × width of road.
3 Place aggregate at set intervals along either side of the road to be treated using half 210 litre drums with the bottom of the drum removed.	See Table 5, page 17.
4 Using sand or gravel, construct a small windrow along the edges of the area to be treated.	Rope may be used as a substitute.
5 Construct surface treatment in 5 metre length sections.	No more than 3.5 metre wide sections.
6 Arrange for the heating of MC3000 cut-back bitumen. Heat to 155°C or if a thermometer is not available, until the binder steams and flows very easily.	The heating of MC3000 must be done in a tractor drawn heater tank fitted with a diesel fuelled burner and a hand lance sprayer fitted.

Continued

SINGLE OTTA SEAL (Continued)

<i>Construction</i>	<i>Notes</i>
7 Apply correct binder spray rate to the surface area by hand sprayer.	
8 Spread binder over area with brushes after application by watering cans.	
9 Immediately after the binder has been spread, apply graded gravel onto top of binder using hand shovels.	Be sure to prevent traffic or pedestrians entering the construction area until after the binder and aggregate has been spread.
10 Roll the gravel surface	Begin as soon as gravel has been applied to binder.
11 Repeat 8 to 10 until the area of the road to treated that day has been completed.	Continue rolling for as long as possible. 2 hours minimum as a guide. Traffic may be allowed onto the surface during rolling.
12 Remove excess gravel.	Sweep surface clear of excess gravel after a period of 1 week. Retain gravel to be used elsewhere.

14 Double Otta seal

Description of treatment

Suitable for roads and tracks carrying more than 500 vehicles per day. In this respect, this treatment is not strictly necessary for low-volume roads. It is included in the manual to mirror the application of double surface dressing, a seal that is recommended for the upgrading of unpaved roads. A double Otta seal is two bituminous surfacing layers approximately 32 mm thick in total, made up of graded aggregate from natural gravel or crushed rock in combination with a soft bituminous binder.

Bituminous binder

MC3000 cut-back bitumen.

Spray rate

1st layer 2nd layer

1.8 l/m² 2.0 l/m²

Minimum 200 penetration grade

bitumen based emulsion, HFMS-2s,

ASTM specification D2397.

2.4 l/m² 2.4 l/m²

Screened gravel spread rate

See Table 4, page 16.

Equipment and tools

- Measuring tape of minimum 10 metre length.
- String.
- Shovels.
- Rakes.
- Brooms.
- Hand lance sprayer.
- Safe method for the heating of MC3000.
- Buckets.
- Tamping tool.
- 12 tonne Pneumatic roller (if available) or pedestrian roller and heavily loaded lorry.

Materials

- Water.
- MC30 cut-back bitumen or invert emulsion prime.
- MC3000 cut-back bitumen or HFMS-2s emulsion.
- Screened gravel.

DOUBLE OTTA SEAL

<i>Preparation</i>	<i>Notes</i>
1 Decide area of surface to be prepared that day.	Area = section length × section width.
2 Sweep clear loose material and excess dust.	
3 Fill in depressions and holes in surface with gravel and compact.	
4 Sweep clear repaired areas.	
5 Lightly apply water to prepared surface area.	Use watering cans.
6 Prime surface to be treated.	Apply prime by hand sprayer.
<i>Construction 1st layer</i>	<i>Notes</i>
1 Mark out area of road surface to be treated in one day with a string line into 5 metre sections.	
2 Calculate area of first 5 metre length section to be treated.	Area (m ²) = 5 × width of road
3 Place aggregate at set intervals at either side and along the side of the road to be treated using half 210 litre drums with the bottom of the drum removed.	See Table 5, page 17.
4 Using sand or gravel, construct a small windrow along the edges of the area to be treated.	This is to prevent overspray of binder.
5 Construct surface treatment in 5 metre length sections.	No more than 3.5 metre wide sections.
6 Arrange for the heating of MC3000 cut-back bitumen. Heat to 155°C or if a thermometer is not available, until the binder steams and flows very easily.	The heating of MC3000 must be done in a tractor drawn heater tank fitted with a diesel fuelled burner and a hand lance sprayer fitted.

Continued

DOUBLE OTTA SEAL (Continued)

<i>Construction 1st layer</i>	<i>Notes</i>
7 Apply correct binder spray rate to the surface area by hand sprayer.	
8 Spread binder over area with squeegees after application by watering cans.	
9 Immediately after the binder has been sprayed, apply graded gravel onto the top of binder using hand shovels.	Be sure to prevent traffic or pedestrians entering the construction area until after the binder and aggregate has been spread.
10 Roll the gravel surface.	Begin as soon as gravel has been applied to binder.
11 Repeat 8 to 10 until the area of the road to be treated that day has been completed.	Continue rolling for as long as possible. 2 hours minimum as a guide. Any traffic may be allowed onto the surface during rolling.
12 Remove excess gravel.	Sweep surface clear of excess gravel after a period of 1 week. Retain gravel to be used elsewhere.
<i>Construction of 2nd layer</i>	<i>2 to 3 months after construction of 1st layer</i>
1 Sweep clear all loose material and excess dust from the first Otta seal layer.	Construct the 2nd layer in the same way as the 1st by following stages 1 - 12.

15 Pre-mixed bitumen and gravel

Description of treatment

A material made up of washed natural gravel coated with bitumen emulsion that is laid immediately after mixing to a thickness of approximately 40 mm while the emulsion is in an unbroken state.

Bituminous binder

Emulsion, (60% slow setting grade).

Application rate

2 litres per 25kg gravel

Aggregate

1 cubic metre is approximately 230kg.

Equipment and tools

- Measuring tape of minimum 10 metre length.
- String.
- Shovels.
- Rakes.
- Brooms.
- Hand sprayer or watering cans.
- Concrete mixer.
- Wheelbarrows.
- Buckets.
- Tamping tool.
- Pedestrian roller or tractor or truck.
- Wooden batons approximately 40 mm thick.

Materials

- Water.
- MC30 cut-back bitumen or invert emulsion prime.
- Stable grade emulsion.
- Screened gravel.

PRE-MIXED BITUMEN AND GRAVEL

<i>Preparation</i>	<i>Notes</i>
1 Define area of surface to be prepared that day.	
2 Sweep clear loose material and excess dust.	
3 Fill in depressions and holes in surface with gravel and compact.	
4 Sweep clear repaired areas.	
5 Lightly apply water to prepared surface area.	
6 Prime surface to be treated.	
7 Mark out area of surface to be treated and place wooden batons at the sides of this area.	24 hours after priming.
<i>Mixing</i>	<i>Notes</i>
Mechanical mixing method.	Dirt and mud must not be carried by the wheelbarrows onto the surface to be treated.
1 Start the concrete mixer rotating.	Any standard concrete mixer may be used.
2 Add a portion of the emulsion first to the mixer.	To prevent aggregate clinging to the bottom of the mixer.
3 Add the amount of aggregate suitable for the size of mixer in use.	
4 Add the rest of the emulsion.	If the aggregate contains a large amount of fines then more water should be added to the mix.
5 Mix for a short time.	The time of mixing should only be for as long as to fully coat the aggregate. Prolonged mixing will strip the emulsion from the aggregate.

Continued

PRE-MIXED BITUMEN AND GRAVEL (Continued)

<i>Mixing</i>	<i>Notes</i>
Hand mixing method.	
1 Pre-mixed bitumen and gravel may be made by fully manual methods.	In hand mixing the emulsion is poured over the aggregate, which is turned over by shovels until coating is complete.
<i>Spreading and placing</i>	<i>Notes</i>
1 Discharge the mixture into wheelbarrows.	
2 Empty the barrow loads of premix onto the road surface between wooden batons.	
3 Spread the pre-mix over the surface to the depth of the wooden batons (40 mm) with rakes and shovels.	See Plate 16. Take care to avoid segregation of the aggregate. During the operation, the tools must be dipped into water and wiped clean to prevent build up of material.
4 Wait until the emulsion in the pre-mix has broken to the full depth of the layer.	
5 Roll the spread premix with a pedestrian roller.	Water may be sprayed onto the roller drum to act as a lubricant.
6 Spread coarse sand over the rolled pre-mix.	A seal of bitumen and crusher dust or sand will give a more waterproof surface.
7 No traffic is to be allowed on the surface on the day of construction.	
8 When work has finished for the day, barrows must be cleaned of any remaining pre-mix.	Wheelbarrow operators to be responsible.



Plate 16 Placing of material between wooden batons

16 Penetration macadam

Description of treatment

Construction using coarse followed by smaller coarse aggregate, penetrated in-situ by a bituminous binder then thoroughly rolled.

Bituminous binder

Rapid setting emulsion.

Application rate

5.5 - 7.0 litres/m²

Aggregate

Nominal single sized material.

Formation

60% of 40 mm

30% of 28 mm

10% of 14 mm - 20 mm

Equipment and tools

- Measuring tape of minimum 10 metre length.
- String.
- Shovels.
- Rakes.
- Brooms.
- Watering cans.
- Wheelbarrows.
- Buckets.
- Tamping tool.
- 8 tonne roller.

Materials

- Water.
- Cationic rapid break emulsion.

PENETRATION MACADAM

<i>Preparation</i>	<i>Notes</i>
<ol style="list-style-type: none"> 1 Define area of surface to be prepared that day. 2 Sweep clear loose material and excess dust. 3 Fill in depressions and holes in surface with gravel and compact. 4 Sweep clear repaired areas. 	
<i>Construction</i>	<i>Notes</i>
<ol style="list-style-type: none"> 1 Unload aggregate outside the area of road to be treated. 2 Lay the 40 mm aggregate on the road surface. 3 Lay the 28 mm aggregate. 4 Lay the 14 mm-20 mm aggregate. 5 Roll and compact the aggregate. 6 Dampen the surface of the aggregate. 7 Apply emulsion to the newly rolled surface at the required rate. 	<p>Ensure aggregate does not become contaminated with dirt and dust.</p> <p>Aggregate may be laid by hand. See Plate 17.</p> <p>Rolling should begin from the edges of the road and work towards the centre.</p> <p>Continue rolling until no movement of the aggregate is seen. See Plate 18.</p> <p>See Plate 19.</p> <p>Apply with watering cans. See Plate 20.</p>



Plate 17 Largest aggregate placed by hand



Plate 18 Compacted surface



Plate 19 Aggregate damping by hand



Plate 20 Application of emulsion binder

17 Maintenance

Whichever bituminous surface has been constructed it is essential the road surface, shoulders and adjacent land be inspected at regular times so that any failures can be identified and repaired by appropriate maintenance. The outcome of failing to carry out maintenance will almost certainly lead to common failures in the surface of the road that must be repaired, include cracking, rutting, shoving, potholes and edge damage.

It is beyond the scope of this manual to describe all the possible failures and defects that may occur but attention should be given to the condition of shoulders and roadside areas with respect to drainage. It is essential to maintain the adequate drainage of water from the road surface to keep the road structure and surface sound. Therefore, attention and maintenance should be applied to the drainage system including ditches, piped drains and culverts. Some common problems and suggested remedies are as follows.

Obstructions on road shoulders.

These cause slowing or prevention of surface water flowing from the road surface therefore obstructions should be removed.

The level of the shoulders becomes higher than level of road.

This results in water ponding at the edges of the road surface, causing weakening of the underlying layers of the road. The maintenance action is to reshape and remove material from the shoulders to the correct level and to clear any excess vegetation that may be contributing to the problem.

The level of the shoulders becomes lower than the level of the road with ruts and depressions.

Not enough support is given to the road and the shoulders become soft allowing edge breaks from the road. Material should be added to the shoulders and compacted back to the level of the road pavement.

Obstructions in ditches and drains

Growths of vegetation, fallen trees, loose silt or rock cause blockage of the ditch. The ditch should be cleared and cleaned.

Silting

Caused by water flowing too slowly leading to blockage of the ditch. The ditch should be deepened.

Ponding of water in ditches and on the shoulders.

The ditch cross-section is too small or the gradient of the ditch is too flat. If left alone the shoulder material will become soft and can erode. In extreme cases the road can be flooded leading to weakening of the pavement layer. The ditches should be deepened and new turn out drains constructed.

Appendix A: Worked examples

Priming

An unpaved road, 100 metres long and 3.5 metres wide, within a village, is to be treated with a sand seal. The track is to be primed using an invert emulsion and applied with a hand lance.

- 1 Calculate the spray delivery rate of the hand lance by timing how long it takes to fill a 10 litre container.
- 2 Time to fill container = 65 seconds.
- 3 Therefore delivery spray rate = $10 \text{ litres} \div 65 \text{ seconds} = 0.154 \text{ litres per second}$.
- 4 Application spray rate of invert emulsion = 1.2 litres per square metre.
- 5 Mark out the length of the track using string or other means into convenient length sections, for example 5 metre long sections.
- 6 Each section therefore covers an area of $5 \times 3.5 = 17.5$ square metres.
- 7 Each section should receive $17.5 \times 1.2 = 21$ litres of invert emulsion.
- 8 The time to spray this section area = $21 \div 0.154 = 136$ seconds.
- 9 The priming should be carried out by two people pushing the emulsion drum carrier backwards along the track as the hand lance operator sprays each 5 metre long section in 136 seconds by spraying from side to side. A timekeeper calls out the time in intervals to the hand lance operator so checks on the coverage of emulsion can be made.
- 10 Stage 9 should be practised on waste ground if operators are new or inexperienced in the use of the hand lance.

Sand seal

An unpaved road that carries mainly pedal cycle and pedestrians, 3 metres wide, 500 metres long through a village, is to be sand sealed using labour-based methods. A cationic emulsion is to be used as the bituminous binder. Only watering cans are available.

- 1 The area of the road should first have been primed and swept clear of any loose material.
- 2 Area to be sand sealed = $3 \times 500 = 1500$ square metres.
- 3 Binder spray rate = 1.6 litres per square metre.
- 4 Therefore $1.6 \times 1500 = 2400$ litres of emulsion required.
- 5 The watering cans hold 10 litres of emulsion.
- 6 Therefore 1 watering can will cover 6.25 square metres.
- 7 Allow 1 watering can of emulsion to be spread by brooms or squeegees to 6 square metres of the track.
- 8 As the track is 3 metres wide, 2 metre lengths can be covered at a time by one watering can.
- 9 The sand should be applied at 13 to 19 kilograms per square metre.
- 10 Therefore, 78 to 114 kilograms should be spread over each 6 square metre section.
- 11 Roll the surface with a pedestrian roller.

Slurry seal

A 3 metre wide unpaved track along 300 metres of its length is to be slurry sealed using labour-based methods. The mixing of the slurry is to be carried out by a concrete mixer of 110 litre capacity.

- Area of road to be treated = $3 \times 300 = 900$ square metres.
- Each batch mix requires amounts of materials as follows.
 - Crusher dust = $0.6897 \times 110 = 75.9$ litres.
 - Emulsion = $0.1724 \times 110 = 19$ litres.
 - Water = $0.1149 \times 110 = 12.6$ litres.
 - Cement = $0.0230 \times 110 = 2.5$ litres.

Half the width of the track will be constructed at a time.

Therefore half the width = 1.5 metres.

To construct a slurry seal of 5 mm thick, each mix of 110 litres will cover approximately a section length of 14.5 metres and is calculated from,

Width of section = 1.5 metres = 150 centimetres

Slurry seal thickness = 5 mm = 0.5 centimetres

Volume of mixer = 110 litres = 110×1000 cubic centimetres

$$\text{Length} = \frac{\text{Volume}}{\text{Width of section} \times \text{Slurry seal thickness}}$$

$$\text{Length (cms)} = \frac{110 \times 1000}{150 \times 0.5} = \frac{110000}{75} = 1466.7$$

$$\text{Length (metres)} = \frac{1466.7}{100} = 14.7$$

Single surface dressing

In a hot and dry climate, 250 metres of a rural road 3.6 metres wide, carrying 30 vehicles per day, through a village is to be single surface dressed with angular 10 mm chippings whose ALD has been measured as 6.2 mm. A hand-operated sprayer with a rate of delivery of 0.25 litres per second is available for the application of bituminous binders. A 60% bituminous emulsion binder is to be used. Watering cans contain 9 litres. The full width of the road may be treated at once.

Prime

- 1 Total area of road to be treated is $250 \text{ metres} \times 3.6 \text{ metres} = 900$ square metres.
- 2 Sweep the area clear during the day.
- 3 Lightly dampen the road surface with water applied by watering cans
- 4 Prime surface with MC30 cut-back. Apply at 1.0 litres per square metre.
- 5 Volume of prime needed for 900 square metres = $1.0 \times 900 = 900$ litres.
- 6 Total time to spray 900 litres over 250 metres = $900 \div 0.25 = 3600$ seconds = 60 minutes.
- 7 To ensure the correct spray rate of prime is applied, the operator of the sprayer should in 1 minute cover $(250 \div 60) =$ approximately 4.2 metre length of the road.

Single surface dressing

- 1 Chipping spread rate = 8.5 kg/m^2 (see Table 14).
- 2 One 'spot' of chippings will cover 16.7 square metres (see Table 14).
- 3 Length of road one 'spot' will cover is $16.7(\text{area}) \div 3.6(\text{width}) = 4.6$ metres (approximately 4.5 metres).
- 4 Therefore 'spot' the chippings along the road approximately every 4.5 metres
- 5 For convenience, measure and mark out the first 45 metres of the road to be treated into 4.5 metre length sections.
- 6 Therefore area of each section = $4.5 \times 3.6 = 16.2$ square metres.

Emulsion binder	}	Binder spray rate see Table 12.
Hot and dry climate		
Angular 10 mm chippings		
ALD = 6.2 mm		

- 7 Binder spray rate = 1.6 litres per square metre.
- 8 Volume of binder to spray first section = $16.2 \times 1.6 = 25.92$ litres.
- 9 To spray each section, the hand sprayer should apply the binder in $25.92 \div 0.25 = 103.68$ seconds.

Alternatively, if watering cans were used to apply the binder then to cover each section of 16.2 square metres with 25.92 litres would require 2.9 watering cans of 9 litre capacity. Therefore,

Apply 3 watering cans of binder to section 1 and spread evenly with brooms.

- 10 Spread chippings over surface of binder using hand shovels.
- 11 Repeat the above for section 2,3,4,-,-,-,-,10 and begin rolling operation when sufficient sections have been treated so the roller is not in the way of the spraying and spreading operation.
- 12 Repeat above sequence until the entire 250 metre length has been treated.

Double surface dressing

In a hot and dry climate, 450 metres of a rural road 6 metres wide, carrying 30 vehicles per day, through a village is to be double surface dressed with 14 mm and 6 mm chippings of measured ALD 8.4 mm and 3.4 mm respectively. The chippings are rounded in shape. A hand-operated sprayer with a rate of delivery of 0.25 litres per second is available for the application of bituminous binders. A 60% bituminous emulsion binder is to be used. Watering cans contain 9 litres. The two lanes or sides of the road must be surface dressed separately.

Prime

- 1 Total area of road to be treated is $450 \text{ metres} \times 6 \text{ metres} = 2700$ square metres.
- 2 Sweep the area clear during the day.
- 3 Lightly dampen the road surface with water applied by watering cans.
- 4 Prime surface of road with MC30 cut-back bitumen. Apply at 1.0 litres per square metre.
- 5 Therefore the volume of prime required for 2700 square metres = $1.0 \times 2700 = 2700$ litres.
- 6 The total time to spray 2700 litres over the 450 metre length of road, will take $2700 \div 0.25 = 180$ minutes.
- 7 To ensure the correct rate of prime is applied, the operator of the sprayer should in 1 minute cover $(450 \div 180) =$ approximately 2.5 metre length of the road.

Surface dressing 1st layer

- 1 Chipping spread rate = 11.5 kg/m^2 . (see Table 14).
- 2 Half the width of the road must be treated at a time. Therefore width = 3 metres.
- 3 One 'spot' of chippings will cover 12.3 square metres (see Table 14)
- 4 Length of road one 'spot' will cover is $12.3(\text{area}) \div 3(\text{width}) = 4.1$ metres (approximately 4 metres).
- 5 Therefore 'spot' the chippings along the road approximately every 4 metres.
- 6 For convenience, measure and mark out the first 40 metres of the road to be treated into 4 metre length sections.
- 7 Therefore area of each section = $4.0 \times 3.0 = 12.0$ square metres

Emulsion binder	}	Binder spray rate see Table 11.
Hot and dry climate		
Rounded 14 mm chippings		
ALD = 8.4 mm		

Emulsion binder spray rate = 1.9 litres per square metre.

- 8 Volume of binder to spray first section = $12.0 \times 1.9 = 22.8$ litres.
- 9 The hand sprayer should apply the binder in $22.8 \div 0.25 = 91$ seconds.

Alternatively, if watering cans were used to apply the binder then to cover each section of 12 square metres with 22.8 litres of binder would require a little over 2.5 watering cans of 9 litre capacity. Therefore,

Apply 2.5 watering cans of binder to first section and spread evenly with brooms.

- 10 Spread chippings over the surface of the binder using hand shovels.
- 11 Repeat the above for section 2,3,4,-,-,-,-,10 and begin rolling operation when sufficient sections have been treated so roller is not in the way of the spraying and spreading operation.
- 12 Repeat above sequence until entire 450m has been treated.
- 13 Repeat 1 to 12 for the other side of the road.

Surface dressing 2nd layer applied 3 months after 1st layer.

- 1 Chipping spread rate = 4.6 kg/m² (see Table 14).
- 2 One spot of chippings will cover = 30.8 square metres (see Table 14).
- 3 Half the width of the road must be treated at a time. Therefore width = 3 metres.
- 4 Length of road one 'spot' will cover = $30.8(\text{area}) \div 3(\text{width}) = 10.3$ metres (approximately 10 metres).
- 5 Therefore 'spot' the aggregate on either side and along the road every 10 metres.
- 6 For convenience, measure and mark out the first 100 metres of the road to be treated into 10 metre sections.
- 7 Therefore area of each section = $10 \times 3.0 = 30$ square metres

Emulsion binder	}	Binder spray rate see Table 13.
Hot and dry climate		
Rounded 6 mm chippings		
ALD = 3.4 mm		

8 Emulsion binder spray rate = 1.5 litres per square metre.

9 Volume of binder to cover first section = $30 \times 1.5 = 45$ litres.

10 The hand sprayer should apply the binder in $45 \div 0.25 = 180$ seconds.

Alternatively, if watering cans were used to apply the binder then to cover each section would require 5 watering cans of 9 litre capacity. Therefore,

Apply 5 watering cans of binder to first section and spread evenly with brushes.

11 Spread chippings over the surface of the binder using hand shovels.

12 Repeat the above for section 2,3,4,-,-,-,-,10 and begin rolling operation when sufficient sections have been treated so roller is not in the way of the spraying and spreading operation.

13 Repeat above sequence until the entire 450m has been treated.

14 Repeat 1 to 12 for the other side of the road.

Single Otta seal

250 metres of rural road 3.5 metres wide, carrying 20 vehicles per day, running through a village is to be treated with a single Otta seal. A hand-operated sprayer with a rate of delivery of 0.3 litres per second is available for the application of bituminous binders. MC3000 cut-back bituminous binder is to be heated by a tractor drawn heater tank fitted with a diesel fuelled burner. A road diversion is possible and therefore the entire width of the road may be treated at once.

- 1 Total area of the road to be treated = $3.5 \text{ metres} \times 250 \text{ metres} = 875 \text{ square metres}$.
- 2 The 250 metre length of road is marked out into 5 metre long sections = 50 sections.
- 3 Each section is therefore = 17.5 square metres.

Prime

- 1 The rate of spray of the MC30 prime = 1.0 litres per square metre.
- 2 Therefore each 5 metre section will need = $17.5 \times 1.0 = 17.5 \text{ litres MC30}$.
- 3 The time to spray this amount with the hand sprayer with a rate of delivery of 0.3 litres per second = $17.5 \div 0.3 = 58.3 \text{ seconds}$.
- 4 The time to prime the 250 metre length of the road = 48.6 minutes in total.

Single Otta seal

- 1 Aggregate spread rate = 10 - 11 kg/m² (see Table 4).
- 2 One 'spot' of aggregate will cover 7.5 square metres (see Table 4).
- 3 Length of road one 'spot' will cover is $7.5(\text{area}) \div 3.5(\text{width}) = 2.1 \text{ metres}$.
- 4 Spot the aggregate along the road every 2 metres (see Table 5).
- 5 For convenience, measure and mark out the first 20 metres of the road to be treated into 2 metre length sections.
- 6 Therefore area of each section = $3.5 \times 2 = 7.0 \text{ square metres}$.
- 7 Binder spray rate = 2.0 litres per square metre.
- 8 Volume of binder to spray each section = $7.0 \times 2.0 = 14.0 \text{ litres}$.
- 9 The hand sprayer should apply the binder in $14.0 \div 0.3 = 46.7 \text{ seconds}$.

Alternatively, if watering cans were used to apply the binder then to cover each section of 7.0 square metres would require approximately 1.5 watering cans of 10 litre capacity. Therefore,

Apply 1.5 watering cans of binder to first section and spread evenly with brushes.

10 Spread aggregate over the surface of the binder using hand shovels.

Repeat the above for the following sections and begin rolling operation when sufficient sections have been treated so roller is not in the way of the spraying and spreading operation.

Repeat above sequence until the entire 250 metre length of the road has been treated.

Double Otta seal

1st layer

If the road previously described in the construction of a single Otta seal was to have been treated with a double Otta seal, then first a single Otta seal should be constructed as before except the rate of spray of MC3000 for the first layer is 1.8 l/m^2 .

2nd layer

- 1 Begin construction two or three months after the construction of the single Otta seal.
- 2 Sweep clear loose gravel from surface.
- 3 The stages of construction are the same as for the single Otta seal except,
- 4 Binder spray rate = 2.0 litres per square metre.
- 5 Volume of binder to spray first section = $7.0 \times 2.0 = 14.0$ litres.
- 6 The hand sprayer should apply the binder in $14.0 \div 0.3 = 46.7$ seconds.
- 7 Alternatively, if watering cans were used to apply the binder then to cover each section of 7.0 square metres would require approximately 1.5 watering cans of 10 litre capacity.
- 8 Apply 1.5 watering cans of binder to first section and spread evenly with brushes.
- 9 Spread aggregate over the surface of the binder using hand shovels.
- 10 Repeat the above for the following sections and begin rolling operation when sufficient sections have been treated so roller is not in the way of the spraying and spreading operation.
- 11 Repeat above sequence until the entire 250 metre length of one side of the road has been treated.

Pre-mixed bitumen and gravel

An unpaved road, 6 metres wide, that approaches a bridge down a short hill of 30 metres in length is to be improved by surfacing with pre-mixed bitumen and gravel to a depth of 40 mm. A stable grade emulsion (CSS60) is chosen as the bituminous binder.

- 1 The road surface is prepared by reshaping and compaction and is primed before the start of construction of the pre-mixed bitumen and gravel surface.
- 2 Aggregate that is to be used as the gravel is screened to remove large stones greater than 12 mm in size.
- 3 The area of the road to be surfaced is 6 metres \times 30 metres = 180 square metres. 90 square metres each side of the road.
- 4 Therefore, the volume of gravel needed for one side of the road is,

$$90 \times \frac{40}{1000} = 3.6 \text{ cubic metres}$$

- 5 1 cubic metre of gravel weighs approximately 230 kilograms.
- 6 Therefore, the total weight of gravel needed is $230 \times 3.6 = 828$ kilograms. Each mix contains 150 kilograms of gravel.
- 7 For one side of the road, 5.5 mixes are needed in total.
- 8 The aggregate is moistened slightly before mixing with the emulsion in an ordinary rotary concrete mixer of 200 litre capacity.
- 9 2 litres of emulsion are mixed with every 25 kilograms of aggregate.
- 10 The mixer is run a short time until the emulsion has coated all of the aggregate.
- 11 The mixture is then loaded into wheelbarrows and spread with steel rakes between wooden batons of 40 mm depth.
- 12 The pre-mix is then rolled.
- 13 Steps 9 - 12 are repeated for the other side of the road.

Penetration macadam

A parking area for heavy trucks is on an unpaved surface, 6 metres wide, 50 metres in length. It is to be improved by surfacing with Penetration Macadam. A rapid break cationic emulsion (CRS60) is chosen as the bituminous binder.

Reshape and compact the existing surface. Priming is not required for this construction method.

Area to be constructed = 6 metres \times 50 metres = 300 square metres.

Binder application rate = 7 litres per square metre.

Amount of emulsion required in total = 7 \times 300 = 2100 litres.

Appendix B: Design of surface dressing

The average least dimension (ALD) of a representative sample of some 200 chippings each is taken from stockpiles of screened aggregate.

Adjustment weighting factors, see Table B1, are used to match the conditions found at the construction site and overall weighting factor is calculated (F) from them. An example is shown in Table B2 where F is calculated for single and double dressings.

Using the ALD and 'F' values in equation B1 gives the required basic rate of spray of binder in terms of MC3000.

$$R = 0.625 + (F \times 0.023) + [0.0375 + (F \times 0.0011)] \times \text{ALD} \quad (\text{B1})$$

Where F = Overall weighting factor

ALD = the average least dimension of the chippings

R = Basic rate of spray of bitumen.

If emulsion is used as the binder then the basic rate of spray of binder is given calculating $R \times (90\% \text{ bitumen})$.

Example

Using the ALD values of 4.9 mm and 2 mm and the F factors from Table B2, for a single or first dressing, the rate of spray for MC3000 is 1.09 kg/m² or 1.64 kg/m² for emulsion containing 60 per cent bitumen. For the second dressing, the rate of spray for MC3000 is 0.9 kg/m² or 1.35 kg/m² for emulsion containing 60 per cent bitumen.

In the design, there is also an option to increase the bitumen application rate by 8 per cent to ensure that the maximum durability is obtained on low traffic volume roads.

Table B1 Weighting factors for surface dressing design

<i>Property</i>	<i>Description</i>	<i>Factor</i>	
Total traffic (all motorised classes)	Vehicles/lane/day		
	Very light	0 - 50	+3
	Light	50 - 250	+1
	Medium	250 - 500	0
	Medium-heavy	500 - 1500	-1
	Heavy	1500 - 3000	-3
	Very heavy	3000+	-5
Existing surface	Untreated or primed base		+6
	Very lean bituminous		+4
	Lean bituminous		0
	Average bituminous		-1
	Very rich bituminous		-3
Climatic conditions	Wet and cold		+2
	Tropical (wet and hot)		+1
	Temperate		0
	Semi-arid (hot and dry)		-1
	Arid (very dry and very hot)		-2
Type of chippings	Round/dusty		+2
	Cubical		0
	Flaky		-2
	Pre-coated		-2

Table B2 Adjustment factors for single and double surface dressings

	<i>First or single dressing</i>		<i>Second dressing</i>	
Traffic	Very light	+3	Very light	+3
Surface condition	Primed roadbase	+6	Very lean bituminous	+4
Climate	Hot and wet	+1	Hot and wet	+1
Type of chippings	Cubical	0	Cubical	0
Total, 'F' Factor		+10		+8

Appendix C: Hand lance delivery spray rates

<i>Time to fill container (Seconds)</i>	<i>Rate of delivery Litres per second</i>	
	<i>10 litre container</i>	<i>5 litre container</i>
30	0.333	0.167
31	0.323	0.161
32	0.313	0.156
33	0.303	0.152
34	0.294	0.147
35	0.286	0.143
36	0.278	0.139
37	0.270	0.135
38	0.263	0.132
39	0.256	0.128
40	0.250	0.125
41	0.244	0.122
42	0.238	0.119
43	0.233	0.116
44	0.227	0.114
45	0.222	0.111
46	0.217	0.109
47	0.213	0.106
48	0.208	0.104
49	0.204	0.102
50	0.200	0.100
51	0.196	0.098
52	0.192	0.096
53	0.189	0.094
54	0.185	0.093
55	0.182	0.091
56	0.179	0.089
57	0.175	0.088
58	0.172	0.086
59	0.169	0.085
60	0.167	0.083

$$\text{Rate of delivery (litres per second)} = \frac{\text{Volume of container}}{\text{Time to fill container}}$$

