

Implementing employment intensive road works

A **cidb** practice manual

Contributing to contractor development in
job creation

MANUAL 4

Bituminous pavement seals

Published by the Construction Industry Development Board (cidb)
Private Bag X14, Brooklyn Square, 0075

Copyright vests in the cidb
© 2007, cidb, Pretoria

ISBN: 978-0-620-38198-7

MARCH 2007

Implementing employment intensive road works

MANUAL 4

Bituminous pavement seals

cidb is a public entity established in terms of the CIDB Act, 2000 to provide strategic direction for sustainable growth, reform and improvement of the construction sector and its enhanced role in the country's economy. In pursuit of this aim cidb partners with stakeholders and regulates the construction industry around a common development agenda underpinned by best practice procurement and project processes.

Construction Industry Development Board

Private Bag X14, Brooklyn Square, 0075
Tel: 27 12 - 481 9030 Fax: 27 12 - 343 7153
email: cidb@cidb.org.za website: www.cidb.org.za

Constructing shared growth

This set of practice manuals for employment intensive road construction, draws on the experience of the South African Construction Industry in the development of road building contractors, supervisors and designers, in implementing road works and creating jobs; and builds upon the labour-based best practice guidelines that have been published by the Construction Industry Development Board. (cidb) (see www.cidb.org.za):

“.....with the right construction technology, South Africa can successfully address infrastructural backlogs in a cost-efficient way and to acceptable engineering standards. We are saying we can do this while maximising job opportunities....”

(Ms Thoko Didiza, Minister of Public Works. Vuk'uphile learners welcoming ceremony, Nkangala, Mpumalanga, 29 June 2006.)

In assembling this publication, the cidb has collaborated with the Council for Scientific and Industrial Research (CSIR), and the International Labour Organisation (ILO) in fulfilment of the cidb's mandate to promote “national social and economic objectives, including the labour absorption in the construction industry”. (CIDB Act 38 of 2000). The cidb is committed to further partnerships with industry and stakeholders, to promote the use of these manuals and the training of SME contractors within the framework of the National Contractor Development Programme and the Construction Charter.

These manuals are supported by the Expanded Public Works Programme (EPWP), which directs a significant and increasing proportion of South Africa's public investment towards a labour intensive programme of construction, drawing the unemployed into productive work and providing access to skills development.

Implementing employment intensive road works

• **MANUAL 1: The fundamentals of road construction**

- Module 1: Basic mathematical concepts and calculations
- Module 2: Survey concepts
- Module 3: Material concepts
- Module 4: Material-related concepts
- Module 5: Typical road terms and components

• **MANUAL 2: Planning and contract management**

- Module 1: Documentation on which a contract is based
- Module 2: The role and authority of parties involved in the contract
- Module 3: The establishment and management of a construction camp
- Module 4: Health and safety issues
- Module 5: Contract planning and preparation of a programme
- Module 6: Quality control of the work
- Module 7: Local labour employed on special public works programmes
- Module 8: Broad environmental issues

• **MANUAL 3: Gravel pavement layers**

- Module 1: Safety during construction
- Module 2: Setting out
- Module 3: Construction of unstabilised gravel pavement layers (excluding base)
- Module 4: Construction of a gravel wearing course
- Module 5: Construction of a stabilised base course
- Module 5.1: Emulsion-treated base course (ETB)
- Module 5.2: Composite emulsion-treated base
- Module 6: Indicative production and task rates

• **MANUAL 4: Bituminous pavement seals**

- Module 1: Safety during construction
- Module 2: Procedure for operation and applying binder using the motorised hand sprayer
- Module 3: Construction of a single seal
- Module 4: Construction of a slurry seal
- Module 5: Construction of a Cape seal
- Module 6: Construction of an Otta seal
- Module 7: Indicative production and task rates

• **MANUAL 5: Concrete and masonry drainage works and structures**

- Module 1: Safety during construction
- Module 2: Concrete and mortar
- Module 3: Construction of lined channels and chutes
- Module 4: Construction of culverts/small bridges
- Module 5: Construction of drifts and causeways
- Module 6: Construction of erosion control structures
- Module 7: Process for placing pipes without the use of plant
- Module 8: Indicative production and task rates

• **WORKSHOP DRAWINGS**

Workshop drawings of selected items of specialised equipment



OVERVIEW of the practice manuals

The South African White Paper *Creating an Enabling Environment for Reconstruction, Growth and Development in the Construction Industry* (1999), expresses a vision for public-sector delivery aimed at optimising employment opportunities through labour-intensive construction. This can be realised in the delivery of infrastructure through the adoption, where technically and economically feasible, of

- labour-based methods of construction and manufacture where labour, utilising hand tools and light equipment, is preferred to the use of heavy equipment for specific activities.
- labour-based technologies where there is a shift in balance between labour and equipment, in the way the work is specified and executed for selected works components.

This **cidb** practice manual for *Implementing Employment Intensive Road Works* follows on from the **cidb**'s guide to best practice for *Labour-based Methods and Technologies for Employment-Intensive Construction Works*. The latter covers a broad spectrum of construction works. It establishes desirable and appropriate standards, processes, procedures and methods; relating to the design and implementation of labour-based construction technologies, methods for earthworks and for materials manufacture. This first set of guidelines provides sufficient technical information to enable those, responsible for the design of projects, to make confident and informed choices on their use in projects.

Implementing Employment Intensive Road Works aims to provide practical and technical guidance to small and medium sized (SME) contractors, supervisors and designers who are involved in the construction and upgrading of roads using labour and light plant. The need for these technical manuals was identified during the training of SME contractors, involved in the Gundo Lashu programme in Limpopo Province – a programme of labour-based upgrading of rural roads, promoted by the Department of Public Works, Roads and Transport in collaboration with the International Labour Organisation (ILO).

The development of this series of manuals is based on:

- experience gained in South Africa over the last ten years, including that of the Gundo Lashu project presently being implemented by the Road Agency Limpopo, with technical assistance from the ILO,
- best practices implemented by a number of Sub-Saharan countries,
- the relevant **cidb** best practice guidelines, in its series of *Labour-based Methods and Technologies for Employment-Intensive Construction Works*.

These manuals support the objectives of South Africa's Expanded Public Works Programme (EPWP), and are aligned with the *Guidelines for the Implementation of Labour-intensive Infrastructure Projects under the Expanded Public Works Programme (EPWP)* of the Department of Public Works, obtainable on www.epwp.gov.za.

Acknowledgements

These manuals were compiled by the CSIR in collaboration with, and funding from, the ILO and **cidb** to promote the implementation of employment-intensive road works.

A **cidb** Focus Group of industry specialists and stakeholders has further reviewed and refined these manuals.

The contribution of these individuals whose passion, commitment and knowledge has enabled the development of this publication as a common resource in the fight against poverty and joblessness, both in South Africa and globally, is acknowledged. Special thanks to:

- Adrian Bergh and Alex McKay of the CSIR.
- Jon Hongve of the ILO.
- Rob Little, Bryan Westcott, Ian van Wyk and Ron Watermeyer of the **cidb** Focus Group.
- Maikel Lieuw Song, Basotho Seetsa and Mpayo Kasure of the Department of Public Works, as members of the **cidb** Focus Group.
- The many organisations and individuals referred to in the references quoted in these manuals.

MANUAL 4: Bituminous pavement seals

Contents

Introduction	9
Module 1: Safety during construction	10
Module 2: Procedure for operating and applying binder	13
using the motorised hand sprayer	
Module 3: Construction of a single seal	23
Module 4: Construction of a slurry seal	38
Module 5: Construction of a Cape seal	52
Module 6: Construction of an Otta seal	74
Module 7: Indicative production and task rates	90
References	92



Introduction

1. Aim

The aim of this manual is to provide contractors, involved in the labour-based construction of bituminous seals, with a detailed description of the materials, plant and equipment and processes involved in the construction of this work.

2. Composition

The manual comprises the following modules:

- Module 1: Safety during construction
- Module 2: Procedure for operating and applying binder using the motorised hand sprayer
- Module 3: Construction of a single seal
- Module 4: Construction of a slurry seal
- Module 5: Construction of a Cape seal
- Module 6: Construction of an Otta seal
- Module 7: Indicative production and task rates

3. Notes to designer/consultant

A set of 'Notes to designer/consultant' is included at the end of the modules comprising this manual, where applicable. These notes are provided to highlight important aspects, applicable to that module that the designer/consultant should take into account.

4. Supplementary manuals

- Manual 1: The fundamentals of road construction
- Manual 2: Planning and contract management
- Manual 3: Gravel pavement layers
- Manual 5: Concrete and masonry drainage works and structures

5. Bibliography

Surfacing seals for rural and urban roads. 1998. Pretoria: Department of Transport (Draft technical Recommendations for Highways; Draft TRH3).

Guidelines for low-volume sealed roads. July 2003: South African Transport and Communications Commission (SATCC).

Labour Intensive Construction Techniques Volume 7: Upgrading techniques for low volume roads/streets. August 1996: Pretoria: Department of Transport (LICT 7).

Labour enhanced construction for bituminous surfacings: Manual 12 – Methods and procedures: August 1994: South African Bitumen and Tar Association (SABITA).

The Design, Construction and Maintenance of Otta Seals: Guideline No. 1: June 1999: Republic of Botswana, Ministry of Works, Transport and Communications.

Labour enhanced construction for bituminous surfacings: Manual 11: March 1993: South African Bitumen and Tar Association (SABITA).



MODULE 1: Safety during construction

1. General

A number of parties are involved with safety during construction, namely:

- The travelling public using the facility/road under construction.
- The contractor executing the work.
- The client/consulting engineer responsible for designing, specifying and supervising the contract.

The *Occupational Health and Safety Act – Act 85/1993* has important implications for the contracting parties. It is important that the parties are conversant with the act and its implications, as it affects the execution of the work and that the necessary Health and Safety Plan is in place, in accordance with the client's Health and Safety Specifications. Refer also to Manual 2: Module 4: Health and safety issues.

Main objectives of this act are:

- To provide for the health and safety of persons at work, and for the health and safety of persons in connection with the use of plant and machinery.
- The protection of persons, other than persons at work, against hazards to health and safety arising out of, or in connection with, the activities of persons at work.

2. Safety of road users/public

The safety of the public is materially affected by the actions of the contractor and his staff i.e. the manner in which traffic is accommodated during construction, the erection of suitable road signs and warning devices, and adherence by the workers to these road signs and other safety arrangements.

Requirements for the accommodation of traffic are laid down in the relevant specifications, referred to in the scope of the work, in the contract documents.

Construction based on methods to promote job creation means that more people will be involved in the execution of the contract, for a greater length of time than would normally be the case with conventional methods. It is therefore even more important to comply with any safety requirements.

3. Health and safety of workers

3.1 General

The health and safety aspects of the workers are largely governed by the *Health and Safety Act – Act 85/1993*.

Compliance with the requirements for the accommodation of traffic, set out in paragraph 2 above, is not only intended for the wellbeing of the public but also to protect the workers involved on the road.

The following minimum practical requirements are, however, drawn to the contractor's attention:

- The issue of protective clothing; boots, gloves, overalls, etc. to the workers is essential. This is particularly applicable to labour working on, or in close proximity to, distributors and/or sprayers.
- The use of diesoline by workers to clean hands, arms and tools, when working with bitumen, must be discouraged – the use of paraffin is preferable.
- A properly equipped first aid kit must be available at all times.



- Transportation of workers on open trucks/trailers must be controlled, e.g. all passengers must be seated with no legs hanging over the side of the truck/trailer.
- No children must be allowed on the construction site or contractors camp.
- Fire extinguishers in good working order must be available especially when working with hot binders.

3.2 Special precautions when working with bitumen binders

3.2.1 Fire hazards

- Distributor tankers

When hot binders are delivered to site in distributor tankers (e.g. Otta seals) below spraying temperature; burners (open flame) will be used for heating the binders to the required temperature for spraying and there will be fire risks. Therefore, it is advisable to have fire extinguishers readily available on site, in spite of binder suppliers (supposedly) having distributors equipped with fire extinguishers.

Heating spray bars with open flames, to rectify blocked jets, is also a fire hazard.

- Emulsion drums

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

A person must be in charge of the heating of the drum at all times and should continuously stir the contents in the drum.

3.2.2 Toxicity

Cationic emulsions are toxic and must be treated with care, as it is acidic and must therefore be washed off with water as soon as possible.

3.2.3 General

- When working with the hand sprayer (motorised), ensure that there are no unnecessary spectators standing near or adjacent to the work – accidents do happen.
- Do not allow children to play around on the stockpile of drums of emulsion, or near the work area, especially during sealing operations.

4. Points to note

The contractor should take particular note of the following:

- Competent staff must be used for controlling traffic, as their actions can affect the safety of both the road users and road workers.
- For the same reasons no short cuts must be attempted for the establishment of road signs.
- Detailed attention to staff safety increases productivity and staff harmony.



5. Notes to designer/consultants

5.1 Deviations

According to the *COLTO Specifications*: Section 1500, the contractor is responsible for the accommodation of traffic.

Depending on the size, and experience of the contractor involved in the labour-based construction of the road works, capacity problems may be experienced if he has to construct and maintain by-passes to accommodate the traffic during the construction of the works.

In such cases, consideration should be given to executing the construction of by-passes either departmentally or by a separate contract, prior to the commencement of the work. This departmental team or contractor would then also be responsible for the regular maintenance and, where necessary, watering of the by-pass.

All other items/activities pertaining to the accommodation of traffic would still remain the responsibility of the road contractor.

5.2 Fire hazards

The consultant must ensure that all necessary precautions are taken by the contractor to prevent fires and ensure the safety of the workers and public.

The consultant must be conversant with the latest SABITA manuals, regarding safety measures affecting the asphalt/bitumen industry.



MODULE 2: Procedure for operating and applying binder using the motorised hand sprayer

1. The motorised hand sprayer

The motorised hot bitumen hand sprayer (e.g. Flexian or similar), shall comply with the following specifications:

- Engine: ± 5 kW diesel engine (also available with 3,7 kW petrol engine).
- Pump: Gear type pump, direct drive from the output shaft of the engine reduction gear, through a flexible coupling. The output when spraying is approximately 17 – 18 litres/minute.
- Lance: 5 metre oil-resistant delivery hose, fitted to a 1 metre lance including handle grip, shut off valve and two 65° flat spray adjustable nozzles.
- Heating equipment: Ideally sized burner ring, gas regulator, air control valve, heat deflector shield and gas bottle carrying bracket.



Photo 4.1: The motorised hand sprayer

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

2. Operation

2.1 General

- Before starting the engine, check the oil levels by unscrewing the two oil plugs at the bottom of the engine. The oil level must always be flush with the bottom rim of the oil plugs.
- Use only SAE 30 oil for the spray machine.
- Before starting the machine, check whether there is enough diesel in the tank.



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

2.2 Starting the engine/pump

- The sprayer pump is self-priming. However, if the machine has not been used for a number of weeks, the sprayer pump must be primed.
- This is done by removing the white cone shaped filter and adding just sufficient oil in the filter cap, so that it will not spill when fixing it in place on the engine.
- Before starting the engine, the intake pipe/sump of the spray machine must be placed in the 210 litre drum of emulsion, and the control valve on the spray lance must be open.

Note

Do not tamper with the relief valve on the bypass.

- Start the engine by switching it to the on position, opening the choke and pulling the starter rope. The sprayer pump will take approximately one minute to prime.
- Once primed, the control valve on the spray lance can be set to the off position. The engine can be left running as the sprayer has a built-in, automatic bypass system.

- When there is difficulty in starting the engine in cold weather, remove the rubber cap on the top of the engine, put ± 5 ml of the oil in the tube and replace the rubber cap.

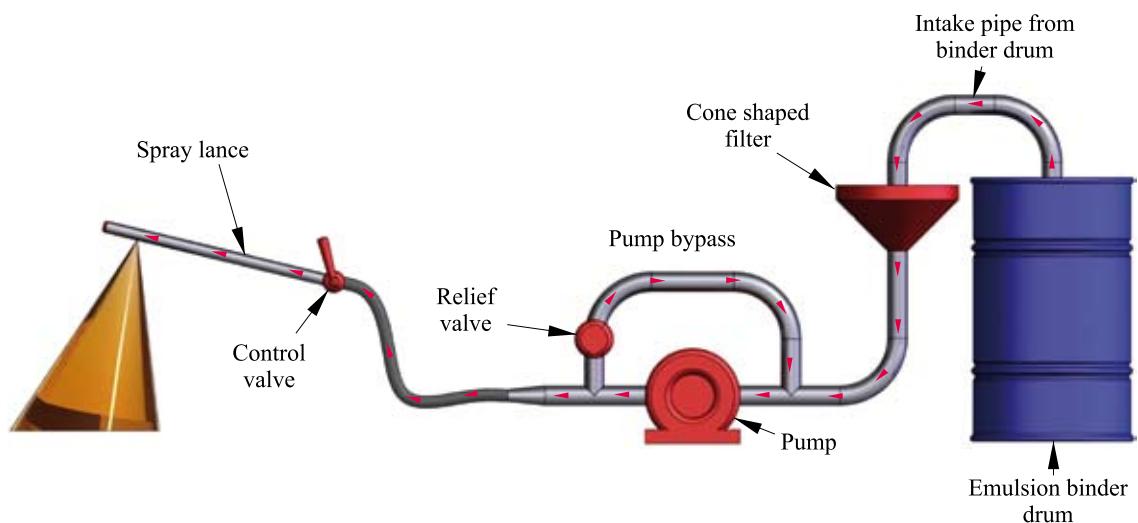


Figure 4.1: Schematic layout of motorised hand sprayer



2.3 Heating of binder/emulsion

- On the top of the gas cylinder there is a valve which controls the flow of gas in the system. This valve is usually open when spray work is being done.
- There is a flexible tube/pipe connecting the cylinder with the burner.
- The valve controlling the gas pressure is close to the top of the cylinder and controls the intensity of the flame from the burner (i.e. the second valve).

Once this valve has been set for the day's work, it should not be re-adjusted every time the machine is used, unless the flame is too weak or too strong.

- The third valve is on the gas pipe near the burner, at the bottom of the spray machine. It is this valve which is opened for lighting the burner and adjusting the flame to the size required.

CAUTION

- Use the flint and not matches to light the burner. If flint is not available, use a rolled-up length of paper.
- Never light the burner with the drum on the machine.
- First light the burner, then place the drum in position.
- Never leave the drum being heated, unattended – always have someone checking the temperatures and gently stirring the emulsion to prevent the emulsion from boiling over.

2.4 Maintenance of the machine

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

2.5 Safety precautions

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

2.6 Spray procedure

- Before any spraying of the emulsion commences, it is essential to have three clean half drums (105 litres) available on site. Half fill one drum with water and half fill the second with paraffin.
- Before using any drums of emulsion for spray work, it is essential to check the contents to establish if there has been settlement of the bitumen in the emulsion in the bottom of the drum.

Open the drum and dip a broom handle into the drum. Test the bottom of the drum for settlement. When extracting the dipper, the consistency of the emulsion coating of the dipper can be gauged visually. Settlement in the drums is a problem and the drum must not be used until the problem has been rectified.



This is achieved by cutting open the drum and stirring the contents until a uniform consistency is obtained, and pumping the contents into a clean drum. The suction of the thick sludge, into the spray system, can cause severe delays and problems.

- Once the machine has been primed, with the sump/intake pipe in the drum of tested emulsion, spraying can commence.
- When the contents of one drum have been depleted, switch the engine off. Replace the empty drum with a full drum of tested emulsion. Start the engine and proceed with spraying.
- At the end of a shift or at lunch break, remove the sump from the drum and spray out the emulsion in the system. Immediately place the sump in the $\frac{1}{2}$ drum of water and continue to re-circulate the clean water through the system until there is clear water flowing through the system.
- Once the flow of water is clear, place the sump in the $\frac{1}{2}$ drum of paraffin and circulate the paraffin through the system back into the drum.
- Note that you have a maximum of only two minutes to move the sump from the water into the drum of paraffin.
- If the containers of water and paraffin are not ready, switch off the engine until the containers are ready.

Under no circumstances must the engine run for more than two minutes without feeding the sump with emulsion, water or paraffin.

- The same paraffin must be used as much as possible – this paraffin cannot be used for fuel.
- The water must be replaced for each daily shift.
- When spraying ceases, and after cleaning, the spray lance must not be placed on the ground with the nozzles in the dirt. Two saddles fitted to a $\frac{1}{2}$ drum overcomes this problem. (Figure 4.2)
- The third $\frac{1}{2}$ drum is used for checking the rate of delivery of the pump. The rate of delivery of the pump must be determined before surfacing work commences.



Figure 4.2: Rack for spray lance

2.7 Determining the delivery rate of the sprayer

2.7.1 Delivery rate

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

The methods for testing the delivery of the pump are as follows:

Method 1:

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

Method 2:

- Dip the drums of emulsion to be sprayed with a measured dipstick – L_1 .
- Spray a measured area of say $3,5 \text{ m} \times 2 \text{ m} = 7 \text{ m}^2$.
- Dip the drum after spraying – L_2 .

The quantity of emulsion sprayed in litres is $L_1 - L_2$.

- Record the time (T) in seconds which elapsed to spray the measured area.
- The amount of binder sprayed in litres per second is then

$$\frac{L_1 - L_2}{T} \text{ (l/s)}$$
- The rate of delivery can then be compared with the manufacturer's rate of delivery of 17 l/m (0,283 l/s).

Note

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

2.7.2 Time control of spray rates

Knowing the rate of delivery of the pump in litres per minute, and the rate of application of the binder that is required for any layer of aggregate, it is possible to calculate the time, in minutes and/or seconds, that the spray operation allows for covering a certain section using a motorised hand sprayer machine (litres/m² divide by litres/min = minutes/m²).

2.8 Training of spray equipment operators and team

2.8.1 Uniformity

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

The operations include:

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

Once the unit is comfortable in all the phases/aspects of the spray operation, the next step is to apply the diluted 1:10 emulsion on the section of road to be surfaced. At the same time, the use of the protective screens (see Photo 4.2) to protect any concrete works, such as kerbing, channelling, etc. must be introduced, and the labour trained in the systematic moving of the screens along the edge of the area to be surfaced. (For a clean operation this is essential.) The screens must move slightly ahead of the binder application.



Photo 4.2: Spraying using protective screens and reinforced paper

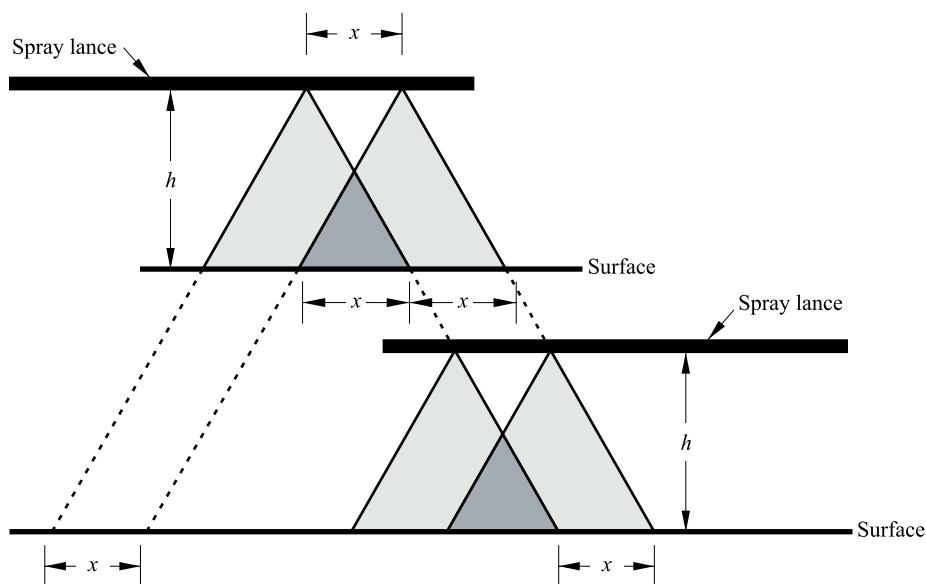


Figure 4.3: Spraying height and sequence of spraying

Once the correct height h for spraying above the road surface has been determined, it can be maintained by tying a piece of wire of the correct length to the lance as illustrated in Figure 4.4.

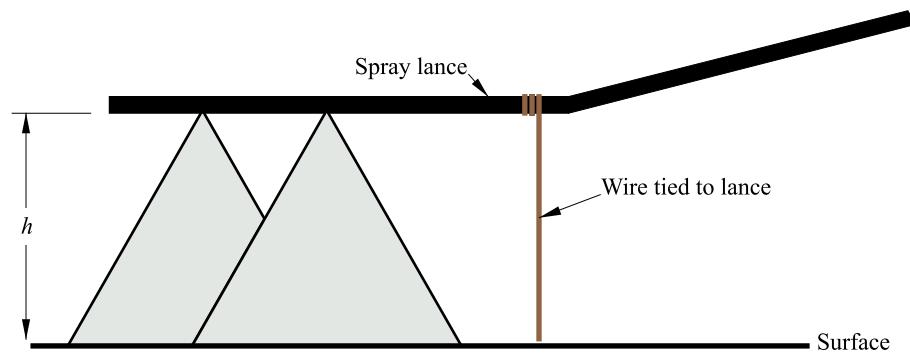


Figure 4.4: Maintaining correct height for spraying

2.9 Application of binder

2.9.1 Checks

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

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



- The delivery rate of the pump must be established as described.
- That the aggregate has been correctly supplied and spotted.
- That the surface to be sealed is clean, and any repairs required properly attended to.
- That the area to be surfaced has been correctly set out.
- That arrangements to protect the kerbs, etc. are in place.
- Reinforced paper has been placed at the start and finish joints.
- That all members of the team are at their posts and ready for action, i.e. labour for spreading the chips and moving the spray screens, and recording operators are in position. (Photo 4.3)



Photo 4.3: Spraying operation

2.9.2 Control of application using a trial/control section

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

Before a trial section can be done, the following information must be established:

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

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

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

Example

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

Spray application rate of penetration layer: 1,7 litre/m² (tack coat of 0,7 litres/m² subtracted from total requirement)

Width of road: 3,5 m

Control length: 2 m

Area of control section: 7 m² (2 m × 3,5 m)

Amount to be applied to control section: 7 × 1,7 = 11,9 litres

Time to apply 11,9 litres over control section: 11,9/0,283 = 42 seconds

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

* clock reset to zero

Table 4.1: Calculated time for spraying control section

Every time the spraying stops at the end of a control section, be it one control section initially or four sections in total, the dipstick readings must be taken and recorded, before the commencement of the next spray. It must also be taken at the end of the initial control section and at the end of control section 4 (or 5 if 5 sections are sprayed).

The rate of application of binder using the time (clock), and delivery rate of the sprayer described in Section 2.7.1, should be checked against dipstick readings as illustrated in Table 4.2 a.

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

Table 4.2 a: Check using dips

Where:

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

Table 4.2 b: Clarification of symbols

Once the time for spraying control section 1 for the 2 m length of road has been calculated and sprayed, the clock must be set at zero and the time taken for spraying sections 2, 3, 4 (and 5) must be calculated and the spray operator guided for each section by the time controller.

The time the spray operator actually takes for each section must be recorded in column 3. The variation of spray application can be checked by comparing the actual application rate calculated in column 5, with the design spray rate. The recording of the times in column 3 must be done by a separate operator (recording operator) as it cannot be done by the time controller.

The dipstick readings are done by using a steel rod calibrated/graduated in 10 litre intervals up to 210 litres. The amount of emulsion sprayed for each cycle of spraying is recorded in litres.

The time controller, recording operator and spray operator must work very closely together. Spraying can only commence after the time controller has zeroed the stopwatch and gives the signal to start spraying.

The recording operator will mark the separate sections for checking at 2 m intervals and record the time at the end of each 2 m section that is sprayed. From these readings, a double check of the accuracy of the work can be established by multiplying the pump delivery D by the time taken to spray each section.

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



MODULE 3: Construction of a single seal

1. Specification

The specification will call for the construction of a single-seal bituminous surface treatment, constructed in accordance with the relevant specifications referred to in the scope of work in the contract documents.

2. Materials

Materials required for the construction of the single seal are:

- Surfacing aggregate of the specified size (obtained from a commercial source/quarry).
- Bituminous binder in the form of a bitumen emulsion.

3. Construction plant and equipment

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

- Shovels
- Brooms
- Builders' wheelbarrows (capacity \pm 65 – 67 litres)
- Hammer
- 7 mm sisal rope, 2 \times 50 m rolls
- Reinforced paper, 4 rolls \times 1 metre wide
- Steel pegs, 300 mm \times 9 mm
- Chalk-line equipment
- Steel tape, 50 m
- 105 litre drums open ended (Photo 4.4 a) with lifting handles ([Workshop drawing LIC 010](#)) for spotting aggregate
- 105 litre drums (checking spray rates and cleaning spray equipment)
- Drum lifter for lifting full drums of binder ([Workshop drawing LIC 008](#))
- Dip stick for dipping emulsion in drums ([Workshop drawing LIC 001](#))
- Manually operated chip spreader (Photo 4.4 b) (Optional)
- Suitably sized vibratory pedestrian roller (Bomag 75 or equivalent)
- Motorised hand sprayer (Photo 4.6)
- Spray screens (Photo 4.6 and 4.7) and (Figure 4.5) ([Workshop drawing LIC 007](#))

Quite simple

The above may appear complicated but if the process is carried out with water a few times, and then with diluted emulsion, it is quite simple.



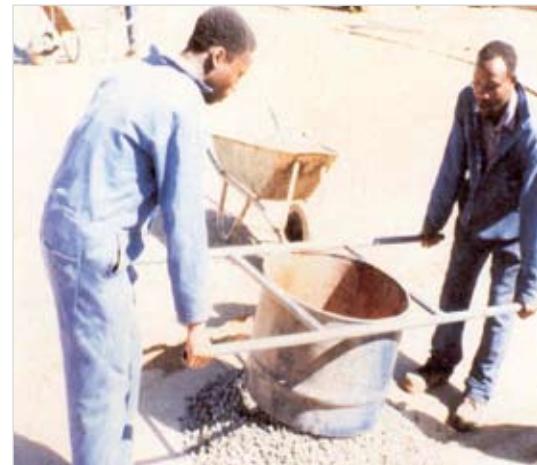


Photo 4.4 a



Photo 4.4 b



Photo 4.6: Spraying with motorised hand sprayer with screens and reinforced paper in use

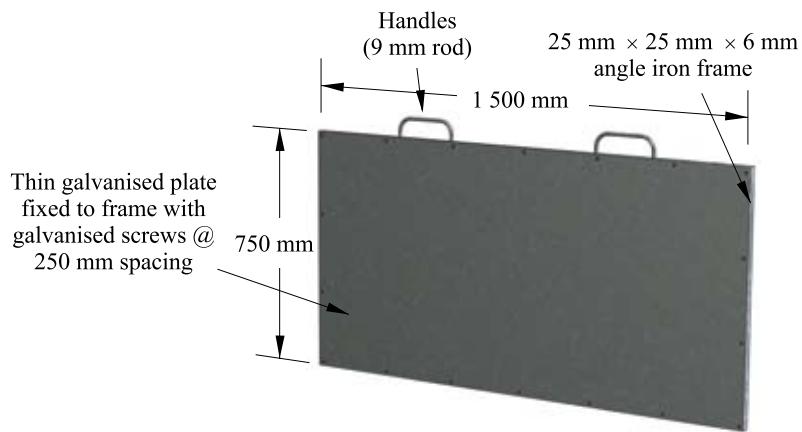


Figure 4.5: Sketch of spray screen (Refer to Workshop drawing LIC 007)

4. Construction

4.1 Preparation of surface

- Sweep the road clean. All loose material and mud that has been brought onto the surface by traffic must be removed.
- Stake out width of road to be surfaced, marking out the edge of the road with a 7 mm sisal rope.
- If necessary, lightly spray the surface with a diluted 1:8 emulsion (1 litre emulsion to 8 litres water). Normally with an ETB, this should only be necessary if the ETB has been exposed to traffic for an extended period. This application of emulsion and water could be regarded as lightly priming the ETB (0,5 – 0,6 litres/m² of diluted Anionic stable-grade emulsion should be applied).
- Protect any kerbs and drains, etc. from the emulsion spray. (Photo 4.7)
- Use reinforced paper for the construction joints at the beginning and end of each spray. (Photo 4.8)



Photo 4.7: Protection of kerbs, drains etc.





Photo 4.8: Neat construction joint due to use of reinforced paper

4.2 Application of bituminous binder

4.2.1 General

When working with any binder on site, cleanliness is essential. If spillage of the binder does take place, it must be cleaned up immediately.

4.2.2 Spraying the binder

Application of the binder

The emulsion binder is applied using the motorised hand sprayer in accordance with Module 2: Procedure for operating and applying binder using the motorised hand sprayer.

Heating of binder

The heating of the emulsion binder must be done carefully by stirring the binder while it is being heated, to avoid surging and boiling over. The binder temperature must be continuously checked with a thermometer. It normally takes approximately 45 – 60 minutes to raise the temperature to 50°C, if ambient or overnight temperatures are low i.e. < 10°C.

The heating of emulsion specifically applies when using cationic emulsion. Anionic emulsion can be applied in the warm summer months without heating, but it is advisable to heat it in cool winter weather.

Spraying of binder in more than one application

Because of the low viscosity of the emulsion (compared with a penetration bitumen), it is not possible to spray emulsion at more than $\pm 0,6 - 0,7$ litres/m², without the binder tending to flow (even on the flattest surfaces).

Therefore, to overcome this problem, the tack coat is sprayed at 0,6 – 0,7 litres/m², and the balance of the calculated binder is applied as a penetration spray, where the aggregate will inhibit any untoward flow of the binder.

4.3 Application of aggregate

4.3.1 General

The application of aggregate must only commence after approximately 4 metres of road has been sprayed to avoid aggregate falling on unsprayed road.

Two methods of applying the aggregate are described:

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



Photos 4.9 and 4.10: Spotting of aggregate

A half 210 litre drum with the bottom of the drum removed and two handles fitted to the side of the drum, for ease of handling can be used for this operation. This ensures that the correct amount is placed at each position.

Each labour unit is responsible for applying the two heaps of aggregate (2×105 litre) to the area applicable for these two heaps, as determined by the engineer, (and must not use aggregate of adjacent areas). This will ensure uniform, correct application of aggregate.

A shovel of aggregate is taken. Then the aggregate is pitched into the air while twisting the shovel rapidly. This sprays the chips uniformly over the area to be covered. In this way the stone will fall onto the wet tack coat while the dust, if any, will fall onto the top of the stone or, if there is a breeze, will be blown across the road away from the surface.

Once sufficient stone has been applied so that one can walk on the surface without coming into contact with the wet binder, the bare spaces can be filled with more stone. The aggregate must be placed shoulder to shoulder but care must be taken not to have double layers of stone.

Gently broom the surface and distribute any loose stone forming double layers. The better this process is done, the better and more efficient the seal will be.

Once the surface has been covered with the aggregate without bare patches of binder showing, rolling with the pedestrian roller can commence.

After the surface has been rolled once (i.e. a complete coverage of the roller), care must be taken to cover bare patches or remove any double layers of aggregate by brooming, to obtain a single layer of aggregate.

The first roll must be done without vibration but subsequent rolling, when the aggregate is properly placed with full coverage obtained, can be done with intermediate vibration of the roller switched on.



The rolling must be done in straight lines, parallel to the centre line or edges of the road. It is essential that rolling is done uniformly across the width of the road surface. Typically three passes should be sufficient to seat the aggregate. (Photo 4.11)



Photo 4.11: Rolling

4.4 Application by a manually operated chip spreader

4.4.1 Chip spreader

The use of the Chippy hand spreader (Photo 4.4 b), will facilitate the efficient uniform application of aggregate by hand labour and, therefore, reduce the amount/intensity of brooming required.

The Chippy, which can be bought or hired from the company, has a capacity of three wheelbarrow loads of aggregate and is operated by four people – one to steer the Chippy and three to push it. The Chippy starts with a full load and spreads chips at a width of 1,2 metres.

4.4.2 Trial section

Before any sealing is done with the Chippy, it must be adjusted for correct application by first doing dry runs on an unsprayed surface.

Arrangements should be made with the manufacturer to train the operators of the Chippy, in the correct method of operation during the trial run and first operation on the bitumen binder.

4.4.3 Application methodology

As with the spreading of the aggregate by hand, predetermined quantities of the aggregate are spotted along the side of the road, using 105 litre half drums at distances determined by the engineer, depending on the ALD and the application rate of the aggregate.

When Chippies are used for spreading aggregate, the spotting of stone must be based on 2×105 litres of stone per stockpile. This conveniently is the capacity of 3 wheelbarrows which also equals one fully loaded Chippy.

Photo 4.12 depicts three chip spreaders being used at the same time. In this instance the procedure, as determined by the manufacturer, must be strictly followed. As a general rule only three Chippies will be required where the binder is applied by a bulk distributor.

Where the binder is applied by a motorised hand sprayer, one Chippy will be sufficient.



Photo 4.12

The aggregate is loaded into the Chippy by wheelbarrows (± 66 litres) and the Chippy guided along the length of the road in accordance with the manufacturer's instructions.

Using a hand sprayer and one Chippy, the procedure illustrated in Figure 4.6 is recommended for applying the aggregate using 2×105 litre drums at the calculated spacing.

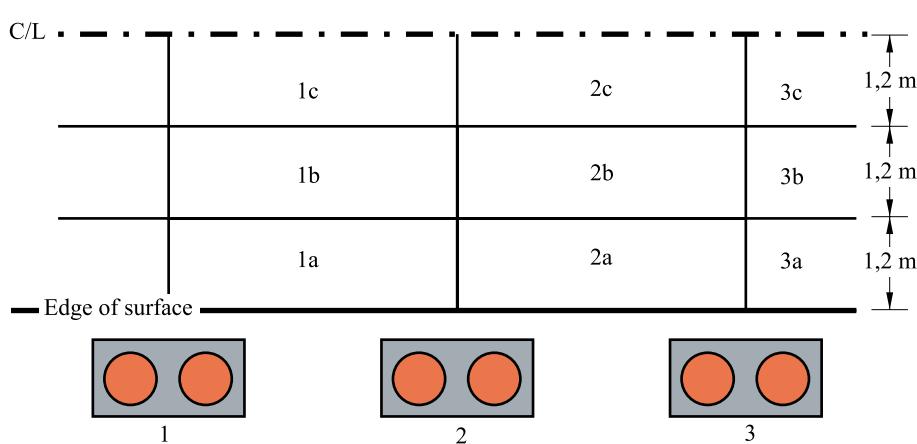


Figure 4.6: Procedure for applying aggregate

Once sufficient stone has been applied and one can walk on the surface without coming into contact with the wet binder, the bare spaces can be filled with more stone. The aggregate must be placed shoulder to shoulder. However, care must be taken not to have double layers of stone.

Gently broom the surface to distribute any loose stone that may be forming double layers. The better this process is done, the better and more efficient the seal will be.

Once the surface has been covered with the aggregate, without bare patches of binder showing, rolling with the pedestrian roller can commence.

After the surface has been rolled once (i.e. a complete coverage of the roller), care must be taken to cover bare patches, or remove any double layers of aggregate by brooming, to obtain a single layer shoulder to shoulder.

The first roll must be done without vibration but subsequent rolling, when the aggregate is properly placed with full coverage obtained, can be done with intermediate vibration of the roller switched on.

The rolling must be done in straight lines, parallel to the centre line or edges of the road. It is essential that rolling is done uniformly across the width of the road surface. Typically three passes should be sufficient to seat the aggregate. (Photo 4.11)

4.5 Application of penetration spray

The remainder of the bitumen emulsion that was not applied in the tack coat, is now sprayed as a penetration spray.

The same precautions regarding joints and protection of kerbs, drains, etc. apply, as was the case for the tack coat.

If the surface is left open for any period before applying the penetration spray, the following must be attended to:

- Any dust, dirt or sand blown into the surface voids, must be removed/blown out with a compressor.
- The surface must be rolled once to reseat any aggregate that may have been disturbed by unauthorised traffic.

The road can be opened to traffic once the emulsion has broken.



5. Notes to designers/consultants

5.1 General comment

The attention to detail when preparatory planning for surfacing work is being done, is essential. Rates of application of both binder and aggregation are dependent on small measurements which, when multiplied by large areas, result in major costs.

Once the rates of application have been established, it is equally essential to apply them as accurately as possible.

5.2 General description

The single seal normally consists of either a 13,2 mm or 9,7 mm aggregate.

5.2.1 Application of aggregate

Rate of application and spotting of aggregate

The rate of application of the aggregate is extremely important, as this rate enables you to calculate the quantity of stone which is required for the work in question.

Find the size of the work or area to be sealed, by measuring the length of the road in metres and the width of the road in metres, $L(m) \times W(m) = S(m^2)$ (Area).

If the rate of application/ m^2 is known, then the quantity or volume is found by multiplying the Area (m^2) \times Rate m^3/m^2

$$\begin{aligned} &= A(m^2) \times R(m^3)/m^2 \\ &= V(m^3) \end{aligned}$$

The rate of application of the aggregate is determined by the average least dimension (ALD) of the aggregate.

Application rate

$$\begin{aligned} &= A(m^2) \times R(m^3)/m^2 \\ &= V(m^3) \end{aligned}$$

Any particle of aggregate, if dropped on a surface, will always fall on the surface with its smallest dimension vertical to the plane of the surface. (Figure 4.7)

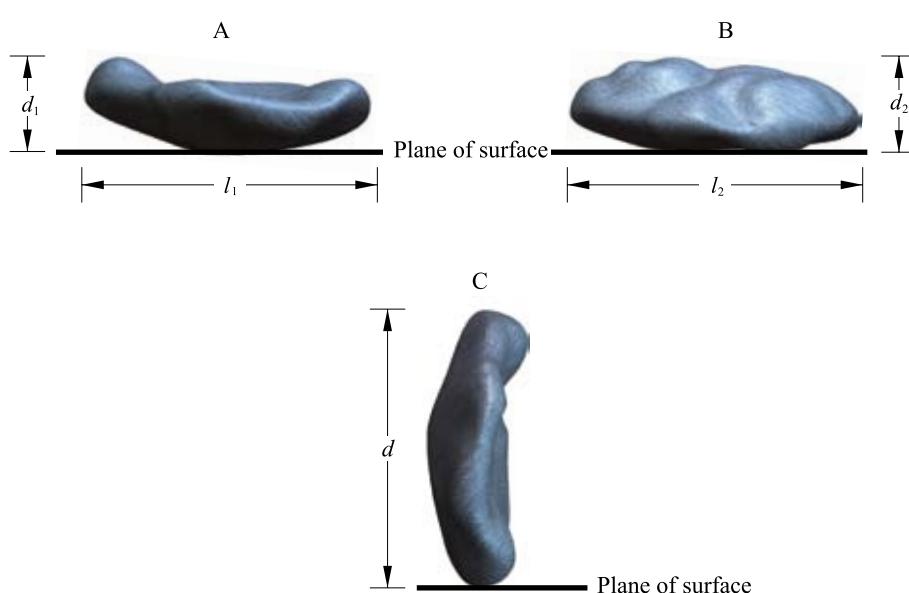


Figure 4.7: ALD of aggregate



It does not matter what the shape of the particle of aggregate is, it will always fall on the road with d_1 and d_2 , i.e. the least or smallest dimension, vertical to the road surface.

Sample A, if dropped on the road will never come to rest on the road in the position where d , the maximum dimension, is vertical to the road surface.

There are two ways of obtaining the ALD, and therefore the rate of application:

- By measuring the average least dimension of the aggregate, i.e. average least dimension:

The ALD of a sample of stone 200 particles of the specified aggregate size (e.g. 9.5 mm) is taken, and the minimum dimension of each particle is measured with a vernier calliper.

These measurements are added up and divided by 200 to obtain the ALD.

If the ALD of the aggregate determined above is 8.3 mm, the volume of stone required to cover 1 square metre will be:

$$\frac{1 \text{ m} \times 1 \text{ m} \times 8,3 \text{ mm}}{1 \text{ 000}} = 0,0083 \text{ m}^3/\text{m}^2$$

- Using the pan and cylinder method of obtaining the rate of application.

The pan and cylinder method is the reverse of the ALD method. A single layer of stone is placed shoulder to shoulder in a measured area (pan), and the volume of the stone is found by pouring the stone into a cylinder of known dimensions. The ALD can be read off the gauge in the cylinder in mm. If this reading in mm is divided by 1 000, it will give the volume in m^3/m^2 for rate of application. (Figure 4.8)

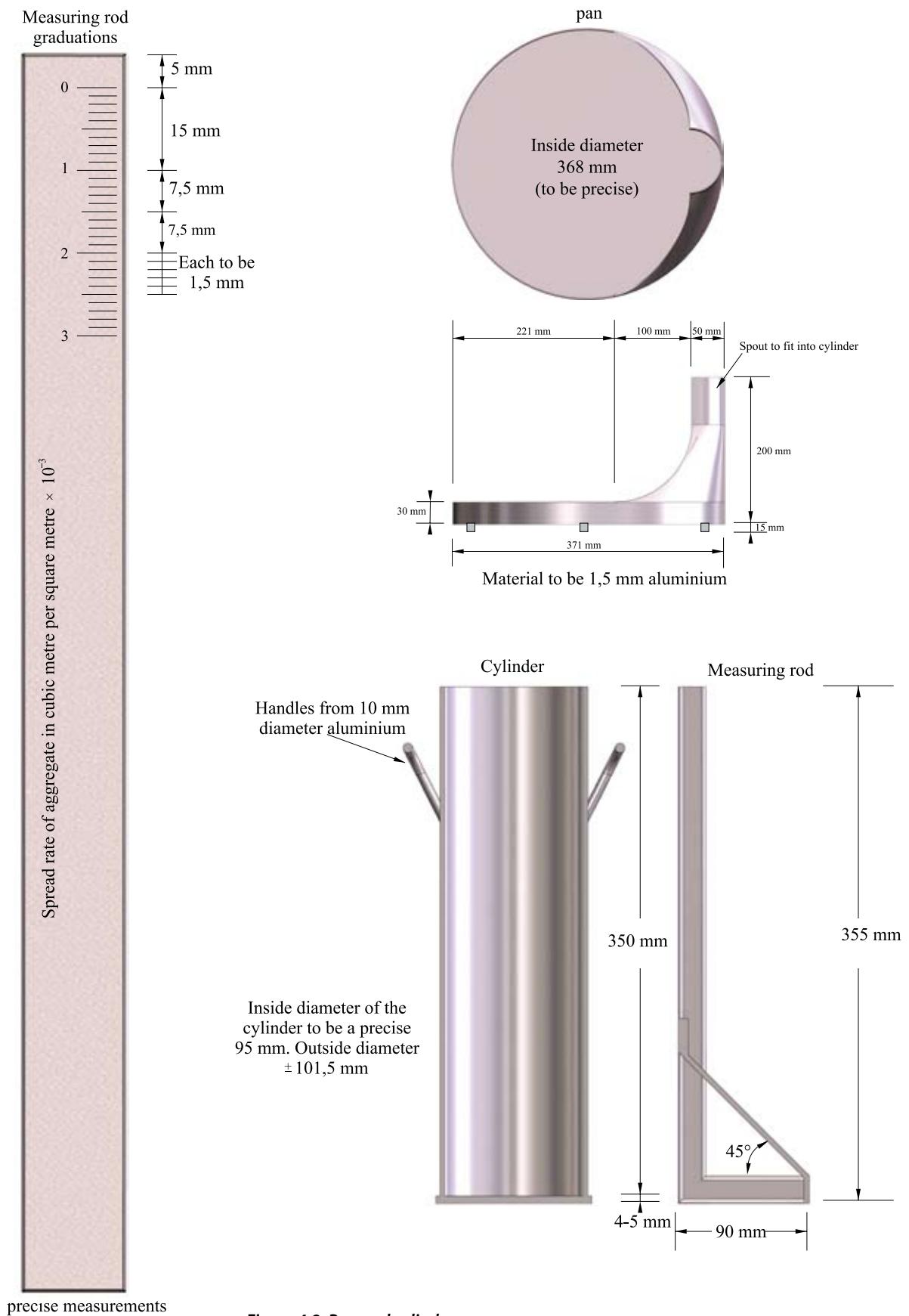


Figure 4.8: Pan and cylinder



Once the rate of application has been calculated, then the total quantities of aggregate required for a project can be found.

$$\begin{aligned} \text{Length of road (m)} \times \text{breadth of road (m)} &= \text{Area m}^2 \\ \text{Area (m}^2\text{)} \times \text{Rate of application in m}^3/\text{m}^2 &= \text{Area (m}^2\text{)} \times \text{Rate (m}^3/\text{m}^2\text{)} \\ &= \text{Volume in m}^3 \end{aligned}$$

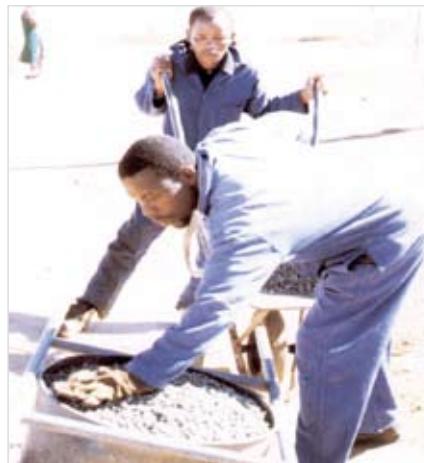
Having calculated the volume of aggregate required for the ALD, a percentage must be added for wastage – 5% under ideal conditions and 10% for severe conditions.

If the stone is placed on a clean surface and all the aggregate can be picked up, the 5% will cover the wastage, but if the stone is placed on a rough shoulder then it will not be possible to use all the stone from the stockpile, so 10% must be allowed.

$$\begin{aligned} \text{Volume calculated} &= 100\% \text{ to allow 5\% then} \\ \text{Volume adjusted} &= 105\% \\ \text{Volume calculated} \times 1.05 &= \text{Adjusted volume to be ordered} \end{aligned}$$

Spotting of aggregate

To obtain a uniform application of aggregate by hand labour, it is necessary to place the heaps of aggregate in predetermined quantities and at uniform intervals, along the side of the road to be surfaced. This is known as spotting the aggregate quantities. See Photos 4.13 and 4.14.



Photos 4.13 and 4.14: Spotting of aggregate

The aggregate can be placed in heaps along the side of the road that is to be surfaced. A half 210 litre drum with the bottom of the drum removed and two handles attached to the drum for ease of handling, can be used for this operation.

The spacing of the aggregate heaps can be calculated as follows:

$$\begin{aligned} 210/2 \text{ (half drum)} &= 105 \text{ litres of aggregate} \\ &= 0.105 \text{ m}^3 (1000 \text{ litres} = 1 \text{ m}^3) \\ \text{The application rate (R)} &= \text{m}^3/\text{m}^2 \end{aligned}$$

(Assuming that the rate of application is 0.0083 m³/m² determined from the pan and cylinder test.)



The area that one heap of 0,105 m³ must cover is:

The volume of the heap in m³, divided by the rate of application required in m³/m², will give the area that one measured heap will cover in m².

$$\text{i.e. } \frac{0,105 \text{ m}^3}{0,0083 \text{ m}^3/\text{m}^2} = 12,65 \text{ m}^2$$

If the width of the road is 3,5 m, then the length can be obtained by dividing the area by the width, i.e.

$$\frac{\text{Area}}{\text{Width}} = \text{Length}$$

$$\text{i.e. } \frac{12,65 \text{ m}^2}{3,5 \text{ m}} = 3,6 \text{ m}$$

This is the distance between the spotted heaps of aggregate.

5.2.2 Application of binder for the seal

Types of binder

Emulsions are ideal for manual application, as they do not have to be heated to temperatures of 130°C – 140°C, as is the case for penetration bitumen.

As they contain 35 – 40% water, the problem of over application, resulting in bleeding of the surface, is overcome to a large extent.

The following binders can be used for seal work:

- Anionic spray-grade emulsion (60% bitumen and 40% water).

The viscosity of this binder is lower than the viscosity of a cationic emulsion, and the rate of application for a tack coat reduces to approximately 0,7 to 0,8 litres per m² before the binder tends to flow, even when minimum gradients pertain.

Generally they do not require heating, unless the air temperature at the time of spraying is below 20 – 25°C.

- Cationic spray-grade emulsion (65% bitumen and 35% water).

This emulsion is ideal for seal work. In cool weather it is advisable to heat the emulsion with a low flame to 50°C.

The flow properties of this emulsion are better than Anionic emulsions.

Note

It is essential when using Cationic emulsion for the equipment to be thoroughly cleaned out of any Anionic emulsion. The equipment must be flushed out with water and paraffin.

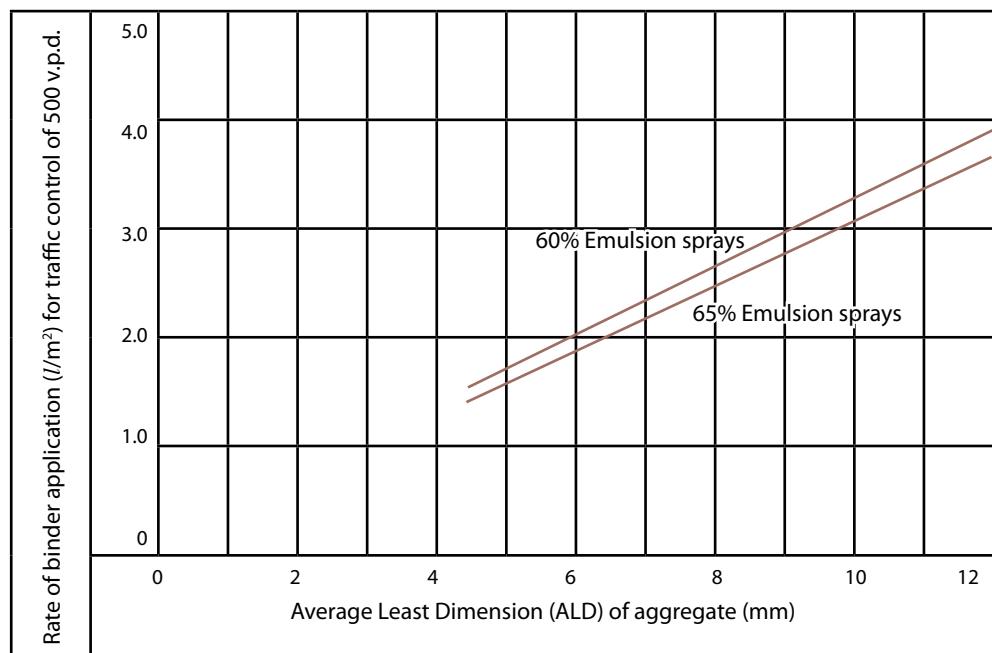
When heating Cationic emulsion, care must be taken to heat it with burners on a low flame. The temperature to which it is heated must not exceed 50°C.

5.3 Rate of application of binder

The amount of binder that is required per m^2 is dependent on the size of aggregate to be used (e.g. less binder is required for a 9,7 mm aggregate than for a 13,2 mm aggregate) and the spacing between the aggregate.

It is therefore essential to determine the ALD of the stone, before the quantity of binder can be determined.

The amount of 60% or 65% emulsion for a single seal can be determined from Graph 4.1 if the ALD of the aggregate is known.



Graph 4.1: Rate of binder application

The ALD of the aggregate is determined using the pan and cylinder method, or using callipers for measuring the least dimension of 200 stones, and calculating the average least dimension.

If the traffic count on the road reduces to only 100 vehicles per day, then a further 10% of binder can be added, as indicated in Table 4.3. If the traffic count reduces from 500 vehicles per day to, say 250 vehicles per day, then add 7.5% of binder.

Traffic count of vehicles per day (Estimate for the street)	Adjustment to calculate total spray
500+ vehicles per day	No adjustment
200 - 250 vehicles per day	Add 7,5% to calculated binder
Less than 100 vehicles per day	Add 10% to calculated binder

Table 4.3

**Example**

If the rate of application of binder for a 13,2 mm aggregate with an ALD of 8 mm is 2,5 litres per m², and the traffic count is between 200 – 250 v p d, then this rate must be increased by either 7,5%:

$$\frac{2,5 \times (100 + 7,5)}{100} = \frac{2,5 \times 107,5}{100} = 2,69 \text{ litre per m}^2$$

Say 2,7 litres per m²

It must be noted that a tack coat should not exceed $\pm 0,7$ litres/m², and the balance of the binder must be sprayed as a penetration spray.

Before any spraying of the binder, it is advisable to train the operator in spraying water and checking the rate of application (using a stopwatch), as described in paragraph 2.8.1.

5.4 Heating of binder on larger projects

On larger projects, it is recommended that separate mobile drum heaters are used to heat the binder.

A drum heater can raise the temperature of a drum of emulsion by 15° to 20°C, in the time taken to spray 210 litres of emulsion.

Depending on the ambient nocturnal temperature, more than one mobile drum heater may be required.

Table 4.4 gives an indication of the time required to heat a 210 litre drum of emulsion to 50°C.

Minimum temperature °C	Spraying temperature °C	Approximate time to heat 210 litre drum (min)
0	50	30 – 40
15	50	20 – 30
20	50	20 – 25
25	50	15 – 20

Table 4.4

MODULE 4: Construction of a slurry seal

1. Specification

The specification will call for the construction of a slurry seal of a specified grading and thickness (e.g. 6 mm), constructed in accordance with the relevant specifications referred to in the scope of work in the contract documents.

2. Materials

Materials required for the construction of the slurry seal are:

- Bituminous binder in the form of a bitumen emulsion, either Anionic spray grade emulsion (60/40) or Cationic spray grade emulsion (65/35) for tacking the base, if necessary.
- Slurry aggregate of the specified grading (obtained from a commercial source/quarry).
- Slurry binder in the form of an Anionic stable grade emulsion (60/40) with Vinzyl resin as emulsifier.

3. Construction plant and equipment

The following specialised plant and equipment is recommended to promote the construction of the slurry seal surfacing by labour-intensive methods:

- Shovels
- Brooms
- Builders' wheelbarrows (capacity \pm 65 – 67 litres)
- Hammer
- Reinforced paper, 4 rolls \times 1 metre wide
- Chalk-line equipment
- Steel tape 50 m
- Steel squeegees ([Workshop drawing LIC 005](#))
- 10 mm thick steel guide rails \times 25 mm \times 2 m (for 6 mm thick slurry)
- 4 mm thick steel guide rail to accommodate wet to dry slurry
- 4 m straight edge (screed) ([Workshop drawing LIC 004](#))
- 5 \times 25 litre measuring containers with lifter ([Workshop drawing LIC 009](#))
- 5 \times 10 litre measuring containers
- Hessian drag
- Drum lifter for lifting full drums of binder if necessary ([Workshop drawing LIC 008](#))



Photo 4.15: Emulsion drum stand

- Concrete mixer 150/200
- Suitably sized vibratory pedestrian roller (Bomag 75 or equivalent)
- 500 litre water tank on trailer or back of LDV
- Steel-framed stand for drums with steel or timber ramps (Photo 4.15)
- 75 mm diameter ball valve for decanting emulsion from drums (Photo 4.15)
- Motorised hand sprayer and spray screens ([Workshop drawing LIC 007](#)) if necessary for applying tack coat to the base (Photo 4.16)



Photo 4.16



4. Construction

4.1 Preparation of surface of base

- Sweep the road clean. All loose material and mud that has been brought onto the surface by traffic must be removed.
- Stake out width of road to be surfaced, marking out the centre and edge of the road with a chalk line.
- Before any slurry is placed, the spreading team must check and rectify the levels of the base, before laying the 10 mm thick slurry to give a final thickness of 6 mm for the slurry surface.
- Place the 10 mm rails along the centre line or quarter points and on edge of the road, and check the accuracy of the base levels and remove any high spots where a cover of less than 8 mm is obtained. Isolated low spots can be accommodated with extra slurry, up to a maximum of 20 mm. Large aggregate in the base can be treated with a 2 kg hammer to ensure a minimum of 8 mm cover.
- If necessary, lightly spray the surface with a diluted 1: 6 emulsion (1 litre emulsion to 6 litres water). Normally with an ETB, this should only be necessary if the road has been exposed to traffic for an extended period. This application of emulsion and water could be regarded as lightly tacking the surface (only necessary if surface is scuffed and dry).
- Protect any kerbs, drains, etc. from the emulsion spray. (Photo 4.17)
- Use reinforced paper for the construction joints at the beginning and end of each spray.



Photo 4.17: Protection of kerbs, drains, etc.

4.2 Construction of the slurry seal

4.2.1 General operation

The preparation and construction of the slurry will need the careful operation and co-ordination of the labour force.

Concrete mixer operator responsibilities:

- Checking the mixer before any work starts. The mixer must be checked for oil and fuel.
- After work is completed for the day, the concrete mixer operator must make sure that the mixer is cleaned. The operators must have a 25 litre drum or $\frac{1}{2} \times 200$ litre drum of water and a large piece of mutton cloth available, as freshly splashed slurry or emulsion can easily be washed off tools and mixer if dealt with immediately. It is better than using diesel or power paraffin.
- It is not necessary to wash out the mixer after every mix, on condition the work is being done on a continuous basis. For long stoppages, e.g. lunch break or major problem, then it is advisable to wash out the mixer.
- Caking of the mix will occur at the mouth of the drum during the process of discharging the mix into the barrows. These cakes tend to break off and contaminate the slurry mix, causing problems during the screeding of the laying process. Use the water-soaked mutton cloth to wash the mouth of the drum. Some of the excess water will fall into the drum, but is of a very limited quantity. This washing process should be done after each barrow load. If done on a continuous basis, the drum would be kept clean.
- The concrete mixer operator and an assistant are responsible for measuring out the correct amount of cement and emulsion to be used, and he/she must also check the consistency of the mix. If too dry, the slurry already discharged must be returned to the mixer for further addition of water and mixing.

Wheelbarrow operator's duties:

- They are required to fill the 25 litre cans or wheelbarrows with aggregate and deliver them to the mixer platform or hopper, ready for use.
- They must place the barrows correctly at the discharge point below the drum of the mixer.
- They must avoid any mud being carried onto the new work.
- They must place the slurry with shovels just ahead of the spreader box (or screed), in sufficient quantities for the squeegee operators to spread the material sufficiently thick for the spreader box (screed) to level the surface quickly and efficiently. The slurry must be placed in approximately straight lines across the width being treated, for relatively easy spreading by the rubber squeegees.
- During the process of shovelling the slurry from the barrow to the road, the shovels must be dipped into the drum of water and wiped with the wet mutton cloth.
- Immediately when the barrow is empty, it must be wiped with a wet cloth to remove any slurry sticking to the barrow as these eventually break loose and contaminate the slurry.

Slurry seal workforce

- Batching and concrete mixer operators.
- Wheelbarrow operators.
- Spreader/laying operators.

Typical spreading team

The spreading team comprises:

- Two operators on the screed.
- Two operators using the squeegees.
- One operator cleaning any untoward spillage of slurry behind the screed, and use of the water hose.
- Two operators laying the rails.

- The barrow operators are responsible for site hygiene at the mixing site and road works site. Any spillage of slurry, emulsion or mud must be cleared, either by picking up the material and burying it or covering it up with gravel.
- At the end of the shift, the barrow operators must clean their equipment and help clean the mixer, as well as park the mixer in a safe place.

Spreading team duties:

- Apart from their responsibilities associated with the placing of the slurry, the spreading team must check and rectify the levels of the base before any slurry is placed.

4.2.2 Batching and mixing of slurry in concrete mixers

- The area on which the concrete mixer and the emulsion drum stand is situated must be clean, well drained and have a sound surface to avoid dirt and mud being carried onto the base by the wheelbarrows. It must also be kept clean during operations to avoid bitumen being carried on to the new work by the wheelbarrows.
- The aggregate to be used in the slurry must be dumped as close to the working site as possible, preferably at the mid point of the length of road that one load of aggregate will cover.
- Using the measuring cans (Photo 4.18), add the correct amount of aggregate to the mixer drum while the drum is turning (Photo 4.19) in the proportions determined by the engineer. (For large mixers wheelbarrows may be used for batching the aggregate.)



Photo 4.18



Photo 4.19

- Add the cement to the aggregate in the drum very slowly (Photo 4.20), making sure no lumps or clods of cement are added (or make a cement slurry before adding to mix).



Photo 4.20

- The mix must be inspected to ensure the uniform distribution of the cement in the aggregate, before any emulsion is added.

Notes

1. The cement must be added to the neat aggregate and no attempt must be made to add the dry cement after the emulsion has been added.
2. If, for any reason, extra cement needs to be added, it must be added as a slurry of water and cement mixture.



When drums of emulsion have been stored for any length of time, the bitumen molecules in the emulsion tend to settle to the bottom of the drum. Therefore, it is essential to roll the drum and mix the contents well before use. It is even recommended that the day before the drums are to be used, they are turned upside down before being rolled for the next day's use.

It is recommended that full drums are stored not vertically but horizontally, ready for rolling and mixing and empty drums are stored vertically – apart from mixing by rolling the drums, it facilitates stocktaking.

- The diluted emulsion must be poured slowly into the mixer and not dumped into the mixer (Photo 4.21). By slowly pouring fluid into the mixer, quicker and more efficient coating of the aggregate will occur, without spillage or splashing of both the emulsion and the slurry. The drum of the mixer must not be in the vertical position when pouring the emulsion. This vertical position is used by the operator to protect him from splash, caused by the dumping of emulsion into the drum. Note that the drum must be just off the horizontal position, and that the emulsion should be poured slowly, deep into the throat of the drum, resulting in very little splash. Pour a little at a time and allow mixing before the next pour is done.



Photo 4.21

- Before adding the water, inspect the mix as it may not need much water to get the correct consistency. Carefully add the water in 2,5 litre amounts (Photo 4.22), and allow thorough mixing before adding further water.



Photo 4.22

- The mixing must produce a consistency which is creamy and although very soft when dropped from the mixer into the wheelbarrow (Photo 4.23), it will fall in similar fashion to fresh cow dung without splashing, with a tendency to flow outwards for some 60 to 70 mm.



Photo 4.23

- The inside of the drum must be continually inspected for caking at the bottom of the drum. This will be evident when, after mixing for ± 2 min, a watery mixture of emulsion and aggregate (poorly graded) appears to form. Some of the aggregate will have caked at the bottom of the drum.
- This will occur if the operator has kept the drum in the semi-vertical position for extended periods while mixing. To rectify this situation, place the drum in the near horizontal position and tap the base of the drum with a 2 kg hammer. Immediately the cake will be released and the mixture will revert to the creamy smooth mixture.

Note

The operator of the concrete mixer is in charge of the discharging operations and must ensure that the barrows are correctly placed, so that when discharging of the drum occurs, the slurry falls well within the bowl of the barrow without any wastage or mess taking place (Photo 4.23). Only half barrow loads must be discharged and not full loads.



4.2.3 Application of slurry

After the surface of the base has been prepared as described in Section 4.1, proceed as follows:

- Mark the lines for the steel rails, using a chalk line and then place the rails with the 10 mm section in the vertical position, to gauge the thickness of the wet slurry to dry to a 6 mm thickness. (Photos 4.24 and 4.25)



Photos 4.24 and 4.25

- The final thickness of the slurry must conform as close to 6 mm as possible, for example. The rails which are used to gauge the wet slurry when being laid are 10 mm thick. (Photo 4.26)



Photo 4.26



- Lightly water the surface, using a sprinkler nozzle on the hose and place the screed box on the rails (if one is being used).
- Place shovels of the slurry just ahead of the screed, in sufficient quantities for the squeegee operators to spread the material sufficiently thick, for the screed to level the surface quickly and efficiently. Placing too much slurry too close to the screed, makes the screed and squeegee operators' work more time consuming.
- During the process of shovelling the slurry from the barrow to the road, the shovels must be dipped into the drum of water and wiped with a wet mutton cloth.

Note

Occasionally the last barrow loads of slurry from the mixer are drier than the first loads and just too dry to spread efficiently. Before discharging the load, it is advisable to return the load to the mixer where a limited amount of water can be added and remixed to correct consistency.

- If some of the load has already been discharged on the road, a light sprinkle of water can be applied to assist in efficient spreading.
- Note that all the hand tools, if continuously cleaned in the $\frac{1}{2}$ drum of water next to the work area, the operation proceeds more efficiently. Instead of using $\frac{1}{2}$ drum of water, a wheelbarrow of water will be more efficient. It can be moved as the work progresses.
- A stable grade Anionic emulsion will take anything from two to three hours for initial breaking of the emulsion to occur, depending on the humidity and temperature prevailing on site. Therefore, if wet weather is predicted and imminent, no slurry work must be attempted.
- No traffic must be allowed to use the surface until the emulsion has broken and set.
- No slurry must be placed on a dry surface. It is essential to ensure that adequate watering facilities are in place before the work starts.
- Cleanliness of equipment is advisable at all times and the due care of the rails, when storing and handling, is essential to prevent the rails being damaged or bent.
- Cleanliness in and about the work site is essential to ensure no free bitumen is carried onto the work by pedestrians or the work's team.
- Once a mix is commenced, there must be no stoppage of the work e.g. lunch breaks, etc., until the cycle of mixing and laying of the mix has been completed.
- The screed operators must be replaced every hour to allow them to do less arduous work for at least an hour.



4.3 Finishing

It is recommended that once a half width of the road has been completed, it is compacted with one complete pass with the 76 Bomag roller (or equivalent) in vibratory mode, 24 hours after the slurry has set. This will extend the life of the seal.

Over-rolling is not advisable as it will result in a slick (slippery surface).

4.4 Construction of second half width of road

The slurry seal on the other half width of the road can now be constructed in accordance with sections 4.2 and 4.3.

When placing the slurry on the second half width of the road (10 mm wet thickness), allowance must be made for the thickness (6 mm) of the dried and compacted slurry already placed on the first half width of the road.

This is achieved by placing 4 mm rails on top of the dried slurry along the centre line of the road and 10 mm rails on the edge of the road as depicted in Figure 4.9.

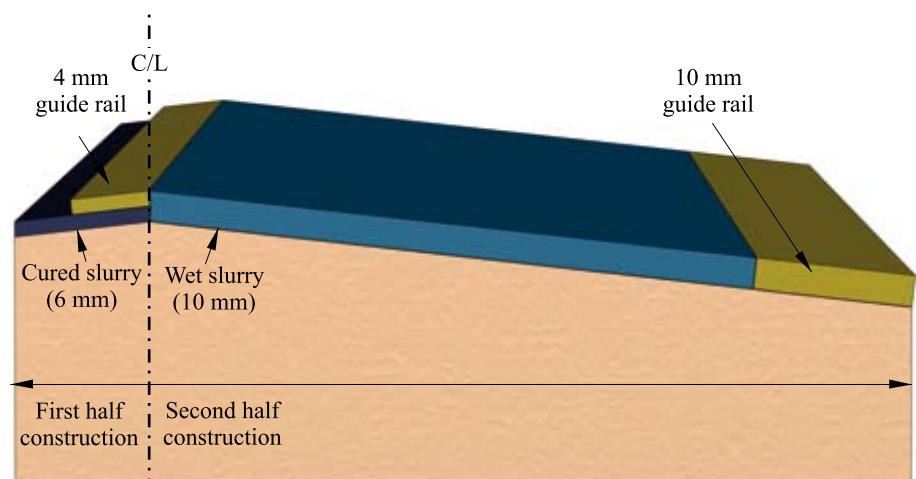


Figure 4.9: Detail to accommodate wet and dry slurry thicknesses

4.5 Construction of second/third strips

If the shape of the base is not true (i.e. it does not have an even straight slope), it is difficult to use a straight screed and ensure a uniform 10 mm wet thickness of slurry. (Figure 4.10)

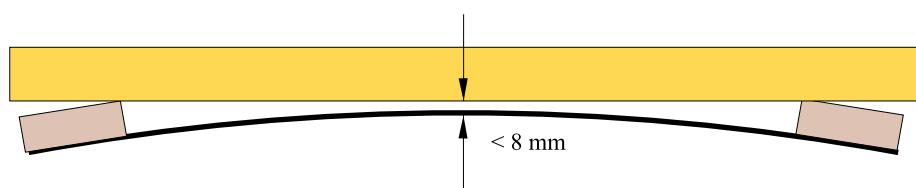


Figure 4.10: Minimum thickness not acceptable

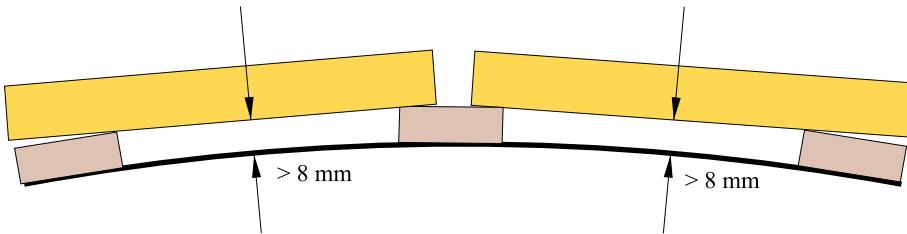


Figure 4.11: Minimum thickness acceptable

By splitting the half width into two or three even parallel sections, it is easier to ensure a consistent thickness of surfacing and achieve the minimum wet thickness of > 8 mm.

5. Notes to designer/consultant

5.1 Design of slurry

5.1.1 Slurry seal binder content

The slurry seal binder must be a stable grade 60% Anionic emulsion. The bulking of the aggregate must be taken into consideration when determining the amount of emulsion for the mix.

Table 4.5 gives an indication of the slurry seal binder content for a range of traffic volumes for 1 m³ of dry aggregate.

Traffic volume (vpd)	Binder content (litres/m ³)
50 – 500	60
500 – 1 500	240
1 500 – 2 500	230

Table 4.5: Binder content

5.1.2 Water content of slurry

The approximate amount of water to be added to the slurry is 235 litres per m³.

This amount could either be increased if the aggregate is completely dry and hot conditions prevail or reduced if the aggregate is damp.

It is recommended a trial mix be prepared and, once the amount of water required is established, it is used consistently for the rest of the work to obtain a uniform mix.



5.1.3 Aggregate for the slurry

Grading of aggregate

The aggregate for the Cape seal slurry must be carefully selected. Generally speaking, the medium grade grading for the slurry must be selected. The grading curve, depicted in Table 4.6, can be used as a guide for selecting the aggregate.

Sieve size (mm)	Percentage by mass passing
6,700	100
4,750	82 – 100
2,360	56 – 95
1,180	37 – 75
0,600	22 – 50
0,300	15 – 37
0,150	7 – 20
0,075	4 – 12

Table 4.6: Grading of aggregate

5.1.4 Bulking of aggregate

Bulking of the aggregate is a problem which must be addressed, especially if the aggregate is damp. If the aggregate is dry, there is no problem. Normally aggregate supplied from the crusher is damp and the problem will arise when part of the heap is damp and part dry.

To overcome this, thoroughly wet the heap to be used with a hose, some 6 to 8 hours, or more, before use (and cover the heap with a plastic cover). Find the degree of bulking, using the following procedure:

1. Determine the inside height of the 25 litre can (say y).
2. Fill the can with damp material in the normal way when feeding the concrete mixer.
3. Strike off the excess material in the can and level with the top of the can.
4. Add water to the can of aggregate until completely saturated, making sure all the air is released by rodding the can with a thin rod (e.g. rake handle or reinforcing bar).
5. Pour off excess water and measure the drop in height of the aggregate (say x).
6. Then x/y will give the degree of bulking (bulking factor) for adjustments of the quantity of emulsion to be used in the mix.

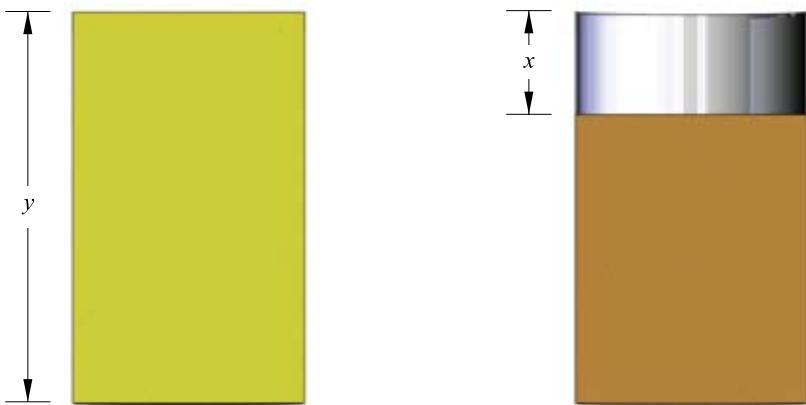


Figure 4.12

Therefore, if the quantity of emulsion to be used in the mix is 290 litres/m³, this amount of emulsion must be reduced by a factor of x/y i.e. x/y times 290.

The amount of emulsion to be used per m³ is therefore:

$$290 - (x/y) \times 290 = 290 (1 - x/y) \text{ litres.}$$

Note

Using uniformly damp aggregate reduces the amount of water to be added to the mixture to produce the slurry. It also overcomes the problem of balling of the fines when emulsion is added.

If the aggregate to be used is completely dry it is recommended that a small amount of water be added to the aggregate in the mixture after adding the cement to ensure no balling of the mix takes place when the emulsion is added.

5.2 Addition of cement

It is essential to add cement to any slurry for the following reasons:

1. It eliminates the segregation of the diluted emulsion from the coarse aggregate and the emulsion floating to the surface of the spread slurry. It also increases the adhesion of binder to aggregate.
2. It acts as a catalyst in the mixed slurry, inducing the emulsion to break by absorbing water from the emulsion.
3. It improves the workability of the slurry, giving it the creamy texture, assisting the coating of the fine and coarse aggregate and keeping it in suspension.
4. It also improves the grading of the aggregate on the finer side of the grading curve.

Normally $\pm 1\%$ of aggregate by mass of cement is added to the mix, but this can be increased to 2% if there is a shortage of fines.

MODULE 5: Construction of a Cape seal

1. Specification

The specification will call for the construction of a Cape seal, consisting of either a 13,2 mm or 19 mm single seal with an application of a slurry seal, constructed in accordance with the relevant specifications referred to in the scope of work in the contract documents.

2. Materials

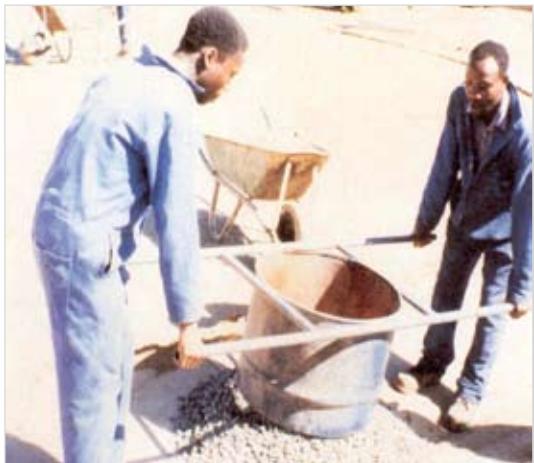
Materials required for the construction of the Cape seal are:

- Surfacing aggregate of the specified size (obtained from a commercial source/quarry).
- Bituminous binder in the form of a bitumen emulsion, either Anionic spray grade emulsion (60/40) or Cationic spray grade emulsion (65/35).
- Slurry aggregate of the specified grading (obtained from a commercial source/quarry).
- Slurry binder in the form of an Anionic stable grade emulsion (60/40) with Vinzyl resin as emulsifier.

3. Construction plant and equipment

The following specialised plant and equipment is recommended to promote the construction of the Cape seal surfacing by labour intensive methods:

- Shovels
- Brooms
- Builders' wheelbarrows (Capacity \pm 65 – 67 litres)
- Hammer
- 7 mm sisal rope, 2 \times 50 m rolls
- Reinforced paper, 4 rolls \times 1 metre wide
- Steel pegs, 300 mm \times 9 mm
- Chalk-line equipment
- Steel tape, 50 m
- Squeegees ([Workshop drawing LIC 005](#))
- 5 \times 25 litre measuring containers with lifting handle ([Workshop drawing LIC 009](#))
- 5 \times 10 litre measuring containers
- Hessian drag
- 105 litre drums open both ends with lifting handles ([Workshop drawing LIC 010](#)) for spotting aggregate (Photo 4.27)
- 105 litre drums for checking spray rates and cleaning spray equipment
- Drum lifter for lifting full drums of binder ([Workshop drawing LIC 008](#))
- Manually operated chip spreader (Photo 4.28) (Optional)



Photos 4.27 and 4.28

- Concrete mixer 150/200
- Steel-framed stand for emulsion drums with steel or timber ramps (Photo 4.33)
- 75 mm diameter ball valve for decanting emulsion from drums (Photo 4.33)
- Motorised hand sprayer (Photo 4.29)
- Suitably sized vibratory pedestrian roller (Bomag 75 or equivalent)
- Spray screens ([Workshop drawing LIC 007](#)) (Photos 4.29 and 4.30) and (Figure 4.12)



Photo 4.29: Spraying operation using motorised hand sprayer, with screens and reinforced paper in place

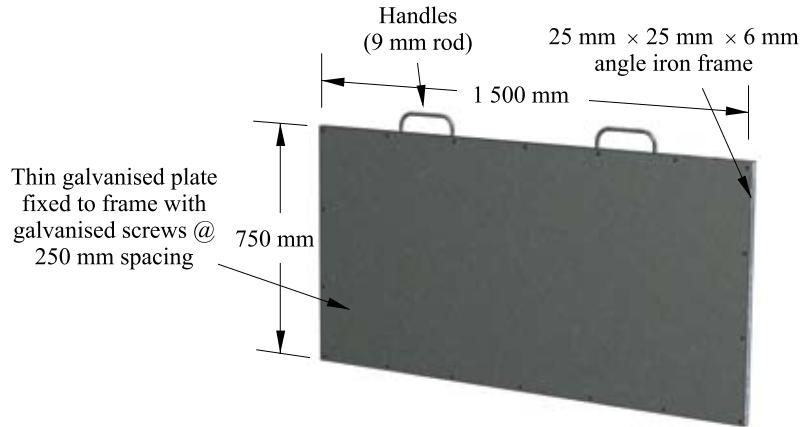


Figure 4.12: Sketch of spray screen (Refer to Workshop drawing LIC 007)

4. Construction

4.1 Preparation of surface

- Sweep the road clean. All loose material and mud that has been brought onto the surface by traffic must be removed.
- Stake out width of road to be surfaced, marking out the edge of the road with a 7 mm sisal rope.
- If necessary, lightly spray the surface with a diluted 1:8 emulsion (1 litre emulsion to 8 litres water). Normally with an ETB, this should only be necessary if the road has been exposed to traffic for an extended period. This application of emulsion and water could be regarded as lightly priming the surface (0,5 – 0,6 litres/m² of diluted Anionic stable-grade emulsion should be applied).
- Protect any kerbs, drains, etc. from the emulsion spray. (Photo 4.30)
- Use reinforced paper for the construction joints at the beginning and end of each spray. (Photo 4.31)



Photo 4.30: Protection of kerbs, drains etc.



Photo 4.31: Neat construction joint due to use of reinforced paper

4.2 Application of bituminous binder

4.2.1 General

When working with any binder on site, cleanliness is essential. If spillage of the binder does take place, it must be cleaned up immediately.

The use of a ramp and stand as illustrated in Photo 4.32 will facilitate the decanting of binder when necessary.



Photo 4.32: Stand for decanting binder



4.2.2 Spraying the binder

Application of the binder

The emulsion binder is applied using the motorised hand sprayer in accordance with Module 2: Procedure for operating and applying binder using the motorised hand sprayer.

Heating of binder

The heating of the emulsion binder must be done carefully by stirring the binder while being heated, to avoid surging and boiling over. The binder temperature must be continuously checked with a thermometer. It normally takes approximately 45 – 60 minutes to raise the temperature to 50°C if ambient or overnight temperatures are low i.e. < 10°C.

The heating of emulsion specifically applies when using cationic emulsion. Anionic emulsion can be applied in the warm summer months without heating, but it is advisable to heat it in cool winter weather.

Spraying of binder in more than one application

Because of the low viscosity of the emulsion (compared with a penetration bitumen), it is not possible to spray emulsion at more than $\pm 0,6 – 0,7$ litres/m², without the binder tending to flow (even on the flattest surfaces).

Therefore, to overcome this problem, the tack coat is sprayed at 0,6 – 0,7 litres/m², and the balance of the calculated tack coat application is applied as the penetration spray, where the aggregate will inhibit any untoward flow of the binder.

4.3 Application of aggregate

4.3.1 General

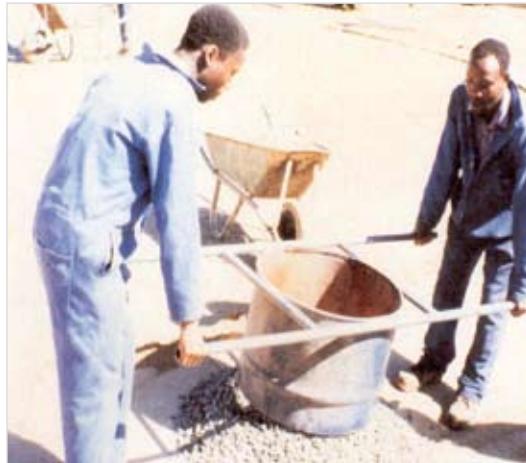
The application of aggregate must only commence after approximately 4 metres of road has been sprayed to avoid aggregate falling on unsprayed road.

Two methods of applying the aggregate are described:

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

4.3.2 Application by spotting of aggregate and spreading by hand

Spot the heaps of aggregate accurately, along the length of the road, at the spacing determined by the engineer. This should be based on the determined application rate in m³/m² of the aggregate, as this will assist in obtaining a uniform rate of application of the aggregate (Photos 4.33 and 4.34). The aggregate should be placed on plastic sheets of 1,5 m \times 1,5 m to reduce wastage.



Photos 4.33 and 4.34: Spotting of aggregate

A half 210 litre drum with the bottom of the drum removed and two handles fitted to the side of the drum, for ease of handling can be used for this operation. This ensures that the correct amount is placed at each position.

Each labour unit is responsible for applying the two heaps of aggregate to the area applicable for these two heaps, as determined by the engineer (the labour must not wander off to adjacent areas). This will ensure uniform, correct application of aggregate.

A shovel of aggregate is taken. Then the aggregate is pitched into the air while twisting the shovel rapidly. This sprays the chips uniformly over the area to be covered. In this way the stone will fall onto the wet tack coat while the dust, if any, will fall onto the top of the stone or, if there is a breeze, will be blown across the road away from the surface.

Once sufficient stone has been applied so that one can walk on the surface without coming into contact with the wet binder, the bare spaces can be filled with more stone. The aggregate must, however, not be tightly packed and care must be taken not to have double layers of stone.

Gently broom the surface and distribute any loose stone forming double layers, to obtain a maximum gap of approximately 3 mm between the stones. The better this process is done, the better and more efficient the seal will be.

Once the surface has been covered with the aggregate without bare patches of binder showing, rolling with the pedestrian roller can commence.

After the surface has been rolled once (i.e. a complete coverage of the roller), care must be taken to cover bare patches or remove any double layers of aggregate by brooming to obtain a single layer.

The first roll must be done without vibration but subsequent rolling, when the aggregate is properly placed with full coverage obtained, can be done with intermediate vibration of the roller switched on.

The rolling must be done in straight lines, parallel to the centre line or edges of the road. It is essential that rolling is done uniformly across the width of the road surface. Typically three passes should be sufficient to seat the aggregate. (Photo 4.35)



Photo 4.35:
Compaction of the aggregate

4.4 Application by a manually operated chip spreader

4.4.1 Chip spreader

The use of the Chippy hand spreader (Photo 4.4 b), will facilitate the efficient uniform application of aggregate by hand labour and, therefore, reduce the amount/intensity of brooming required.

The Chippy, which can be bought or hired from the company, has a capacity of three wheelbarrow loads of aggregate and is operated by four people – one to steer the Chippy and three to push it. The Chippy starts with a full load and spreads chips at a width of 1,2 metres.

4.4.2 Trial section

Before any sealing is done with the Chippy, it must be adjusted for correct application by first doing dry runs on an unsprayed surface.

Arrangements should be made with the manufacturer to train the operators of the Chippy, in the correct method of operation during the trial run and first operation on the bitumen binder.

4.4.3 Application methodology

As with the spreading of the aggregate by hand, predetermined quantities of the aggregate are spotted along the side of the road, using 105 litre half drums at distances determined by the engineer, depending on the ALD and the application rate of the aggregate.

When Chippies are used for spreading aggregate, the spotting of stone must be based on 2×105 litres of stone per stockpile. This conveniently is the capacity of 3 wheelbarrows which also equals one fully loaded Chippy.

Photo 4.36 depicts three chip spreaders being used at the same time. In this instance the procedure, as determined by the manufacturer, must be strictly followed. As a general rule three Chippies will only be required where the binder is applied by a bulk distributor.

Where the binder is applied by a motorised hand sprayer, one Chippy will be sufficient.



Photo 4.36

The aggregate is loaded into the Chippy by wheelbarrows, and the Chippy guided along the length of the road, in accordance with the manufacturer's instructions.

Using a hand sprayer and one Chippy, the procedure illustrated in Figure 4.13 is recommended for applying the aggregate using 2×105 litre drums at the calculated spacing.

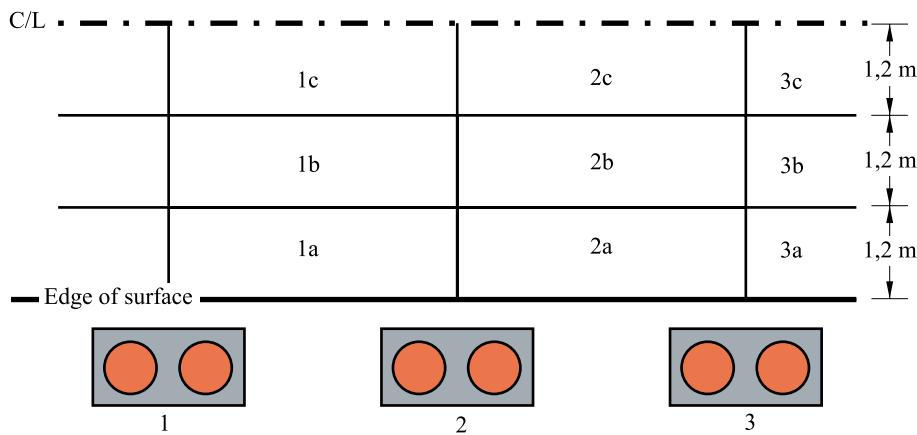


Figure 4.13: Procedure for applying aggregate

Once sufficient stone has been applied and one can walk on the surface without coming into contact with the wet binder, the bare spaces can be filled with more stone. The aggregate must, however, not be tightly packed and care must be taken not to have double layers of stone.

Gently broom the surface and distribute any loose stone that may be forming double layers, to obtain a maximum gap of approximately 3 mm between the stones. The better this process is done, the better and more efficient the seal will be.

Once the surface has been covered with the aggregate, without bare patches of binder showing, rolling with the pedestrian roller can commence.

After the surface has been rolled once (i.e. a complete coverage of the roller), care must be taken to cover bare patches, or remove any double layers of aggregate by brooming to obtain a single layer.

The first roll must be done without vibration but subsequent rolling, when the aggregate is properly placed with full coverage obtained, can be done with intermediate vibration of the roller switched on.

The rolling must be done in straight lines, parallel to the centre line or edges of the road. It is essential that rolling is done uniformly across the width of the road surface. Typically three passes should be sufficient to seat the aggregate. (Photo 4.35)

4.5 Application of penetration spray

Once the aggregate has been uniformly applied and is well seated, the remainder of the bitumen emulsion, which was not applied in the tack coat, is now sprayed as a penetration spray.

The same precautions regarding joints and protection of kerbs, drains, etc. apply, as was the case for the tack coat.

If the surface is left open for any period before applying the penetration spray, the following must be attended to:

- Any dust, dirt or sand blown into the surface voids, must be removed/blown out with a compressor.
- The surface must be rolled once to reseat any aggregate that may have been disturbed by unauthorised traffic.

5. Application of slurry

5.1 General operation

Slurry seal workforce

- Concrete mixer operators.
- Wheelbarrow operators.
- Spreader/laying operators.

The preparation and construction of the slurry will need the careful operation and co-ordination of the labour force.

Concrete mixer operator's responsibilities:

- Checking the mixer before any work starts. The mixer must be checked for oil and fuel.
- After work is completed for the day, the concrete mixer operator must make sure that the mixer is cleaned. The operators must have a 25 litre drum or $\frac{1}{2} \times 200$ litre drum of water and a large piece of mutton cloth available, as freshly splashed slurry or emulsion can easily be washed off tools and mixer if dealt with immediately. It is better than using diesel or power paraffin.
- It is not necessary to wash out the mixer after every mix, on condition the work is being done on a continuous basis. For long stoppages, e.g. lunch break or major problem, then it is advisable to wash out the mixer.
- Caking of the mix will occur at the mouth of the drum during the process of discharging the mix into the barrows. These cakes tend to break off and contaminate the slurry mix, causing problems during the screeding of the laying process. Use the water-soaked mutton cloth to wash the mouth of the drum. Some of the excess water will fall into the drum, but is of a very limited quantity. This washing process should be done after each barrow load. If done on a continuous basis, the drum would be kept clean.



- The concrete mixer operator and an assistant are responsible for measuring out the correct amount of cement and emulsion to be used, and he/she must also check the consistency of the mix. If too dry, the slurry already discharged must be returned to the mixer for further addition of water and mixing.

Wheelbarrow operator's duties:

- They are required to fill the 25 litre cans or wheelbarrows with aggregate and deliver them to the mixer platform or hopper, ready for use.
- They must place the barrows correctly at the discharge point below the drum of the mixer.
- They must avoid any mud being carried onto the new work.
- They must place the slurry with shovels just ahead of the squeegee operators in sufficient quantities for the squeegee operators to spread the material quickly and efficiently to a sufficient thickness. The slurry must be placed in approximately straight lines across the width of the area being treated, for relatively easy distribution by rubber squeegees.
- During the process of shovelling the slurry from the barrow to the road, the shovels must be dipped into the drum of water and wiped with the wet mutton cloth.
- Immediately when the barrow is empty, the barrow must be wiped with a wet cloth to remove any slurry sticking to the barrow as these eventually break loose and contaminate the slurry.
- The barrow operators are responsible for site hygiene at the mixing site and road works site. Any spillage of slurry, emulsion or mud must be cleared, either by picking up the material and burying it or covering it up with gravel.
- At the end of the shift, the operators must clean their equipment and help clean the mixer, as well as park the mixer in a safe place.
 - Two operators using the squeegees.
 - One operator cleaning any untoward spillage of slurry behind the screed and using the water hose.
 - Two operators laying the rails.
 - One operator on the mixer.
 - One operator measuring out cement, emulsion, water and diluting emulsion as required.

5.2 Batching and mixing of slurry in concrete mixers

- The area on which the concrete mixer and emulsion drum stand is situated must be clean, well drained and have a sound surface to avoid dirt and mud being carried onto the base by the wheelbarrows. It must also be kept clean during operations to avoid bitumen being carried on to the new work by the wheelbarrows.
- The aggregate to be used in the slurry must be dumped as close to the working site as possible, preferably at the midpoint of the length of road that one load of aggregate will cover.
- Using the measuring cans (Photo 4.37) add the correct amount of aggregate to the mixer drum, as determined by the engineer while the drum is turning. (Photo 4.38)





Photo 4.37



Photo 4.38

- Add the cement to the aggregate in the drum very slowly (Photo 4.39), making sure no lumps or clods of cement are added (or make a cement slurry before adding to mix).



Photo 4.39

- The mix must be inspected to ensure the uniform distribution of the cement in the aggregate, before any emulsion is added.



Notes

1. The cement must be added to the neat aggregate and no attempt must be made to add the dry cement after the emulsion has been added.
2. If, for any reason, extra cement is to be added, it must be added as a slurry of water and cement mixture.

When drums of emulsion have been stored for any length of time, the bitumen molecules in the emulsion tend to settle to the bottom of the drum. Therefore it is essential to roll the drum and mix the contents well before use. It is even recommended that the day before the drums are to be used, they are turned upside down before being rolled for the next day's use.

It is recommended that full drums are stored not vertically but horizontally, ready for rolling and mixing and empty drums are stored vertically – apart from mixing by rolling the drums, it facilitates stock taking.

- The diluted emulsion must be poured slowly into the mixer and not dumped into the mixer (Photo 4.40). By slowly pouring fluid into the mixer, quicker and more efficient coating of the aggregate will occur, without spillage or splashing of both the emulsion and the slurry. The drum of the mixer must not be in the vertical position when pouring the emulsion. This vertical position is used by the operator to protect him from splash, caused by the dumping of emulsion into the drum. Note that the drum must be just off the horizontal position, and that the emulsion should be poured slowly, deep into the throat of the drum, resulting in very little splash. Pour a little at a time and allow mixing to occur before the next pour is done.



Photo 4.40

- Before adding the water, inspect the mix as it may not need much water to get the correct consistency. Carefully add the water in 2,5 litre amounts (Photo 4.41), and allow thorough mixing before adding further water.





Photo 4.41

- The mixing must produce a consistency which is creamy and although very soft when dropped from the mixer into the wheelbarrow (Photo 4.42), it will fall in similar fashion to fresh cow dung without splashing, with a tendency to flow outwards for some 60 to 70 mm.



Photo 4.42

- The inside of the drum must be continually inspected for caking at the bottom of the drum. This will be evident when, after mixing for \pm 2 min, a watery mixture of emulsion and aggregate (poorly graded) appears to form. Some of the aggregate will have caked at the bottom of the drum.
- This will occur if the operator has kept the drum in the semi-vertical position for extended periods while mixing. To rectify this situation, place the drum in the near horizontal position and tap the base of the drum with a 2 kg hammer. Immediately the cake will be released and the mixture will revert to the creamy smooth mixture.

The operator of the concrete mixer is in charge of the discharging operations and must ensure the barrows are correctly placed, so that when discharging of the drum occurs, the slurry falls well within the bowl of the barrow without any wastage or mess taking place (Photo 4.42). Only half barrow loads must be discharged and not full loads.



5.3 Application of slurry

Before the slurry is applied, it may be necessary to roll the surface once to replace any of the aggregate which may have been dislodged while spraying the penetration spray.

Sufficient water must be added to the mix to ensure a smooth creamy consistency, looking much like wet cow dung when dropped in the road – there must be no segregation of the binder and the aggregate.

Before the slurry is placed, the following procedure must be followed to ensure a neat clean process:

- The work must be set out using a 7 mm string line along the centre line of the road and guide rails along the edge. This will protect the drains or kerbing from becoming contaminated and avoiding overflow of slurry across the centre line.
- Before the slurry is placed, the surface must be gently sprayed with water. (Too much water will dilute the emulsion in the slurry and a free flow of emulsion and water will result, seeping into the concrete drains on the lower side of the road or onto the shoulders.)
- The slurry must be spread with hand squeegees, level with the tops of the aggregate.
- Once a uniform surface has been achieved and before breaking of the emulsion takes place, the surface must be dragged with a damp hessian drag to even out any ridges or high spots that may be left by the squeegees. Note that the hessian drag must be damp and not soaking wet, as this excess water will dilute the emulsion in the slurry and initially cause weeping on the sides of the surface and then segregation of the mix, resulting in an uneven surface.

At the end of the shift the hessian drag must be washed with a hose, to clean out the remaining binder ready for the next shift.

The length of the hessian drag must preferably be 3 metres.

- The surface must not be opened to traffic until the emulsion in the slurry has broken, and depending on the temperature ruling during the day – this could take anything from two to four hours. The slurry must preferably be laid when the air temperature exceeds 10°C.

Note

- The success of the final slurry is very dependent on the grading of the aggregate selected and the uniformity of mixing and placing the materials.
- If 19 mm aggregate is used in the Cape seal, it may be necessary to apply 2 applications of slurry.
- When using 13 mm aggregate, the amount of aggregate for the slurry will vary between 0,006 m³ per m² and 0,007 m³ per m². These amounts can be used for calculating the quantities of aggregate required for the total area to be surfaced.
- For 19 mm aggregate, the amount of slurry aggregate would be approximately 0,008 m³ per m² to 0,009 m³ per m², applied in two applications.

5.4 Finishing

The surface should be rolled with one or two passes ($\frac{1}{2}$ wheel overlap) with a pedestrian roller.

6. Notes to designers/consultants

6.1 General description

The Cape seal consists of either a 13,2 mm or 19 mm single seal, with an application of slurry seal. This seal is user-friendly and is a very strong/robust seal, suitable for heavy or light traffic.

6.2 Application of aggregate

When applying the 13 or 19 mm aggregate to the tack coat for the Cape seal, the aggregate must not be shoulder to shoulder, but must be opened up by one third to one quarter of the nominal size of the aggregate being used, as indicated in Figure 4.14.

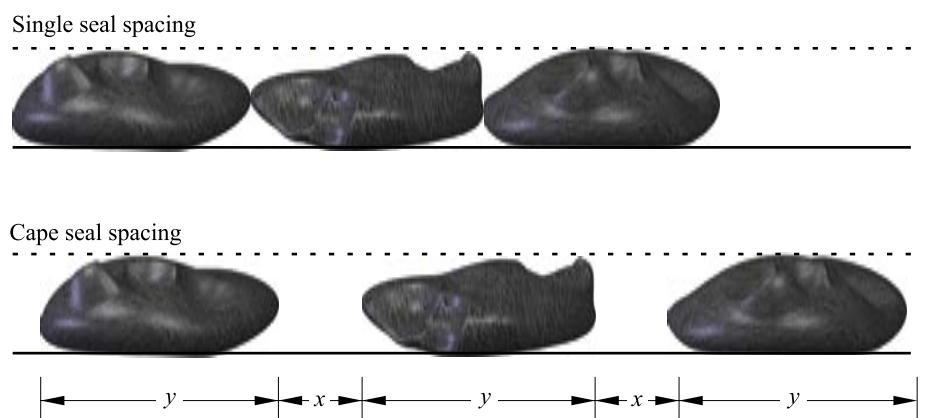


Figure 4.14

6.3 Using pan and cylinder to determine ALD and application rate

6.3.1 Determination of ALD of aggregate

A single layer of stone is placed shoulder to shoulder, in a measured area (pan), and the volume of the stone is found by pouring the stone into a cylinder of known dimensions.

The ALD can be read off the gauge in the cylinder in mm.

6.3.2 Determination of application rate of stone for Cape seal

A single layer of stone is placed as shown in Figure 4.14, with a gap between of 10% – 15% of the aggregate size in the pan. The volume of the stone is found by pouring the stone into the cylinder and taking the reading on the gauge.

If the reading on the gauge in mm is divided by 1 000, it will give the volume in m^3/m^2 for rate of application of the aggregate for the Cape seal.

- By using the pan and cylinder method for determining the ALD of the stone, the spacing/application of the stone can be demonstrated to the labour units placing the aggregate.



- When spacing the stone as above, the quantity required is reduced – the amount of aggregate poured into the cylinder will be less resulting in a lower ALD reading, resulting in lower stone application. This will mean the spotting distance between each 105 litre spot will be further apart. By calculating the distance for spotting the aggregate, this automatically controls the rate of application and the spacing of the aggregate particles.
- If no pan and cylinder is available, 200 pieces of aggregate must be measured with callipers and the average ALD determined. This ALD must be reduced by 10 – 15% and the spotting distances calculated accordingly.

Example where ALD is determined using callipers

Assuming the Average Least Dimension (200 stones) of the aggregate measured with callipers = 8,3 mm.

This must be reduced by 10% or 15% for Cape seal:

$$\begin{array}{lll} 8,3 \times 0,90 & OR & 8,3 \times 0,85 \\ = 7,47 \text{ mm} & OR & = 7,055 \text{ mm} \end{array}$$

The rate of application of aggregate in m^3/m^2 is obtained by dividing the above figures by 1 000:

$$0,00747 \text{ m}^3/\text{m}^2 \quad OR \quad 0,007055 \text{ m}^3/\text{m}^2$$

Allowing for a 5% for wastage the rate of application = $0,00747 \times 1,05 = 0,0078435 \text{ m}^3/\text{m}^2$

Calculation of spotting distance for 15% reduction

Width of road 2 \times 3,5 m and measuring container = half a 210 litre drum = 0,105 m^3
(1 000 litres = 1 m^3)

Number of m^2 that can be covered with 0,105 m^3

$$= \frac{0,105 \text{ m}^3}{0,0078435 \text{ m}^3/\text{m}^2} = 13,39 \text{ m}^2$$

For a width of 3,5 m this amount will cover a length of $13,39/3,5 = 3,8$ metres.

So 105 litres (half 210 litre drum) are spotted/placed every 3,8 m.



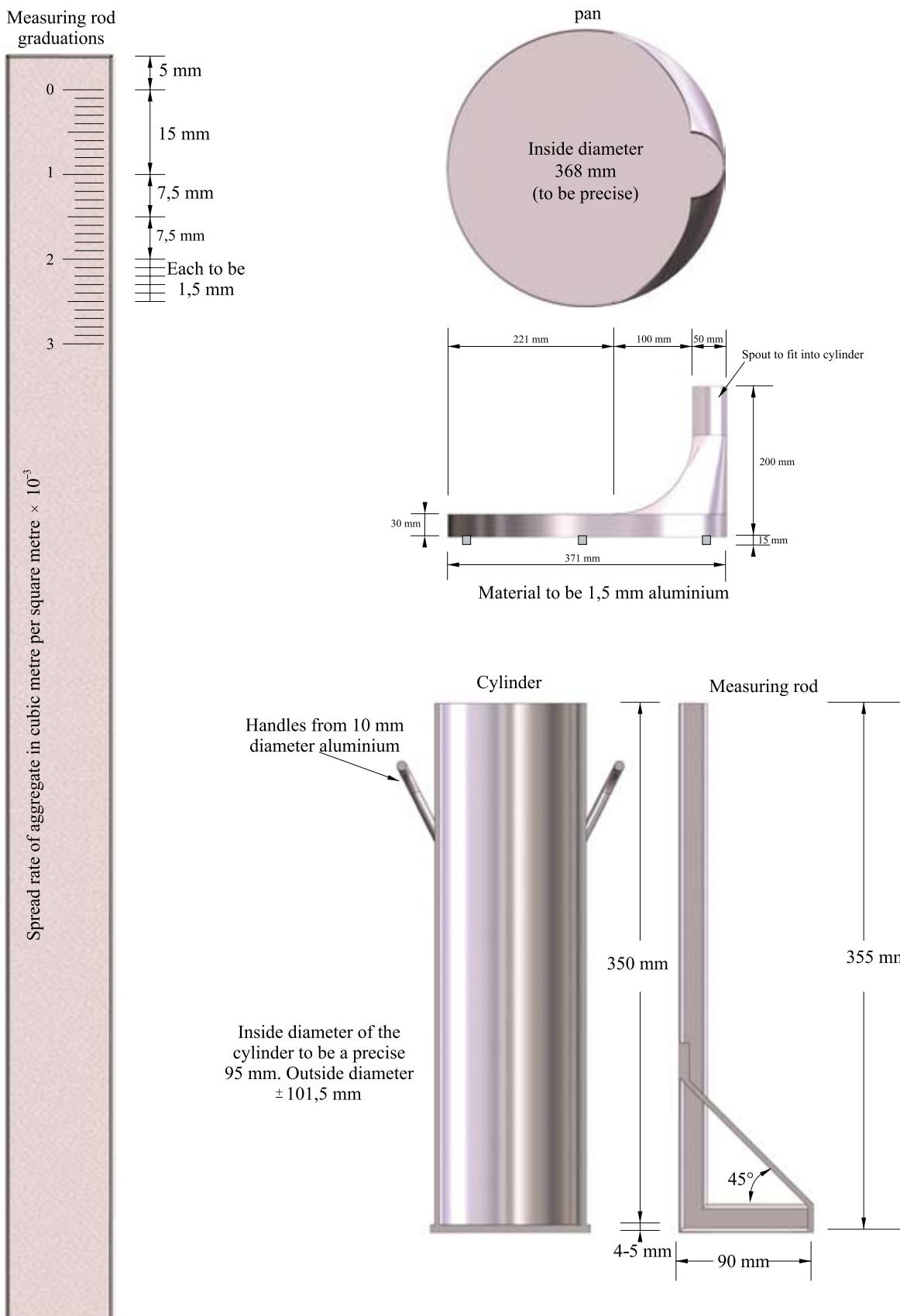


Figure 4.15: Pan and cylinder



6.4 Application of binder for the seal

6.4.1 Types of binder

Emulsions are ideal for manual application as they do not have to be heated to temperatures of 130°C – 140°C as is the case for penetration bitumen.

As they contain 35 – 40% water, the problem of over application, resulting in bleeding of the surface is overcome to a large extent.

The following binders can be used for seal work:

- Anionic spray grade emulsion (60% bitumen and 40% water).

The viscosity of this binder is lower than the viscosity of a cationic emulsion, and the rate of application for a tack coat reduces to approximately 0,7 to 0,8 litres per m² before the binder tends to flow, even when minimum gradients pertain.

Generally they do not require heating unless the air temperature at the time of spraying is below 20 – 25°C.

- Cationic spray grade emulsion (65% bitumen and 35% water).

This emulsion is ideal for seal work. In cool weather it is advisable to heat the emulsion with a low flame to 50°C.

The flow properties of this emulsion are better than Anionic emulsions.

Note

It is essential when using Cationic emulsion for the equipment to be thoroughly cleaned out of any Anionic emulsion. The equipment must be flushed out with water and paraffin.

When heating Cationic emulsion, care must be taken to heat it with burners on a low flame, The temperature to which it is heated must not exceed 50°C.

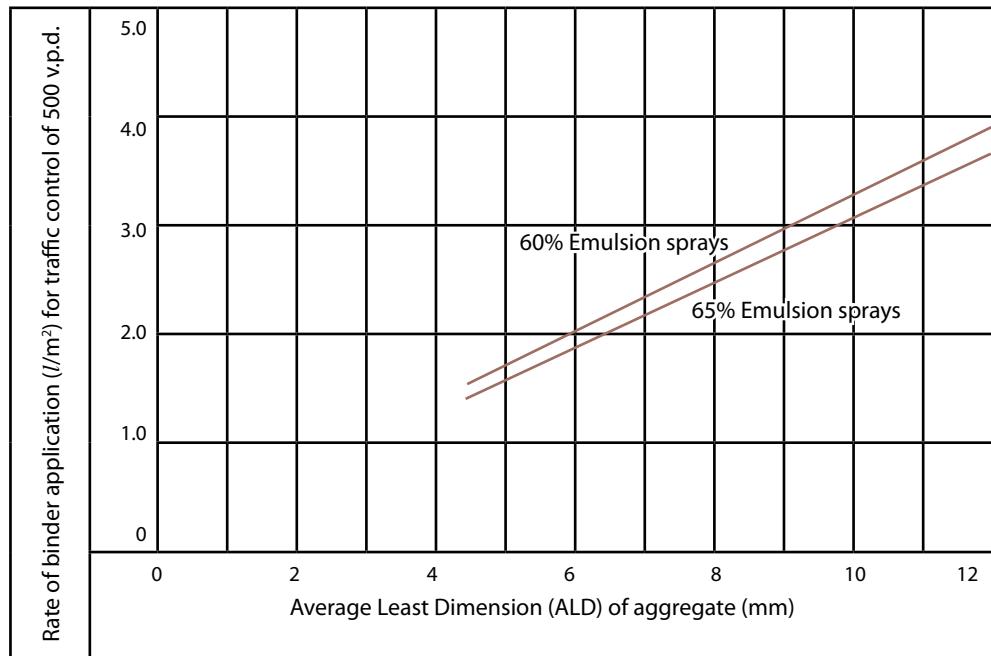
6.4.2 Rate of application of binder

The amount of binder that is required per m² is dependent on the size of aggregate to be used (e.g. less binder is required for a 13 mm aggregate than for a 19 mm aggregate) and the spacing between the aggregate.

It is therefore essential to determine the ALD of the stone before the quantity of binder can be determined.

The amount of 60% or 65% emulsion for a single seal can be determined from Graph 4.2.



**Graph 4.2: Rate of binder application**

The rate of application of the binder must be calculated as for a single seal, using the pan and cylinder method for determining the ALD; or using callipers for measuring the least dimension of 200 stones and calculating the average least dimension.

The rate of application of the binder will be reduced by some 10% - 15% for a Cape seal, as the stones will not be lying shoulder to shoulder, as is the case with a single seal. This reduction in the rate of application is acceptable in the Cape seal, as the voids will be taken up by the slurry seal.

All that is required of the binder is that there must be sufficient residual bitumen to hold the aggregate in place, and also bind the slurry seal to the aggregate. If the residual bitumen is excessive the surface will bleed.

Before any spraying of the binder, it is advisable to train the operator in spraying water and checking the rate of application (using a stopwatch), as described in Section 4.3.2.

It must be noted that a tack coat should not exceed $\pm 0,7$ litres/m² and the balance of the binder must be sprayed as a penetration spray.

6.4.3 Heating of binder on larger projects

On larger projects, it is recommended that separate mobile drum heaters are used to heat the binder.

A drum heater can raise the temperature of a drum of emulsion by 15° to 20°C, in the time taken to spray 210 litres of emulsion.

Depending on the ambient nocturnal temperature, more than one mobile drum heater may be required.

Table 4.7 gives an indication of the time required to heat a 210 litre drum of emulsion to 50°C.

Minimum temperature °C	Spraying temperature °C	Approximate time to heat 210 litre drum (min)
0	50	30 – 40
15	50	20 – 30
20	50	20 – 25
25	50	15 – 20

Table 4.7: Heating times for binder

6.5 Design of slurry

6.5.1 Slurry seal binder content

The slurry seal binder must be a stable grade 60% Anionic emulsion. The bulking of the aggregate must be taken into consideration when determining the amount of emulsion required for the mix.

Table 4.8 gives an indication of the slurry seal binder content for a range of traffic volumes per m³ of dry aggregate.

Traffic volume (vpd)	Binder content (litres/m ³)
50 – 500	60
500 – 1 500	240
1 500 – 2 500	230

Table 4.8: Binder content

6.5.2 Water content of slurry

The approximate amount of water to be added to the slurry is 235 litres per m³.

This amount could either be increased if the aggregate is completely dry and hot conditions prevail, or reduced if the aggregate is damp.

It is recommended that a trial mix be prepared and, once the amount of water required is established, it is used consistently for the rest of the work to obtain a uniform mix.

6.5.3 Aggregate for the slurry

Grading of aggregate

The aggregate for the Cape seal slurry must be carefully selected. Generally speaking, the medium grade grading for the slurry must be selected. The grading curve depicted in Table 4.9 can be used as a guide for selecting the aggregate.

Sieve size (mm)	Percentage by mass passing
6,700	100
4,750	82 – 100
2,360	56 – 95
1,180	37 – 75
0,600	22 – 50
0,300	15 – 37
0,150	7 – 20
0,075	4 – 12

Table 4.9: Grading of aggregate

Bulking of aggregate

Bulking of the aggregate is a problem which must be addressed especially if the aggregate is damp. If the aggregate is dry, there is no problem. But normally aggregate supplied from the crusher is damp and the problem will arise when part of the heap is damp and part dry.

To overcome this, thoroughly wet the heap to be used with a hose some 6 to 8 hours or more before use (and cover the heap with a plastic cover). Find the degree of bulking using the following procedure:

1. Determine the inside height of a 25 litre can (y).
2. Fill the 25 litre can with damp material in the normal way when feeding the concrete mixer.
3. Strike off the excess material in the can and level with the top of the can.
4. Add water to the can of aggregate until completely saturated, making sure all the air is released by rodding the can with a thin rod (e.g. rake handle or reinforcing bar).
5. Pour off excess water and measure the drop in height of the aggregate (say x).
6. Then x/y will give the degree of bulking (bulking factor) for adjustments of the quantity of emulsion to be used in the mix.

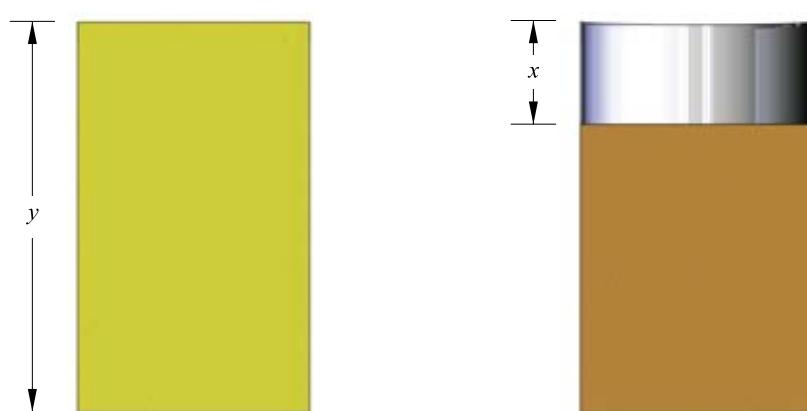


Figure 4.16

Therefore, if the quantity of emulsion to be used in the mix is $290 \text{ litres}/\text{m}^3$, this amount of emulsion must be reduced by a factor of x/y i.e. x/y times 290.

The amount of emulsion to be used per m^3 is therefore:

$$290 - (x/y) \times 290 = 290 (1 - x/y) \text{ litres.}$$

Note

Using uniformly damp aggregate reduces the amount of water to be added to the mixture to produce the slurry. It also overcomes the problem of balling of the fines when emulsion is added.

If the aggregate to be used is completely dry it is recommended that a small amount of water be added to the aggregate in the mixture after adding the cement to ensure no balling of the mix takes place when the emulsion is added.



6.5.4 Addition of cement

It is essential to add cement to any slurry for the following reasons:

1. It eliminates the segregation of the diluted emulsion from the coarse aggregate and the emulsion floating to the surface of the spread slurry. It also increases the adhesion of binder to aggregate.
2. It acts as a catalyst in the mixed slurry, inducing the emulsion to break by absorbing water from the emulsion.
3. It improves the workability of the slurry, giving it the creamy texture, assisting the coating of the fine and coarse aggregate and keeping it in suspension.
4. It also improves the grading of the aggregate on the finer side of the grading curve.

Normally $\pm 1\%$ of aggregate by mass of cement is added to the mix, but this can be increased to 2% if there is a shortage of fines.



MODULE 6: Construction of an Otta seal

1. Specification

The specification will call for the construction of either a double Otta seal or single Otta seal, with a sand-seal bituminous surface treatment of a specified grading, constructed in accordance with the relevant specifications referred to in the scope of work in the contract documents.

2. Materials

Materials required for the construction of the Otta seal are:

- Surfacing aggregate of the specified grading.
- MC or penetration grade bitumen binder.
- Bitumen emulsion for priming of base (if applicable).

3. Construction plant and equipment

The following specialised plant and equipment is recommended, to promote the construction of the Otta seal surfacing by labour-intensive methods:

- Shovels
- Brooms
- Builders' wheelbarrows (capacity \pm 65 – 67 litres)
- Heavy duty hose with spray nozzle, 100 m
- 7 mm sisal rope, 2 \times 50 m rolls
- Reinforced paper, 4 rolls \times 1 metre wide
- Pan and cylinder equipment for testing aggregate
- Steel pegs, 300 mm \times 9 mm
- Chalk-line equipment
- Steel tape, 50 m
- 105 litre drums open ended with handles for lifting (Workshop drawing LIC 010) for spotting aggregate (Photo 4.43)
- Manually operated chip spreader (Photo 4.44) (Optional)



Photos 4.43 and 4.44

- Pneumatic tyre roller (28/30 ton loaded)
- Bitumen tanker and distributor – provided by supplier of hot binder
- Steel-framed stand for emulsion drums with steel or timber ramps (if base primed with emulsion)
- 75 mm diameter ball valve for decanting emulsion from drums (if applicable)
- Motorised hand sprayer for priming of base (if necessary) (Photo 4.45)
- Drum lifter (Workshop drawing LIC 008) for lifting full drums of binder (if necessary)



Photo 4.45



4. Construction

4.1 Preparation of the base

Preparation of the unstabilised base

All loose dust or debris must be broomed off the surface and inspected for false layers which must also be removed for rectification after priming.

- Establish the centre line of pavement and mark out the edges of the surface to be primed with sisal twine, 200 mm wider than width of final surfacing.
- Place 2 × 210 litre drums of water and 2 × 210 litre drums of inverted emulsion prime at suitable distances along the road.
- Using the motorised hand sprayer, spray a 210 litre drum of water uniformly over the surface of the base at approximately 0,5 litres/m². (The 210 litre drum will cover ± 400 m² or ± 100 m of 3,5 m wide road).
- Allow the water to soak in and when the surface is damp, apply the prime (inverted emulsion prime). (See note)
- If the ambient temperature is > 20°C, it is not necessary to heat the prime.
- Apply the prime at approximately 0,7 litres/m². If over applied, the prime will run. It is difficult to over apply as 0,7 litre/m² is the approximate top limit. If the gradients are steep, the prime may run at 0,5 to 0,6 litres/m².
- Ensure that the spray screens are methodically used to prevent over spraying of the shoulders and ensure neat edge lines are achieved.

Note

Do not wet the surface using more than a drum of water at a time. This can be alternated with a drum of prime. The amount of prime sprayed/day will depend on the square metres of base completed per day.

4.1.2 Preparation of stabilised bases

- Emulsion-treated bases (ETB) can be opened to light traffic (< 500 vpd) for extended periods (one to two months), without special treatment. However, before surfacing, the road must be swept clean and apply diluted emulsion (60% stable grade Anionic), i.e. one part emulsion: 6 parts water, at a rate of 0,6 litres/m².
- Lime stabilised bases must be allowed to dry out and then treated and primed as for unstabilised base.

4.2 Spraying of binder

Controls prior to spraying

- Set out centre line and edge lines of the road with 3 mm sisal twine.
- Place reinforced paper at start and end of spray joints.
- Ensure that the supplier of binder has fixed fish plates at ends of spray bar fitted to the tanker.
- Ensure that end-nozzles are fitted to spray bar.



- While the tanker is parked on a level surface, check dipstick reading and record quantity of binder in the tank.
- Ensure the distributor has a valid up-to-date spray certificate. If not, let the laboratory carry out the distribution test on spray bar.
- Check width of spray for spray bar and correct setting of spray guide to ensure spray falls on correct surface of road.
- Before spraying, check spray for blocked nozzles and setting of nozzles.
- Check the temperature of the binder and ensure the same temperature is used for each spray – this will ensure more accurate spray applications.
- Record weather conditions and temperature of road surface.
- Check tachometer for condition setting and recording.
- Spray a test section to check if tanker is spraying at the correct rate, as determined by the engineer and if the spray is even. Repeat until the process is functioning satisfactorily (the material used in this process should be to the suppliers' account). Note dipstick reading, prior to spraying of actual road.
- Ensure there is sufficient labour to cover the binder with aggregate, e.g. if a medium grading is specified and 10 000 litres have been sprayed, $5\ 882\ m^2$ must be covered with aggregate:

$$\begin{aligned}
 &= 5\ 882\ m^2 \times ,016\ m^3/m^2 \\
 &= 94\ m^3 \quad (2 - 3\ m^3/\text{labor unit}) \\
 &= 31 - 47 \text{ labour units required for 8 hours.}
 \end{aligned}$$

- After spraying the section, again take dipstick reading (if entire load not sprayed).

4.3 Spreading of aggregate

Two methods of applying the aggregate are described:

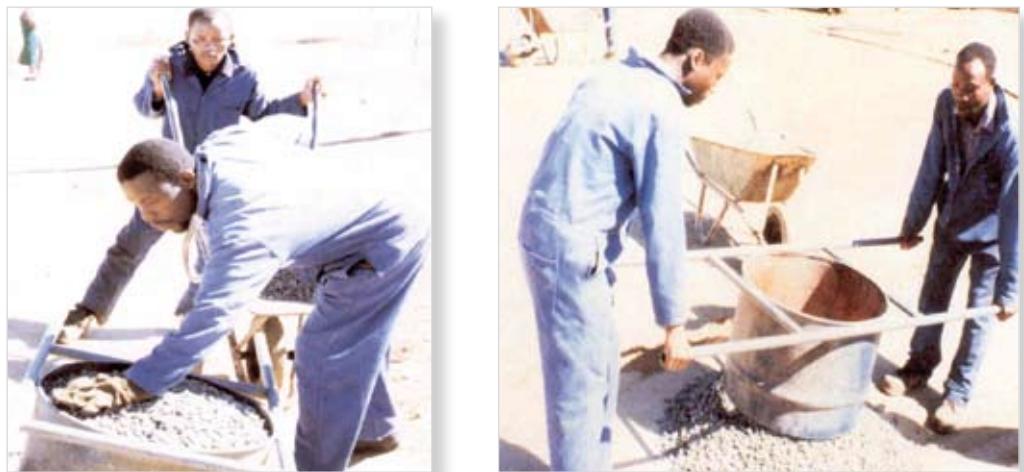
- Spotting of aggregate and spreading by hand.
- Application of aggregate by manual chip spreader.

Note

- Where the aggregate consists of screened material it shall be screened in accordance with the engineer's specification.
- Where crushed stone from a commercial source is used in the construction of the seal the quality and grading of the stone must be controlled at the crusher, prior to delivery, to eliminate disagreements arising when the material is delivered to site.

4.3.1 Application by spotting of aggregate and spreading by hand

- Spot the heaps of aggregate accurately along the length of the road, at the spacing determined by the engineer, based on the determined application rate in m^3/m^2 of the aggregate. This will assist in obtaining a uniform rate of application of the aggregate (Photos 4.46 and 4.47). The aggregate should be placed on plastic sheets of $1,5\ m \times 1,5\ m$ to reduce wastage.



Photos 4.46 and 4.47: Spotting of aggregate

A half 210 litre drum with the bottom of the drum removed and two handles fitted to the side of the drum for ease of handling, can be used for this operation to ensure that the correct amount is placed at each position.

Example:

Assuming medium graded stone applied at $0,016 \text{ m}^3/\text{m}^2$

$$\begin{aligned}
 & \frac{210 \text{ m}^3}{1000} \times \frac{1}{0,016 \text{ m}^3/\text{m}^2} \\
 &= 13,125 \text{ m}^2 \times 1 \\
 & \quad 3,5 \text{ m} \text{ (half road width)} \\
 &= 3,75 \text{ m} \text{ (Figure 4.17)}
 \end{aligned}$$

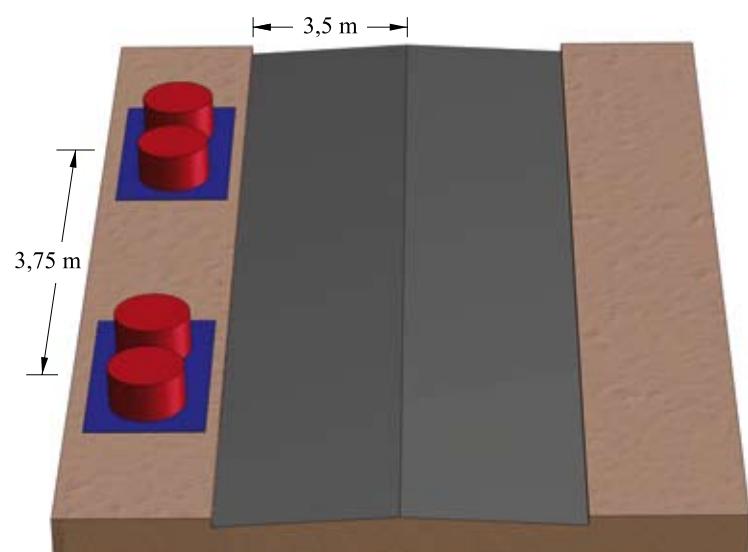


Figure 4.17: Spotting of aggregate



A shovel of aggregate is taken. Then the aggregate is pitched into the air while twisting the shovel rapidly. This sprays the chips uniformly over the area to be covered. In this way the aggregate will fall onto the wet tack coat while the dust, if any, will fall onto the top of the aggregate or, if there is a breeze, will be blown across the road away from the surface.

Once sufficient aggregate has been applied so that one can walk on the surface without coming into contact with the wet binder, the bare spaces can be filled with more stone.

One labour unit can spread 4×105 litres of stone aggregate in one hour, i.e. the time taken to spray and cover $500\text{ m} \times 3,5\text{ m}$ of road.

If spread by hand and 500 m sprays are to be covered, approximately 65 labour units are required to cover the spray in one hour.

Using 180/200 pen. bitumen, the spray must be covered in less than half an hour.

Using MC 3000 or MC 800, the spray must be covered in one hour.

4.3.2 Application by a manually operated chip spreader

Chip spreader

The use of the Chippy hand spreader as (Photo 4.44) will facilitate the efficient uniform application of aggregate by hand labour and therefore, reduce the amount/intensity of brooming required.

The Chippy which can be bought or hired from the company, has a capacity of three wheelbarrow loads of aggregate and is operated by four people – one to steer the Chippy and three to push it. The Chippy starts with a full load and spreads chips at a width of 1,2 metres.

Trial section

Before any sealing is done with the Chippy, it must be adjusted for correct application by first doing dry runs on a clean, dry primed surface.

Arrangements should be made with the manufacturer to train the operators of the Chippy in the correct method of operation, during the trial run and first operation on the bitumen binder.

Application methodology

As with the spreading of the aggregate by hand, predetermined quantities of the aggregate are spotted along the side of the road, using 105 litre half drums at distances determined by the engineer, depending on the grading and the application rate of the aggregate.

When Chippies are used for spreading aggregate, the spotting of stone must be based on 2×105 litres of stone per stockpile. This conveniently is the capacity of 3 wheelbarrows which also equals one fully loaded Chippy.

One Chippy will work quite adequately when the binder is spread by a hand sprayer. If the binder is applied by a bulk distributor, as is the case here, it is recommended that three Chippies are used.

Photo 4.48 depicts three chip spreaders being used at the same time. In this instance the procedure, as determined by the manufacturer, must be strictly followed.



Photo 4.48

The aggregate is loaded into the Chippy by wheelbarrows and the Chippy guided along the length of the road, in accordance with the manufacturer's instructions.

Brooming of surface

The aggregate must be broom dragged, with a light broom drag, to even out the application of aggregate after one pass of the pneumatic roller. Hand brooms might be required to spread heavy uneven applications, as well as brooming back/cleaning unsurfaced lane of over applied stone, i.e. using the centre-line twine as the line to work to.

Rolling of the surface

Rolling with a 28/30 ton roller, correctly loaded, is more efficient than two 15 ton rollers.

Each section must receive at least 5 - 8 complete passes with a 30 ton roller on the first day and repeated on the next two days.

During the rolling process, the section must be broom dragged. Any loose aggregate must be broomed back onto the road during this period of rolling, to cover bleeding spots.

Control of traffic

During the three days of rolling and brooming, speed of traffic must be controlled to 50 km/h. This should be sustained for two to three weeks. Warning signs for loose chips and speed limit signs must be erected with flagmen and cones used for restricting speed.

STOP/GO operation must be used when the construction is done in half widths.

Note

Some bleeding in localised areas and in the wheel paths of traffic is a normal part of the curing process for Otta seals.

It is advisable to apply rolling when blinding off the surface where bleeding has occurred and choose a hot time of the day for this work.

Immediate post construction care

Aggregate that has been dislodged by traffic after the construction and rolling period should be broomed back into the wheel tracks, as required, during the next two to three weeks.

Two to three weeks after construction, any excess aggregate can be swept off the road and the traffic speed conditions lifted. (In the case of natural gravel with a fairly high content of fines, this period may have to be extended.)



4.4 Application of sand cover or second Otta seal

4.4.1 Preparation of surface

The first seal must be allowed to cure for a period of eight to twelve weeks, as directed by the engineer, depending on the curing conditions and the binder type before applying the following sand or Otta seal.

4.4.2 Application of binder

As for Section 4.2

4.4.3 Application of aggregate

As for Section 4.3

4.4.4 Brooming of surface

As for Section 4.3.2

4.4.5 Rolling of the surface

As for Section 4.3.2

4.4.6 Control of traffic

As for Section 4.3.2

4.4.7 Immediate post construction care

As for Section 4.3.2

5. Notes to designer/consultant

5.1 General

Description

The Otta seal originated in Norway and was developed by the Norwegian Public Roads Administration.

Basically it consists of the application of a relatively thick film of comparatively soft bituminous binder, sprayed on a prepared/constructed base. This is covered with a graded aggregate which is well rolled with a pneumatic roller to provide a 16 – 32 mm thick bituminous surfacing. The excess aggregate has to be broomed off.

The binder, under rolling and trafficking, can work its way through the aggregate – giving a premix-like appearance. During the first four to six months of service, the surface may appear to be rich in bitumen or may even bleed. This necessitates the spreading of sand or crusher dust over the affected areas to absorb the excess bitumen.

The treated road is allowed to cure for eight to twelve weeks before a sand cover seal or second Otta seal is applied.

This type of surfacing contrasts with the conventional seal surfacing, where a single sized crushed aggregate is placed and compacted on a film of binder, with the objective of the aggregate adhering to the binder.

Note

The Otta seal requires the use of a hot penetration bitumen (generally 150/200) binder which has to be applied by tanker.

A pneumatic roller is required to effectively roll the aggregate (28/30 ton loaded).

Before the use of the Otta seal is considered an analysis of comparative costs or cost effectiveness must be made.

The skid resistance of the Otta seal must be carefully monitored where excessive bleeding occurs.

5.2 Aggregate

5.2.1 Key properties

A large variety of material sources can be used for the production of graded aggregate for use in Otta seals.

The following materials are among those that have been used successfully:

- Screened natural gravel from weathered granitic rocks.
- Crushed and screened gravel from sandstone and lake deposits.
- Screened river/lake gravel and sand.
- Crushed, screened rock from a variety of rock types such as igneous rocks and pedogenic deposits of calcrete and silcrete.

Note

Where crushed stone from a commercial source is used in the construction of the seal the quality and grading of the stone must be controlled at the crusher, prior to delivery, to eliminate disagreements arising when the material is delivered to site.

Aggregate strength

Aggregates of relatively lower strength may be used for Otta seals, compared to those typically specified for conventional chip seals (Table 4.10).

Aggregate strength	Vehicles per day at the time of construction	
Requirements	< 100	> 100
Min. dry 10% FACT	90 kN	110 kN
Min. wet/dry strength ratio	0,60	0,75

Table 4.10: Aggregate strength requirements for Otta seals

Grading

The aggregate grading for Otta seals is relatively relaxed and allows for a rather wide grading envelope. However, the grading curve of the aggregate should fall within the designated area and should be as smooth and parallel to the envelopes as possible. Table 4.11 gives the general grading requirements for Otta seals.



Material properties	Requirements	TMH test method
Placticity index	Max. 10	A 3
Flakiness index	Max. 30 (applies only for crushed material)	B 3T
Sieve sizes (mm)	Overall grading requirements (% passing)	
19,000	100	A 1
16,000	80 – 100	
13,200	52 – 100	
9,500	36 – 98	
6,700	20 – 80	
4,750	10 – 70	
2,000	0 – 48	
1,180	0 – 38	
0,425	0 – 25	
0,075	0 – 10	

Table 4.11: Material requirements for Otta seal

5.2.2 Screened natural gravel

As-dug gravel should be screened to remove oversize particles and excessive fines. Low moisture content in the material is desirable, to avoid clogging of the finer mesh of the sieve. If moist material cannot be avoided, it may be necessary to increase the mesh size of the sieve. However, the screened natural gravel must conform to the material requirements as defined in Table 4.11. The presence of fines in the screened material is acceptable, provided appropriate compensation is made for the binder viscosity, binder application rate and construction methodology.

Note

The PI requirement of 10 (Max.), which is based on current practice, is not recommended – the material should preferably be non-plastic.

5.2.3 Aggregate for sand-cover seals

A sand-cover seal is normally applied over a single Otta seal, instead of using a double Otta seal for low volume roads (< 500 AADT).

The aggregate for the sand-cover seal will normally consist of crusher dust or screened river sand. Alternatively, Kalahari sand can be used if no better material is available within an economical haulage distance.

5.2.4 Aggregate requirements

General

The preferred aggregate grading will, to some extent, depend on the traffic volume at the time of construction as well as during the two months immediately following the sealing operation, as this contributes significantly in forming the Otta seal. If a 30 ton pneumatic roller is used to compact the seal, this requirement falls away.

Maximum particle size

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

Fines content

The amount of fines (< 0,075 mm) should preferably not exceed 10%. A higher fines content may result in construction problems, as the binder tends to coat the finer particles before the larger ones. This may lead to a less durable surfacing with inferior surfacing characteristics. However, aggregate with fines contents up to 15% have performed well on one project in Botswana, and no surfacing defects have yet been recorded, due to excessive fines contents on any project in the country.

Flakiness

No requirement for flakiness is specified for natural gravel or as mixture of crushed and natural gravel in Otta seals. For crushed rock, it is preferable that the weighted flakiness index does not exceed 30. The weighted flakiness index is determined on the following fractions:

9,5 – 13,2 mm 6,7 – 9,5 mm 4,74 – 6,7 mm

Sand-cover seals

Material for a sand-cover seal used in Otta seals can be crusher dust, river sand, Kalahari sand or a combination of these materials. The material should be free from organic matter and lumps of clay, and should be non-plastic. All material should preferably pass the 6,7 mm sieve.

5.2.5 Preferred aggregate grading

The design of Otta seals allows for a variety of aggregate gradings to be used, as long as the grading curve falls within the designated area of the general grading envelope and runs as smoothly and parallel to the envelope as possible.

As guidance for the designer of Otta seals, three grading envelopes, depending on traffic, have been produced to allow for a more rational design. However, the designer should always bear in mind that all types of aggregate which fall within the general specified envelope can be used, provided the binder viscosity and spray rates are tailored accordingly.

The only limitation, regarding the aggregate grading used in an Otta seal, is the open grading which should not be used for traffic volumes above AADT 1 000.

Table 4.12 indicates the preferred aggregate grading for design purposes, according to traffic volume.

AADT	Best Suited Grading
Less than 100	Open
100 – 1 000	Medium
More than 1 000	Dense

Table 4.12: Preferred aggregate grading for Otta seals

The grading envelopes for open, medium and dense grading are given in Table 4.13 the design procedure for Otta seals.



Alternative grading envelopes				
Sieve sizes (mm)	Open grading (% passing)	Medium grading (% passing)	Dense grading (% passing)	TMH test method
19,000	100	100	100	
16,000	80 – 100	84 – 100	93 – 100	
13,200	52 – 82	68 – 94	84 – 100	
9,500	36 – 58	44 – 73	70 – 98	
6,700	20 – 40	29 – 54	54 – 80	
4,750	10 – 30	19 – 42	44 – 70	
2,000	0 – 8	3 – 18	20 – 48	
1,180	0 – 5	1 – 14	15 – 38	
0,425	0 – 2	0 – 6	7 – 25	
0,075	0 – 1	0 – 2	3 – 10	

Any material falling within the open, medium and dense grading envelopes may be used as aggregate in an Otta seal. However, for traffic level AADT > 1000 vpd at time of construction, material within the open grading envelope shall NOT be used.

Table 4.13: Grading envelopes for open, medium and dense gradings

5.2.6 Aggregate application rates

It is important to apply sufficient amounts of aggregate to ensure that there is some surplus material during rolling and through the initial curing period of the seal. This aggregate embedment will normally take about two weeks to be achieved where crushed aggregate is used, after which any excess aggregate can be swept off. Where natural gravel is used the initial curing period will be considerably longer.

The aggregate application rates should fall within the ranges given in Table 4.14.

Table 4.14 lists the criteria for the selection of bitumen type and spray rates for the design of Otta seals. No correction of bitumen spray rates should be made in the design, to compensate for the solvent used in the cutback bitumen.

In contrast to the procedures adopted for the design of Chip seals on shoulders, no special design procedure is required for Otta seals on shoulders.

Aggregate application rates			
Type of seal	Aggregate spread rates (m ³ /m ²)		
	Open grading	Medium grading	Dense grading
Otta seals	0,013 – 0,016	0,013 – 0,016	0,018 – 0,020
Sand cover seals	0,010 – 0,012		
The aggregate application rates will very often be increased in order to reduce the risk of bleeding.			

Table 4.14: Design procedures for Otta seals

5.3 Binder

5.3.1 Type of binder

Table 4.15 shows the recommended type of binder for Otta seals made with the three respective aggregate gradings, under typical site conditions, as described in the table.

When using weak natural gravel, containing a fairly high proportion of fines, the correct binder type will be MC 3000 viscosity range, depending on weather conditions.

It should be noted that in Table 4.15 an MC 3000 viscosity-grade bitumen is recommended, for use with medium grade aggregates in cold weather. However, project experience in the country has shown that crushed stone aggregate 150/200 pen. bitumen, cut back slightly with power paraffin during the cold months, has also worked well.

Choice of bitumen in relation to traffic and grading			
AADT at the time of construction	Types of bitumen		
	Open grading	Medium grading	Dense grading
More than 1 000	Not applicable	150/200 pen. grade	MC 3000 MC 800 in cold weather
100 – 1 000	150/200 pen. grade	150/200 pen. grade in cold weather	MC 3000 MC 800 in cold weather
Less than 100	150/200 pen. grade	MC 3000	MC 800

Table 4.15: Choice of bitumen

5.3.2 Binder spray rates

The required binder spray rates for Otta seals vary, according to the following parameters:

- Traffic (AADT).
- Aggregate grading (open/medium/dense).
- The absorbency of the aggregate particles.
- Whether the base course is primed or not.

Hot spray rates lower than 1,5 l/m² should not be allowed.

For aggregates with a water absorbency of more than 2% the hot spray rate should be increased by 0,3 l/m².

In the case where the base has been primed the hot spray rate should be decreased by 0,2 l/m² for the first layer.

Bitumen spray rates					
Hot bitumen spray rates for un-primed base course (l/m ²)					
Type of Otta seal	Grading	Open	Medium	Dense	
				AADT < 100	AADT > 100
Double	1st layer	1,6	1,7	1,8	1,7
	2nd layer (*)	1,5	1,6	2,0	1,9
Single, with a sand-cover seal	Fine sand	0,7	0,7		0,6
	Crusher dust or coarse river sand	0,9	0,8		0,7
	1st layer (*)	1,6	1,7	2,0	1,9
Single (*)		1,7	1,8	2,0	1,9
Maintenance		1,5	1,6	1,8	1,7

(*) On a primed base course, the spray rate shall be reduced by 0.2 l/m² in the first layer.

Notes: – Where the aggregate has a water absorbency of more than 2%, the bitumen spray rate shall be increased by 0.3 l/m².
– Binder for sand-cover seal shall be MC 3000 for crusher dust or coarse river sand and MC 800 for the sand.

80/100 pen. grade bitumen shall NEVER be used in Otta seals unless softened or cut back to meet the above viscosity requirements.

The cut back bitumen grades can be made by blending 80/100 pen. grade on site using the following proportions:

To make 150/200 pen. grade: 3 - 5% softener mixed with 95 - 97% 80/100 pen. grade
Softener can be a purpose-made petroleum distillate, alternatively engine oil, old or new.
In addition 3% points of power paraffin shall be used.

The cut-back bitumen grades can be made by blending 150/200 pen. grade on site using the following proportions:

To make MC 3000 5 - 8% power paraffin mixed with 92 - 95% 150/200 pen. grade
To make MC 800 15 - 18 power paraffin mixed with 82 - 85% 150/200 pen. grade
Circulation in the tank shall be carried out for at least 1 hour after mixing.
Diesel shall not be used for cutting back to MC grades.

Table 4.16: Design procedures for Otta seals

Note: The above modification must not be attempted by inexperienced contractors – it is best left to suppliers and ordered as MC 3000 or MC 800.

5.3.3 Prime coat

It is claimed that Otta seals do not require primed surfaces on which they are to be constructed (except in the case of calcareous material).

On labour-intensive projects, where the work proceeds relatively slowly and the constructed base may be opened to traffic for extended periods, it is recommended that the base be primed, using an inverted emulsion prime at the maximum rate of 0,7 litres/m², depending on porosity/absorption of the base.

The prime can be applied with the motorised hand sprayer as the work proceeds and so protect the base or open the base to light traffic.

If the base is an ETB, a diluted emulsion can be used instead of the inverted prime.

5.4 Use of pan and cylinder to determine aggregate application rate for Otta seal

5.4.1 General

The pan and cylinder method is a quick manner of determining the ALD (average least dimension) of the aggregate, i.e. by placing the aggregate in the pan, shoulder to shoulder, pouring this quantity of aggregate into the cylinder using a graduated scale measuring the depth of aggregate in the cylinder. (Figure 4.18)

This depth of aggregate equates to the ALD of the stone and, if divided by 1 000, gives the rate of application in m³/m² required for the aggregate.

This procedure is applicable for normal seals for determining the ALDs.

5.4.2 Use for Otta seal

The pan and cylinder is eminently suitable for determining the rate of application of the aggregate for Otta seals as follows:

- Fill the pan with the approved graded stone to a depth required in the field, e.g. 16 mm or 19 mm and how it should look after application – before rolling.
- Pour the contents in the pan into the cylinder, carefully without spilling any of the aggregate.
- Drop the cylinder three or four times from a height of 50 mm onto a firm surface to settle the contents. Level off the top of the surface on which you place the graduated scale.
- Read off the remaining height on the graduated scale and this reading will give the theoretical ALD/or thickness of the layer as placed in the pan and required in the field, e.g. 20,6 mm.
- By dividing this reading on the graduated scale by 1 000, the rate of application in m³/m² is established.

$$\text{e.g. } \frac{20,6 \text{ mm} \times 1 \text{ m} \times 1 \text{ m}}{1 \text{ 000}} = 0,0206 \text{ m}^3/\text{m}^2$$

- From this required rate of application, the spotting distances can be calculated for the known half width of the road.

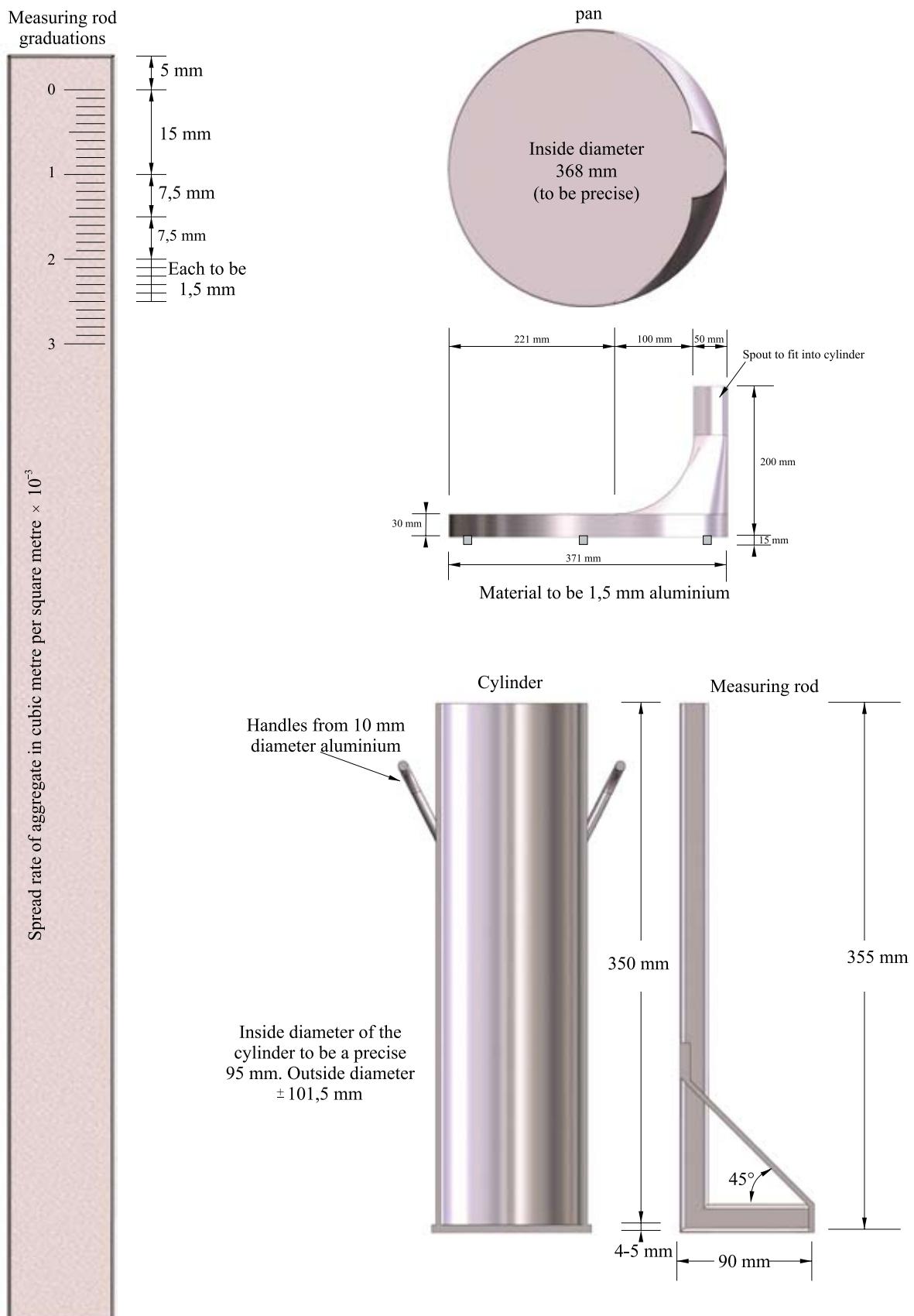


Figure 4.18: Pan and cylinder



MODULE 7: Indicative production and task rates

Indicative production rates and team sizes for selected activities based on a 7-hour production day

Activity	Description	Unit	Production rate	Team size
Hauling	0 – 20 m (wheelbarrow)	m ³	10 – 13	1
	40 – 60 m		8 – 10	1
	60 – 80 m		6 – 8	1
	80 – 100 m		5 – 6	1
Surfacing	Sweep base course		500 – 750	1
	Spread chips and back chip (by hand from spots)	m ²	200 – 400	1
	Spray with hand sprayer	210 litre drums	7 – 9 Note 1	4 – 5 Note 3
	Construct single seal			
	• Apply tack coat and aggregate	m ²	2 000 – 3 000	14 Note 2
	• Apply penetration coat	m ²	800 – 1 100	4 – 5 Note 3
Construct slurry seal (10 mm wet thickness)		m ²	500 – 800 Note 1.1	13 Note 4
	Construct Cape seal			
	• Apply tack coat and aggregate	m ²	2 000 – 3 000	13 Note 2
Construct Cape seal	• Apply penetration coat	m ²	800 – 1 100	4 – 5 Note 3
	• Apply slurry layer	m ²	1 000 – 1 400 Note 1.1	10 Note 5

Notes:

1. The production rate of spraying can be increased by making use of separate mobile drum heaters.
An experienced team could probably increase these production rates.
2. Labour units for applying tack coat and spreading aggregate.

Activity	Number
Spray team (see Note 3)	5
Aggregate spreaders and broomers	8
Supervisor	1

3. Labour units for applying penetration coat.

Activity	Number
Spray operator	1
Spray operator's assistant	1
Time keeper	1
Screen holders	2



4. Labour units for constructing slurry seal (thickness 10 mm).

Activity	Number
Loading and carting wheelbarrows	2
Concrete mixer operator	1
Materials measurements (emulsion/cement/water)	2
Squeegees	2
Screeeding	2
Roller operator	1
Gauges and cleaning	2
Supervisor	1

5. Labour units for mixing and applying slurry to Cape seal.

Activity	Number
Loading and carting wheelbarrows	2
Concrete mixer operator	1
Materials measurements (emulsion/cement/water)	2
Squeegees	2
Hessian drag and job hygiene	1
Roller operator	1
Supervisor	1



References

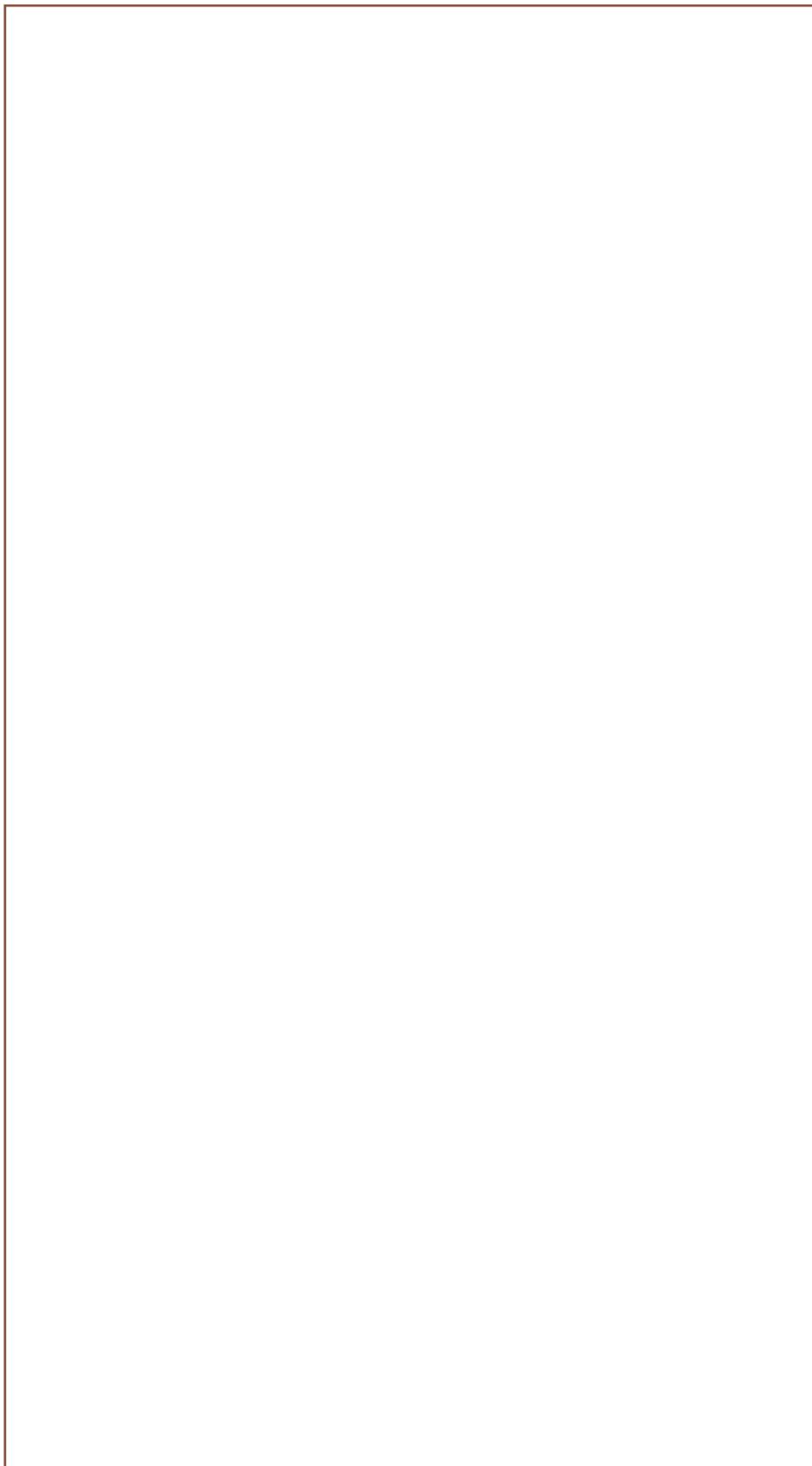
The framework agreement for public works projects using labour intensive construction systems.
Johannesburg: COSATU.

The Productivity of Labour Based Infrastructure Works. 1996. Zimbabwe: ILO.

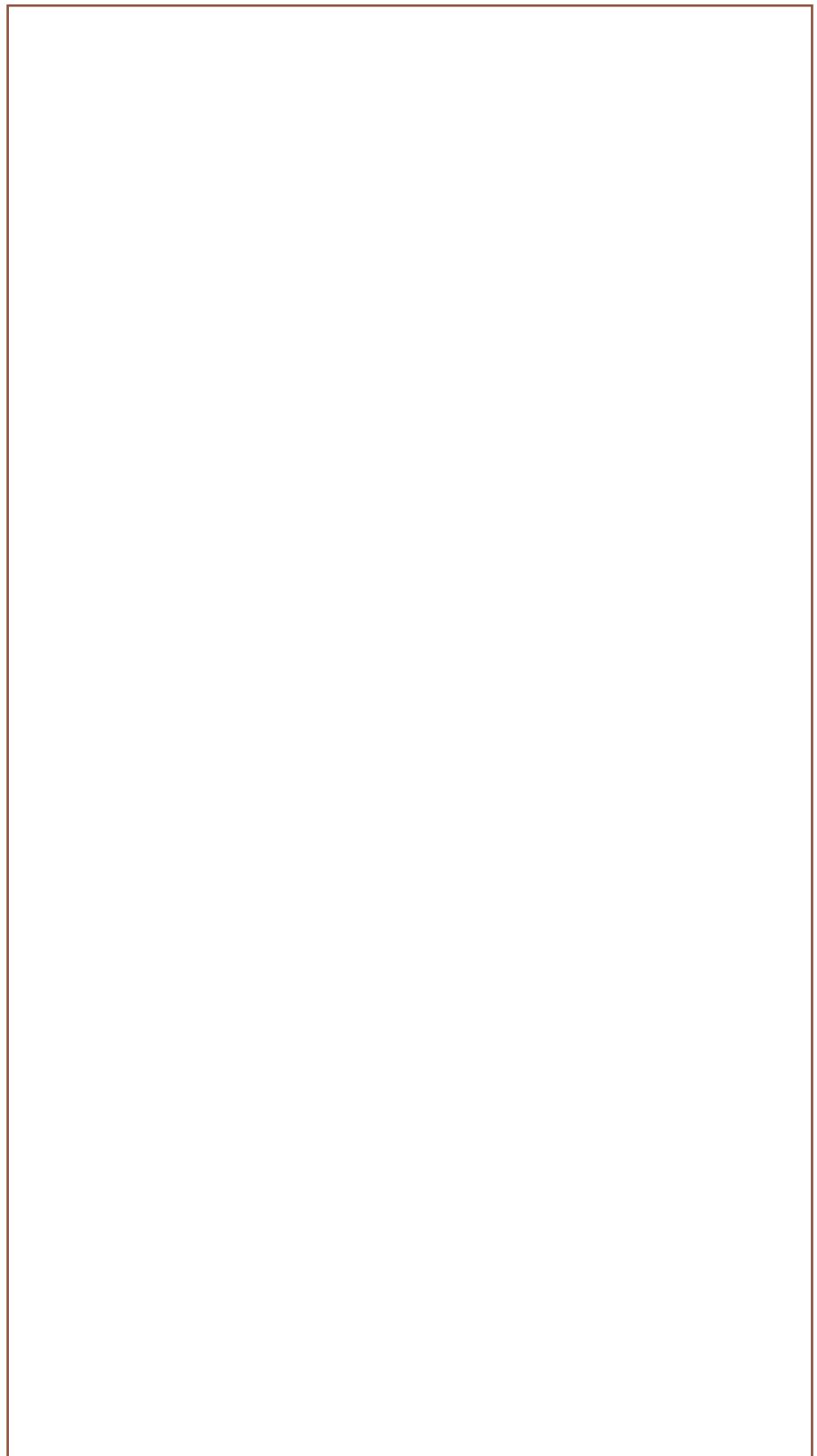
Scott, W. 1983. *Labour Construction Unit: Technical Manual.* Paper included in Labour Based Construction of Civil Engineering Projects: Information ex. Lesotho. Nov 1998.

World Bank study on substitution of labour for equipment. 1995. Washington DC: World Bank.

Notes



Notes



"We have made the firm commitment to confront the challenges of poverty and joblessness. We have made the solemn pledge that we will do everything possible to achieve the goal of a better life for all our people."

President Thabo Mbeki