TECHNICAL RECOMMENDATIONS FOR HIGHWAYS

TRH3 2007

DESIGN AND CONSTRUCTION OF SURFACING SEALS

May 2007 *03659*

PREFACE

TECHNICAL RECOMMENDATIONS FOR HIGHWAYS (TRH) have traditionally been aimed at informing the practising engineer about current recommended practice in selected aspects of highway engineering, based on proven South African experience.

Companion TRH,TMH and Sabita documents to TRH 3 are given on pages (iii), (iv) and (v).

This document was produced by a committee of practitioners from the public, private and research sectors.

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DISCLAIMER

The information given in this document is based on the knowledge and experience of organisations and individuals concerned with bituminous seals. This document only provides guidelines for the selection, design and construction of bituminous seals and is neither a specification document nor a complete manual for the training of inexperienced personnel.

The views expressed and recommendations given are based on the experience of the Committee responsible for the compilation of the document and cannot cover the entire spectrum of possible situations.

The information contained is given in good faith and gives guidelines on how to deal with the problems likely to be encountered. No responsibility will be accepted by the South African National Roads Agency or by any members of the committee which drew up this document for any adverse consequences arising out of the use of this document.

LIST OF COMPANION TRH DOCUMENTS

TRH 1	Prime coat and bituminous curing membranes
TRH 3	Design and construction of surfacing seals
TRH 4	Structural design of flexible pavements for interurban and rural roads
TRH 5	Statistical concepts of quality control and their application in road construction
TRH 6	Nomenclature and methods for describing the condition of asphalt pavements
TRH 7	Use of bitumen emulsions in the construction and maintenance of roads
TRH 8	Selection and design of hot-mix asphalt surfacings for highways
TRH 9	Construction of road embankments
TRH 10	Design of road embankments
TRH 11	Guidelines for the conveyance of abnormal loads
TRH 12	Bituminous pavement rehabilitation design
TRH 13	Cementitious materials in road construction
TRH 14	Guidelines for road construction materials
TRH 15	Subsurface drainage for roads
TRH 16	Traffic loading for pavement and rehabilitation design
TRH 17	Geometric design of rural roads
TRH 18	The investigation, design, construction and maintenance of road cuttings
TRH 19	Standard nomenclature and methods for describing the condition of jointed concrete pavements
TRH 20	The structural design, construction and maintenance of unpaved roads
TRH 21	Not-mix recycling
TRH 22	Pavement Management Systems
TRH 23	Concrete Pavement Maintenance
TRH 25	Guidelines for the hydraulic design and maintenance of river crossings

Note: TRH 2 is no longer available

LIST OF COMPANION TMH DOCUMENTS

TMH 1
Standard methods of testing road construction materials

TMH 2
National standard for the spraying performance of binder distributors

TMH 3
Traffic axle load surveys for pavement design

TMH 5
Sampling methods for road construction materials

TMH 6
Special methods for testing roads

TMH 7
Code of practice for the design of highway bridges and culverts in SA

TMH 8
Verkeerstellingsprosedures vir buitestedelike paaie

TMH 9
Pavement Management Systems

TMH 10
Manual for the completion of as-built materials data sheets

Note: TMH 4 superseded by TRH17

COMPANION ASPHALT ACADEMY GUIDELINE DOCUMENTS

TG 1
The use of modified binders in road construction

LIST OF COMPANION SABITA DOCUMENTS

MANUAL 1
Technical Guidelines: Construction of bitumen rubber seals (1998)

MANUAL 2
Bituminous products for road construction (2002)

MANUAL 5
Guidelines for the manufacture and construction of hot-mix asphalt (1992)

MANUAL 7
SUPERSURF+ Economic warrants for surfacing unpaved roads (2005)

MANUAL 8
Guidelines for the safe and responsible handling of bituminous products (2003)

MANUAL 9
Bituminous surfacing for temporary deviations (1992)

MANUAL 10
Appropriate standards for bituminous surfacings (1992)

MANUAL 11
Labour enhanced construction for bituminous surfacings (1993)

MANUAL 12
Methods & procedures: Labour enhanced construction for bituminous surfacings (1994)

MANUAL 13
LAMBs - The design and use of large aggregate mixes for bases (1997)

MANUAL 14
GEMs - The design and use of granular emulsion mixes (1998)

MANUAL 16
REACT - Economic analysis of short-term rehabilitation actions (1998)

MANUAL 17
Porous asphalt mixes : Design and use (1995)

MANUAL 18
Appropriate Standards for the use of sand asphalt (1996)

MANUAL 19
Technical guidelines for the specification and design of bitumen-rubber asphalt wearing courses (1997)

MANUAL 20
Sealing of active cracks in road pavements (1998)

MANUAL 21
ETB – The design and use of emulsion–treated bases (1999)

MANUAL 22
Hot-Mix Paving in Adverse Weather – Interim Recommendations (2006)

MANUAL 23
Bitumen Hauliers' Code – Guideline for loading bitumen at refineries (2000)

MANUAL 24
User guide for the design of hot mix asphalt (2005)

MANUAL 25
Quality Management in the handling and transport of bituminous binders (2006)

MANUAL 26
Interim guidelines for primes and stone precoating fluids

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1. INTRODUCTION

1.1 GENERAL

For a road to perform optimally (functionally and structurally), a durable, waterproof, skid-resistant and all-weather dust-free surfacing is required to provide the road user with an acceptable level of service and to protect the structural layers of the pavement from the abrasive forces of traffic as well as from the effects of the environment. In South Africa bituminous seals and slurries are commonly used for new construction and for the resealing of existing bituminous roads because they are relatively inexpensive and have proved to be successful on highways, rural roads and urban streets, under traffic conditions varying from light to heavy. This document deals with various forms of surfacing seals using conventional and modified binders, but not with asphalt layers.

As a result of many years of experience in the use of seals and slurries, the road construction industry has built up extensive knowledge on the design, control and construction of these surfacings. In addition, a wide range of road experiments and laboratory studies, carried out in South Africa by researchers and practitioners, has contributed to the establishment of guidelines for the construction and maintenance of durable bituminous seals for use under local conditions.

Drawing from this expertise and research findings, this document is a practical guide to the selection, pre-investigation, design, surface preparation, control of materials, construction aspects and maintenance of the seal process. Apart from providing a clear, concise guide to bituminous seals, it is the intent of this document to improve the understanding of this facet of road construction and maintenance, to promote the appropriate use of seals in South Africa and to ensure that road surfacings are reliable, durable and economical.

1.2 SCOPE OF THE DOCUMENT

The document addresses the main aspects concerning the use of bituminous surfacing seals and is structured in such a way as to guide the user in the process of pre-investigation, selection of seal type, design, surface preparation and construction. To further assist in this process the general activities are shown in Table 1-1 with reference to specific sections in this document and other relevant documentation.

Following from Table 1-1, the first aspect considered is a historical review of seal practice in South Africa and the environment for which this document has been compiled. The second aspect of importance is to recognize the limitations of surfacing seals in order to ensure the appropriate use thereof. Proper investigation of the road and environment is addressed separately to ensure that adequate information is available for selection of the appropriate seal type and binder, to determine the required pre-treatment and to provide adequate input for design purposes. The design and construction of seals are addressed under the heading of each seal type, after which attention is given to material specifications, process control and acceptance control. Design examples for the most common seal types are provided in APPENDIX H.

Table 1-1 - Surfacing seals: Process of seal provision

Seal practice in South Africa	*TRH 3 (Section)*	Other
- History of sealwork in South Africa - Preventive maintenance strategy/ philosophy - Consideration of environment	Chap. 1	
RECOGNIZING LIMITATIONS OF SURFACING SEALS		
- Factors influencing performance	Chap. 2	
PRE-DESIGN INVESTIGATIONS		
DATA GATHERING TO: - Check labour intensive suitability - Select appropriate seal type - Select appropriate binder and aggregate size - Design	Chap. 3	
SELECTION OF SEAL TYPE		
Selection of initial surfacings Decision diagram for reseals Cost comparison and economic analysis	Sect. 4.3 APPENDIX D APPENDIX C, Sect. 4.3.11	
DESIGN		
Pre-treatment Prime coat Sand seals Slurry seals Cape Seals Single seals Double seals Single seals with modified binders Double seals with modified binders Diluted emulsion applications Choked seals Split seals Geotextile seals Stress absorbing membrane interlayers Hot-mix asphalt surfacings	Chap. 6 Sect. 7.2 Sect. 7.3 Sect. 7.4 Sect 7.5 Sect. 7.6 Sect. 7.6 Sect. 7.7 Sect. 7.7 Sect. 7.8 Sect. 7.9 Sect. 7.9 Sect. 7.9 Sect. 7.9	 TRH 1[1] TRH 7[2] TRH 8[3]
CONSTRUCTION		
Material specifications Process and Acceptance control Basic guidelines for each seal type Labour intensive construction	Chap. 8 Chap. 9 Chap. 7 Chap. 11	COLTO[4]
MAINTENANCE PLANNING & BUDGETING		
General guidelines Pavement management Visual Assessment Pavement rehabilitation	Chap. 10	 TRH 22[5], TMH 9[6] TRH 12[7]

1.3 FUNCTIONS OF A SURFACING SEAL

The main functions of a surfacing seal are to:

- Provide a waterproof cover to the underlying pavement;
- Provide a safe all-weather, dust-free riding surface for traffic with adequate skid resistance;
- Protect the underlying layer from the abrasive and destructive forces of traffic and the environment.

Where appropriate, slurry seals are used for rut-filling or to improve the riding quality of the road by smoothing out small irregularities.

Since most seals are relatively thin, they have no load distribution properties. However, the seal itself should be able to accommodate the horizontal and vertical traffic-induced stresses.

1.4 SEALWORK IN SOUTH AFRICA

In its simplest form a seal consists of a coat of bituminous binder sprayed onto the road surface which is then covered with a layer of aggregate (stone or sand). The aggregate cover is applied immediately after the binder has been sprayed and then rolled to ensure close contact and thus good adhesion between the aggregate and the binder film. Rolling initiates the process of orientating the particles into a mosaic pattern and working the binder into the voids between the aggregate particles. The process is completed by the action of traffic, so that finally a dense and relatively impermeable pavement surfacing is obtained.

There are a number of seals in common use, such as single seals, double seals, Cape Seals, slurry seals and sand seals. Other seal types discussed in this document are inverted double seals, geotextile seals, split seals, graded aggregate seals and choked seals. The latter, however, are less often used. The different seal types are illustrated schematically in Figure 1-1 and Figure 1-2.

1.4.1 The South African environment

Air and road temperatures are strongly affected by altitude. From the south coast northwards the temperatures increase little, except in the lowland areas. The duration of sunshine varies from more than 80 per cent of the possible duration in the north western parts to 70 per cent over most of the remainder of the interior and to less than 60 per cent in the coastal areas. Average annual air temperatures vary from less than 13°C in the central mountain areas to 17°C in the broader central and south coastal areas and to 22°C or more in the western, northern and eastern parts of the country. In all these areas maximum air temperatures may exceed 35°C (40°C in the northern and eastern parts of the country). On the Highveld and in the mountainous regions, minimum temperatures may be as low as -8°C (temperatures of below -10°C have been recorded in places). Minimum temperatures mainly occur during June and July.

Air temperatures influence the road surface temperatures which, in turn, dictate the type and grade of binder to be used.

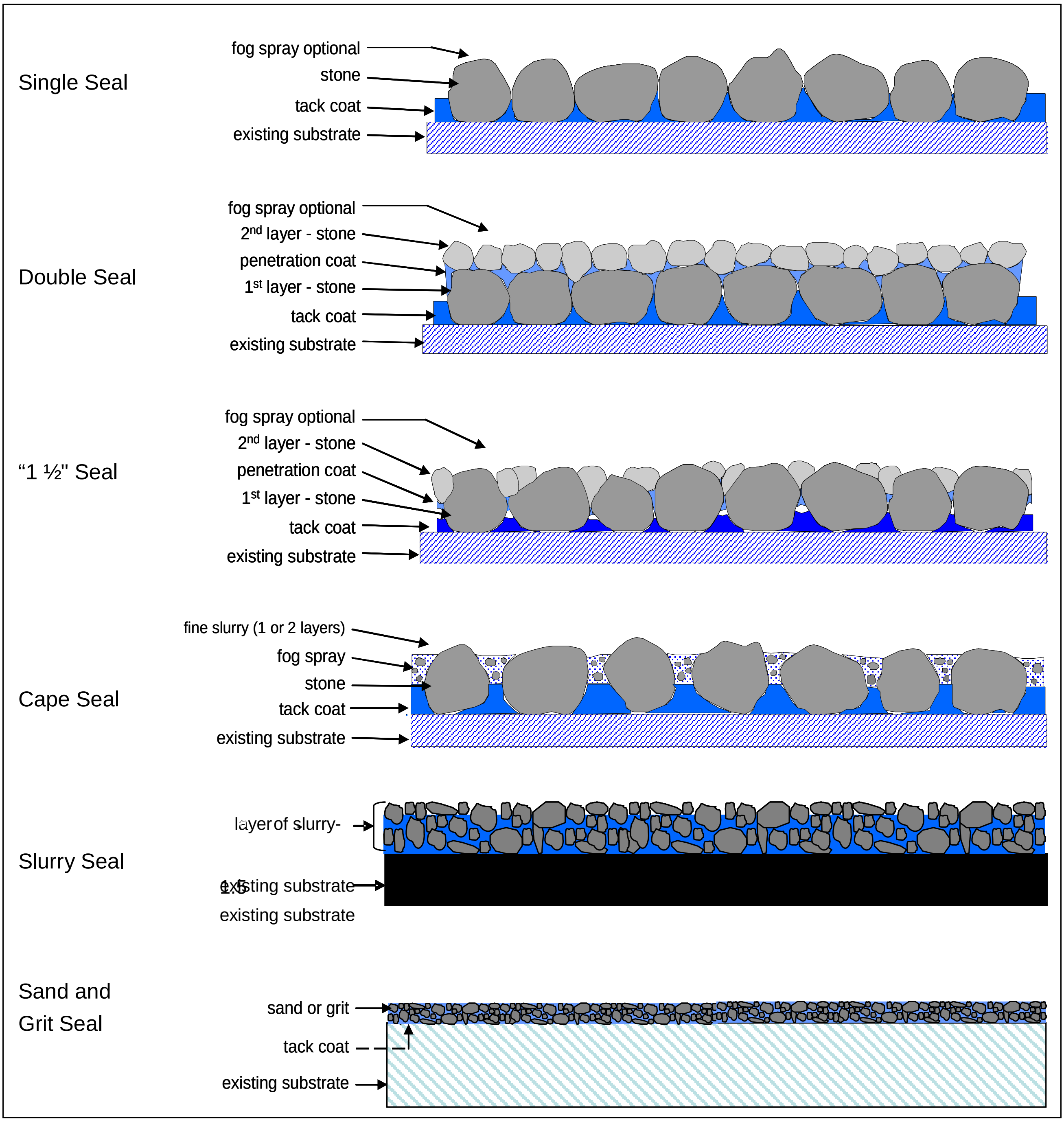


Figure 1-1 Schematic illustration of seal types

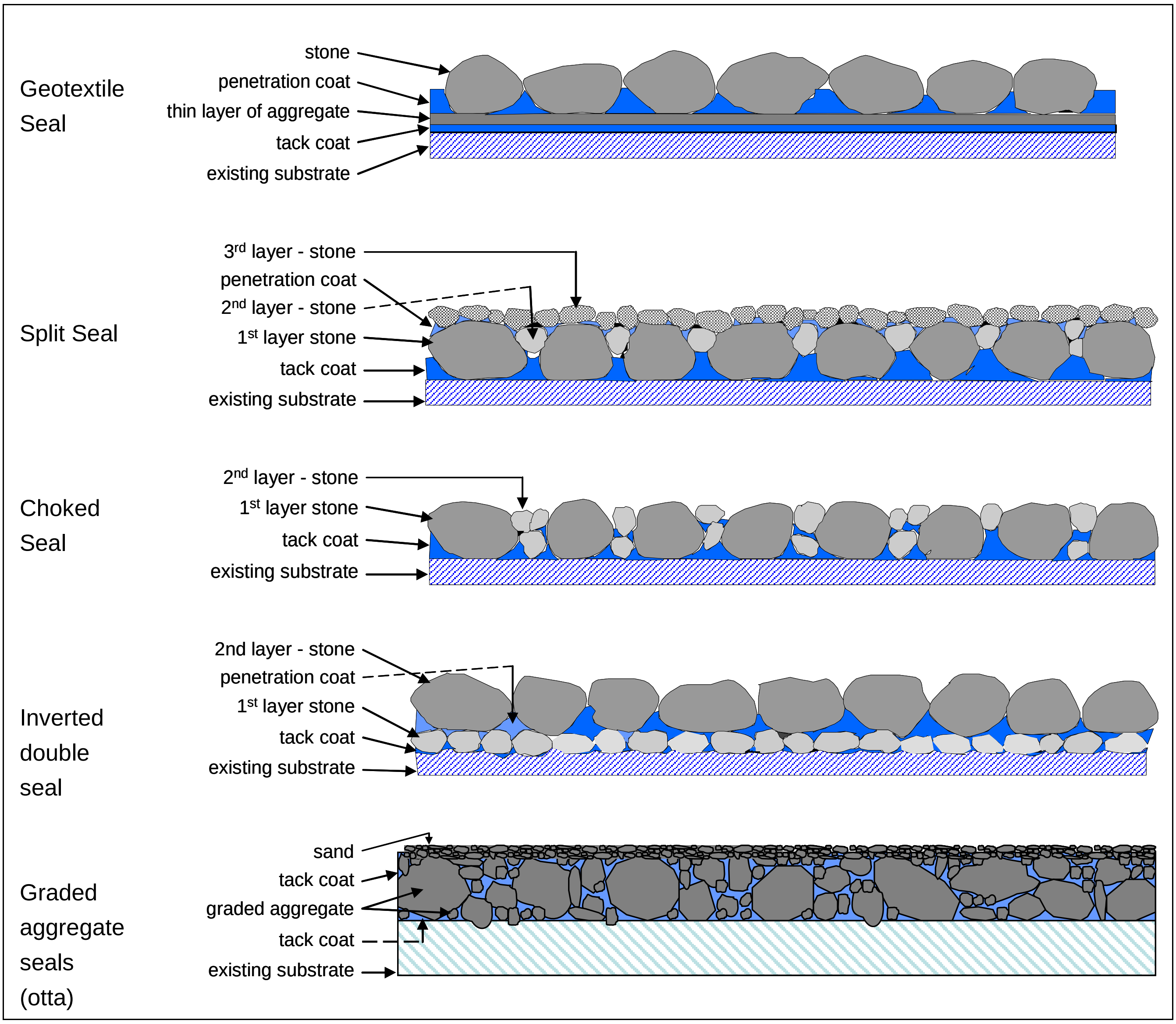


Figure 1-2 Schematic illustrations of various seals

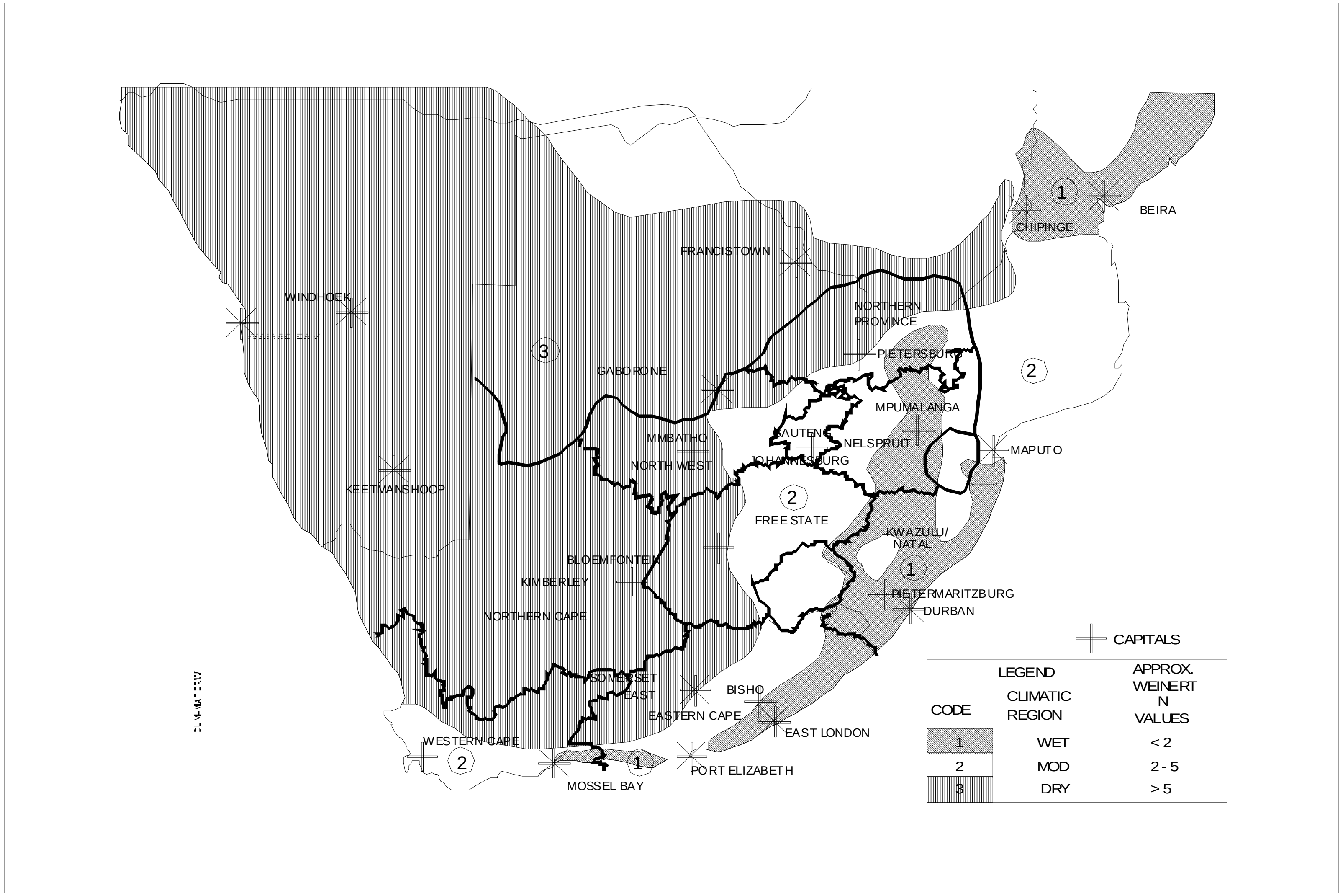


Figure 1-3 Macro-climatic regions of southern Africa (Adapted from Weinert, 1980) [8]

Three fairly distinct rainfall regions can be recognized according to seasonal occurrence: the summer, the winter and the all-season regions. In the central and eastern parts of South Africa rain occurs mainly in the summer months (August to January). In the southwest of the country winter rainfall predominates and rain occurs mainly from May to October. In the southern coastal area rainfall is almost evenly distributed throughout the year. The average annual rainfall increases from less than 125 mm in the west to more than 1000 mm in the east, the central mountain areas and the south western coastal area. The macro climatic regions of southern Africa are illustrated in Figure 1-3.

1.4.2 Road network classification (2003)

Approximately 150 000 km (20%) of the total road network of 750 000 km is surfaced (See Figure 1-4). The majority of these were surfaced or resurfaced with seals with an estimated total distance of 120 000km.

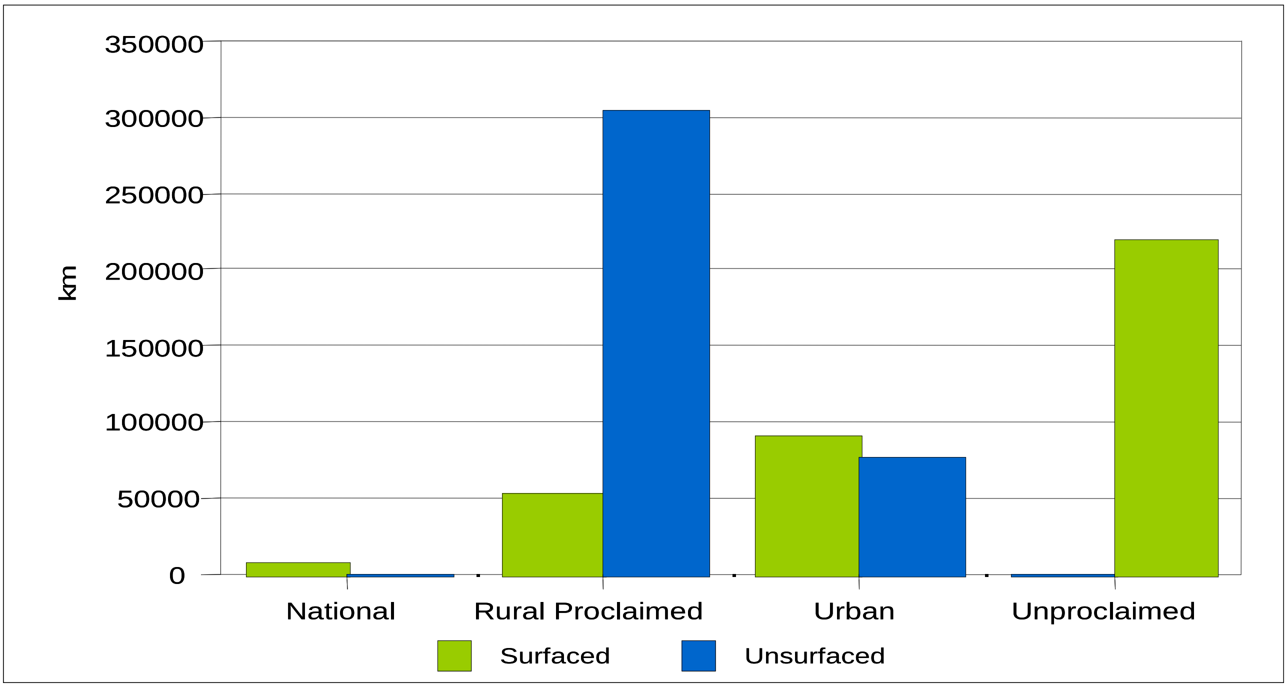


Figure 1-4 Road network classification (2003)

1.4.3 Traffic

Traffic patterns, vehicle type distribution and loading on roads in South Africa vary a great deal. However, only a small percentage of roads carries in excess of 10 000 vehicles per day. Although overloading of heavy vehicles is controlled to some extent, there has been a definite trend towards increased axle loads over the past decade.

Figure 1-5 gives some indication of the average annual daily traffic (AADT) on a part of the total road network. Heavy vehicles make up approximately 15 per cent of the AADT.

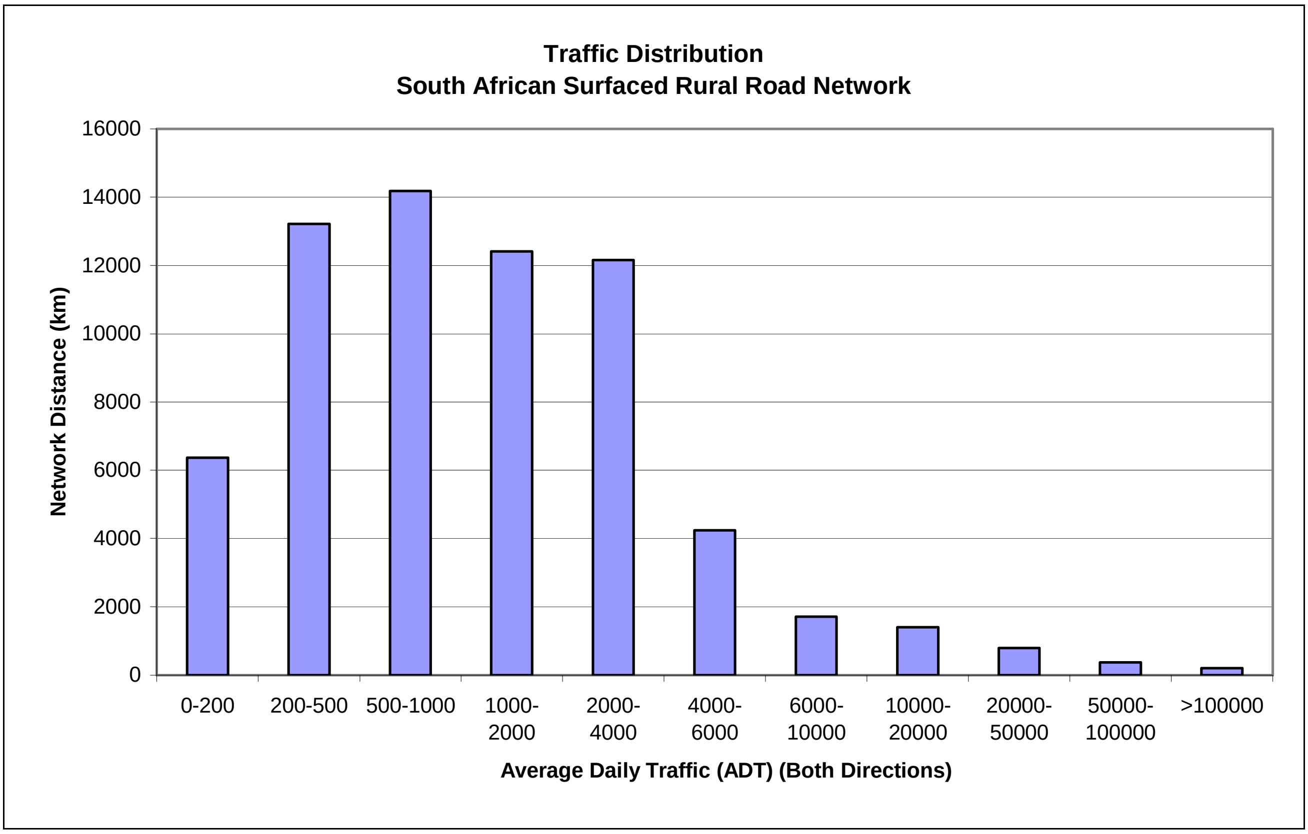


Figure 1-5 Traffic distribution on surfaced rural roads (2006)

1.4.4 Typical flexible pavement compositions

Pavement structures in South Africa typically consist of either natural gravel layers or of natural gravel layers with cemented subbase and base layers. Higher volume roads normally include a cemented subbase and a crushed stone base while some roads in the wetter coastal regions include asphalt base layers.

Most rural roads, at time of construction, are surfaced with double seals or Cape Seals and during maintenance operations, are resealed with single seals or slurries.

Asphalt surfacings are generally only provided on heavily trafficked rural roads, freeways, urban streets and at intersections.

2 FACTORS INFLUENCING THE PERFORMANCE OF SURFACING SEALS

2.1 GENERAL

The performance of a seal is influenced by various factors and combinations thereof. In this chapter the most important factors influencing initial and long term performance are discussed. This chapter also serves as an introduction to pre-design investigations, the selection and design of appropriate surfacings, materials specifications and construction, which are discussed in the following chapters.

The main functions of a surfacing are mentioned in paragraph 1.3. Failure of the surfacing to fulfil any one of these functions would indicate the end of its effective service life. Performance is related to both the effective service life and the degree to which the functions are fulfilled.

The influence of the following factors on seal performance will be discussed:

- Pavement structure and condition
- Existing substrate
- Traffic
- Road geometry
- Design
- Materials
- Preparation, pre-treatment and repairs before construction
- Construction and supervision
- Maintenance
- Physical and social environment.

2.2 PAVEMENT STRUCTURE AND CONDITION

The performance of a seal is, to a large extent, governed by the structural adequacy of the pavement layers under the influence of wheel loads. A seal acts mainly as a wearing course resisting the abrasive action of the moving wheel load and it seals the road pavement to prevent the ingress of surface water.

2.2.1 Base type (applicable to new construction)

The resistance to aggregate penetration into the base is related to the type of material in the base and to the degree of compaction. The embedment of surfacing aggregate into the base will reduce the voids in the seal and may result in a fatty or bleeding surface and/or in skidding problems.

2.2.2 Flexural properties of the pavement structure

High deflections in the pavement structure may result in fatigue of the pavement layers and the surfacing. Rigid seals, cold temperatures and oxidation of the binder will aggravate cracking of the surfacing and ravelling. It is, therefore, important to select a seal and binder suitable for the existing or expected pavement behaviour characteristics. (Guidelines for appropriate seal types and binders are given in Chapter 4.)

2.2.3 Cracking

The reflection of cracks through the surfacing can be related to the magnitude and frequency of the movement between the crack walls due to load repetitions, chemical reactions (which cause shrinkage), temperature changes or to changes in moisture conditions. The greater the crack activity the more quickly will crack reflection occur.

2.3 EXISTING SUBSTRATE

The condition of the underlying surface and the materials of which it is constructed will influence the performance of the new seal. Therefore, these factors should be considered in determining the most appropriate seal type, type and quantity of binder to be applied, the size of stone to be used and the required pre-treatment.

The condition of the existing surface is quantified by visual assessment of defects (e.g. cracking) as well as by measurements of surface texture depth and unevenness, permeability and the expected embedment of stone.

- *Texture depth* values and variations give an indication of the additional binder required owing to the surface texture and may indicate the need for texture treatment.
- *Permeability* gives an indication of the need to pre-treat the existing surfacing by adding additional binder.
- The *expected embedment* of the stone gives an indication of the amount of voids in the seal that would be lost as a result of the embedment of the stone into the existing surface. In this instance, ball-penetration tests provide useful information but do not take into account the softening of the existing binder by the new, sometimes very hot and oily binder applied during resealing.
- The *degree and extent of cracking* provides an indication of the likely reflection of such cracking through the new surfacing or of the relative brittleness and loss of flexibility of the existing surfacing which need to be made up by the new seal. (See Chapter 3, Pre-design investigations.)

Uniform performance of a surfacing along a road can only be obtained if the existing surface is uniform in terms of texture, evenness and permeability. (This can be achieved by appropriate pre-treatment.)

2.4 TRAFFIC

The number, type and combination of vehicles have a marked influence on the performance of a seal. Heavy vehicles have a much greater influence on the performance of a seal than light vehicles. In this document, for purposes of seal design, the effect of one heavy vehicle is considered to be equal to that of 40 light vehicles. In earlier documents an equivalency factor of 20 was used, but increases in axle loads and tyre pressures have necessitated the use of a higher value.

Although the influence of traffic is interrelated with other factors such as road geometry, the influence of the following traffic parameters is considered important.

2.4.1 Volume

The number of vehicles (especially heavy vehicles) greatly affects embedment, wearing and polishing of the stone, which reduces the voids in the seal and results in flushing and reduction in skid resistance. It is also believed that a seal requires a minimum number of vehicles per day to keep the binder alive and flexible (in the order of 50 vehicles per day for conventional binders and even more when polymer modified binders are used).

2.4.2 Loading

Heavy axle loads cause more rapid embedment of the stone into the existing surface than light vehicle loads. Cognizance should be taken of the steady increase in axle loads occurring in South Africa.

2.4.3 Tyre pressures

Recent research shows that tyre inflation pressure has a major influence on bleeding and that certain vertical stresses induced on the surfacing can be much higher than the tyre inflation pressures. Heavy Vehicle Simulator tests[9] showed that there was a significant increase in flushing on sections trafficked with similar wheel loads but with higher inflation pressures. Over ten years average heavy vehicle tyre pressures have increased from 520 kPa to 700 kPa or more.

2.4.4 Vehicle type and characteristics

Vehicles with tandem or tridem axles, turning at intersections, or into/from access roads, cause severe damage to surfacings. Distress typically observed is slippage, debonding of the surfacing or ravelling.

2.4.5 Speed

Surfacings under slower-moving traffic (typically less than 40km/h) generally do not perform as well as those trafficked by fast-moving vehicles. The reasons for this are the extended period of loading, higher horizontal stresses induced as a result of traction, particularly of heavy vehicles accelerating or braking, and fuel or oil spillage.

2.4.6 Traffic distribution and occurrence

Traffic which is concentrated in particular wheel paths (typical on narrow roads), or which occurs early on during the life of the seal (when the binder is still soft), or during cold temperatures (when the binder is brittle), will adversely affect the performance of the seal. (Refer to paragraphs 2.5.4 and 2.7.2.)

2.5 ROAD GEOMETRY

Several aspects of the road geometry may contribute to the poor performance of the surfacing seal, for example:

2.5.1 Gradient

Steep gradients may, because of the traction force of vehicle tyres, result in debonding or slippage of the surfacing, or in flushing. The risk of poor seal performance on ascents and descents increases because of construction difficulties at these sites.

Steep gradients cause slower vehicle speeds and often result in flushing. (Refer to paragraph 2.4.5.)

Canalized water flow down steep gradients can have a severe erosion effect on stone seals. This is particularly true for roads and streets with kerbs in wet, hilly environments.

2.5.2 Sharp curves

Sharp curves cause vehicles to induce high horizontal stresses on the surfacing. These may result in ravelling and slippage of the surfacing. Vehicles on lower volume roads "cut" corners, resulting in the outer part of the road becoming dry and brittle, with consequent stone loss. Because of the camber on curves, higher loads are transferred to the inner side of curves, often resulting in fattiness. The situation may be aggravated by excess binder accumulated at these positions, as a result of "run-off" during construction.

2.5.3 Intersections

Braking and acceleration, particularly of heavy vehicles, create high horizontal stresses in the surfacing which, as mentioned in paragraph 2.5.1, may result in the slippage, flushing and deformation of the surfacing. Fuel and oil spillages at intersections aggravate flushing and deformation.

As mentioned in paragraph 2.4.4, turning actions of heavy vehicles, particularly those with tandem or tridem axles, may cause ravelling and slippage of surfacings.

2.5.4 Road width

Concentrated wheel movements occur on narrow roads, usually resulting in fattiness in the wheel tracks, brittleness between the wheel tracks, and in edge breaks.

2.6 DESIGN

During the design process care should be taken to allow for all the different situations which might occur on a specific road. The pre-design investigation is, therefore, regarded as very important to ensure proper design and maximum seal performance. During construction the designs may be adjusted to incorporate new information or changed conditions.

2.7 MATERIALS

2.7.1 Aggregate

2.7.1.1 Function

The aggregate in a seal has four main functions:

- it provides resistance to the abrasion of moving wheel loads and transfers the wheel load to the underlying pavement structure;
- it provides a skid-resistant surface;
- it provides a structure to accommodate the elastic and impermeable bituminous binder and has sufficient voids to prevent the binder flushing to the surface under loading, and
- it protects the binder from the harmful ultra-violet rays of the sun.

Note:

Certain aggregate characteristics may have functional value, for example:

- *use of light-absorbing qualities to prevent glare, and*
- *provision of a different texture or colour to define demarcated areas.*

2.7.1.2 Factors affecting performance

Aggregate-related factors which affect the performance of a seal are:

- shape, nominal size and grading;
- spread rate;
- adhesion characteristics, cleanness and dust content;
- strength, durability and wearing characteristics, and
- porosity/absorption.

Current specifications for these are given in Chapter 8.

Shape, nominal size and grading

The shape of the aggregate affects its interlocking in the compacted layer and, hence, the stability of the seal. The more angular the aggregate, the better the interlock because there are more points of contact. The shape and size also affect the void content in a seal and the ability of the seal to displace surface water (macro texture).

A single-sized stone develops good interlock and provides maximum contact between the tyre and stone surface. This increases the friction area, causes the stone to resist polishing and abrasion and gives good skid resistance, provided the correct quantity of binder is used.

More voids are available with large single-sized aggregates to accommodate a variation in binder application rate than in small single-sized aggregates. The smaller the aggregate size, the greater the possibility of the voids in the layer being filled with binder. This will cause flushing unless very strict control is exercised during construction.

Larger aggregates allow more binder to be used, resulting in a more impermeable, longer lasting seal.

The use of aggregate which does not have a uniform size results in firm tyre contact over a smaller area (which decreases the skid resistance, especially in wet weather), a higher noise level (because the larger particles are spaced further apart), loss of the larger stone by traffic action, and concentrated wear on the larger particles.

Design methods used in South Africa to determine appropriate application rates have, to a large extent, been developed and refined while applying strict standards with regard to size, shape and grading. *Changing specifications could lead to current design methods not being appropriate to ensure optimal performance.*

Spread rate of aggregate

The aggregate protects the substrate against traffic abrasion and should be applied at such a rate that complete cover with a uniform mosaic is achieved. The aggregate should lie shoulder-to- shoulder, in a single layer and in a tightly knit pattern. All design assumptions are made on this basis.

Excessive ultra-violet damage to the binder, ravelling of the seal and subsequent damage of the lower pavement layers may occur if the spread rate is too low. If the spread rate is too high, the excess aggregate will be forced into the mat, leading to whip-off of the bonded aggregate. Degradation due to crushing and grinding of the aggregate, unnecessary waste of material, and claims for damage resulting from aggregate whip-off and broken windscreens may occur.

Adhesion characteristics, cleanness and dust content

The aggregate should have good binder adhesion characteristics, which it should retain throughout the life of the seal in order for it to remain stable under the action of traffic.

Dusty aggregate adversely affects the adhesion between the aggregate and the binder. (The presence of as little as 1 per cent by mass dust may result in a substantial loss of aggregate.) Moist aggregate does not adhere well to binders (except to bituminous emulsions) and, if traffic is allowed to use the seal coat before adequate bonding has occurred, excessive whip-off may occur. Precoating improves adhesion and obviates the problems associated with hot bituminous binders and aggregates which are not free of dust or moisture.

Note:

Some granite, felsite and quartzite sources in South Africa are known for poor adhesion but have performed reasonably well through careful design, the use of precoating and/ or wetting agents as well as the addition of a fogspray.

Strength, durability and wearing characteristics

The aggregate should be hard enough (crushing strength) to allow only minimal breakage during rolling or under traffic and should not weather significantly during the life of the seal. In addition, the aggregate should be inspected visually and tested for the presence of inferior material and harmful minerals. Weathering tests should also be carried out. (Refer to paragraph 8.1.)

Apart from this, aggregate exposed to abrasion by traffic will attain a smooth surface in time, i.e. it will polish and/or abrade. The degree of possible polishing depends on its mineral composition and crystal structure. The presence of minerals of similar or different hardness in a rock and their grain sizes therefore determines the potential wearing characteristics of the aggregate and the rate at which wear takes place.

Porosity / Absorption
Porous aggregate absorbs primarily the lighter fractions of the bituminous binder. This may then result in the binder not being suitable (too brittle) to retain the aggregate on the road. If the only aggregate available is a porous aggregate, then the use of modified binders is recommended. In addition, porous aggregates should be precoated prior to use.

2.7.2 Binder

2.7.2.1 Function
The service life and performance characteristics of a seal depend on good adhesion between the binder, stone and road surface and on the durability and flexibility of the binder under different climatic conditions. Adhesion is one of the paramount functions of the binder. Loss in retention of the aggregate, the degree of aggregate whip-off and durability are all related to the adhesive forces developed by the binder, which depend on the type, grade and amount of binder applied.

A properly selected binder fulfils two initial functions - it develops both adhesive and cohesive strength. Initially it is fluid to allow time for placing and wetting of the stone and then rapidly becomes harder. The cohesive strength of the binder facilitates opening to the traffic and prevents the stone being pulled out of or whipped off the surface.

The binder should be able to withstand "softening-up" under the higher temperatures encountered in service and to retain the stone under the action of moving wheel loads. On the other hand, at colder temperatures, the binder should stay flexible for as long as possible to prevent reflection cracking, to accommodate road deflections and to prevent, as far as possible, the ingress of moisture into the base.

2.7.2.2 Factors affecting seal performance
Binder-related factors which affect the performance of a seal are:

- binder type and properties;
- grade of binder;
- binder application rate
- viscosity at time of application

Binder type and properties
Penetration grade bitumens, cut-back bitumens, bitumen emulsions and modified bitumens are used as binders for the construction of seals. If the appropriate conventional binder type (penetration grade, cut-back bitumen and bitumen emulsion) is selected for the specific conditions, the performance of seals with these binders should be comparable.

The use of modified binders in South Africa (hot modified binders and modified emulsions) has increased greatly in recent years because of improved performance regarding adhesion, elasticity, lower sensitivity to bleeding and durability - even at sub-zero temperatures. Although these products are more expensive than conventional binders, their improved properties can ensure extended pavement life, less maintenance and, consequently, lower life-cycle costs.

The selection of the appropriate type of binder for the prevailing conditions and critical binder combinations are discussed in Chapter 4. If these guidelines are followed, the risk of poor performance will be minimized.

Binder grade

The selection of the appropriate grade of conventional binder to be used is governed by:

- the expected climatic conditions during construction
- the long-term performance at local ambient temperatures.

Each grade of penetration grade bitumen is characterized by its own temperature/viscosity relationship and has an optimum range over which the bitumen can be sprayed, stored, mixed or pumped. It is essential that the viscosity be kept within the range for spray application in order to obtain optimum performance of the binder, and it is important to refer to the temperature/viscosity curve for the particular binder to determine the temperature range for spray application.

Cut-back bitumens are classified in terms of kinematic viscosity (m^2/s) and, like penetration grade bitumens, they also have characteristic temperature/viscosity curves for each grade of cut-back bitumen. Because of their lower viscosity, they promote initial adhesion at the time of construction and are generally used under lower temperature conditions.

Bitumen emulsions are classified according to the percentage by mass of the penetration grade bitumen contained in the emulsion and according to whether the emulsifying agent has imparted a stabilizing positive charge (cationic) or a stabilizing negative charge (anionic) to the bitumen globules in the emulsion. Cationic emulsions are compatible with most types of aggregate. Anionic emulsions are not compatible with certain quartzites and granites. The penetration grade of the bitumen in the emulsion can be changed by the manufacturer according to the climatic conditions under which it is to be used.

Different grades of modified binders are available in South Africa for application during high and low temperatures. Manufacturers are usually able and willing to change the base bitumen grades or to add cutters to cater for specific conditions.

Binder application rate

For maximum performance the optimum amount of binder should be correctly determined and applied during the construction of seals. A minimum amount is required to hold the stone firmly in place and bind it to the underlying surface. There is also a maximum amount, which, if exceeded, will overfill the voids in the compacted layer, cause flushing and result in reduced skid resistance, particularly in wet weather.

The binder application rate which results in optimal performance is determined by the type of binder selected, volume of the voids in the compacted stone layer, the shape and size of the stone, the amount and type of traffic and the condition of the underlying surface. Adjustments in spray rates are required for steep gradients and other special conditions. These recommendations, as well as construction limitations, are discussed in Chapter 7.

Viscosity at the time of application

Uniformity in the application of the binder is a function of viscosity, which varies with temperature. Each grade of binder has its own temperature/viscosity curve, which will indicate the optimum viscosity required for the best spray application. Operating outside this range will result in streaking if the binder is too cold and therefore not fluid enough, or will cause binder degradation, run-off on steep gradients, and increased fire risk if the binder is too hot.

2.8 PREPARATION, PRE-TREATMENT AND REPAIRS BEFORE CONSTRUCTION

Preparation of the road surface, timeous pre-treatment and repair of defects before sealwork commences are of vital importance to the initial and long-term performance of a seal.

2.8.1 Surface preparation

Failure to provide a clean, dense surface will result in a poor bond between the underlying surface and the seal and will add to the risk of aggregate loss or embedment of the seal.

2.8.2 Pre-treatment

If the existing surface texture varies, or if there is any unevenness (small irregularities or rutting), pre-treatment is advisable to ensure a uniform texture and a smooth riding surface for the effective design and construction of the new seal.

Dry or porous surfaces can be treated by

- spraying a diluted emulsion or rejuvenator
- by applying a sand seal or a small aggregate seal

Coarse textured surfaces can be treated with fine or medium slurry or small aggregate seals to fill the voids in the surface.

Varying textured surfaces can be treated with slurry before application of a single seal.

Rapid setting slurry is often used to improve small irregularities or rutting as an alternative to asphalt on roads with lower traffic volumes.

Areas with excess binder should receive special attention to prevent similar problems occurring prematurely on the new seal. One of the recommended procedures is to roll precoated aggregate into the existing surface.

2.8.3 Repairs

Failure to repair defects such as potholes, sub-surface failures, poorly constructed patches and active or wide cracks will result in these defects reflecting through, or in debonding of the new seal (generally within 3 to 6 months).

2.8.4 Timing of pre-treatment and repairs

All repairs should be done well before the construction of the seal, mainly to ensure stability of the treatments so as to minimize embedment of aggregate.

Details and recommendations for preparation, pre-treatment and repairs are discussed in Chapter 6.

2.9 CONSTRUCTION AND SUPERVISION

Poor performance of seals is often caused by poor construction practices, inadequate supervision or by lack of attention to detail. Each section should be inspected and assessed prior to continuation of operations. Good supervision in all aspects of surface preparation and application is essential.

The correct, uniform application of binder and aggregate, as well as rolling and brooming with properly operated, correctly adjusted and calibrated plant and equipment, is essential for the construction of a seal so that it will perform efficiently during its design life.

It is essential to reduce the initial maximum speed of the traffic on a seal to 60 km/h, or to extend the initial non-trafficked time so that the binder can develop sufficient cohesion to retain the aggregate under traffic.

Check lists, guidelines and practical hints to ensure good performance are given in Chapter 9.

2.10 MAINTENANCE

Some types of seals are much more responsive to timely maintenance than others. Although some problems may be avoided by good design and construction practice, timely maintenance can considerably extend the life of the seal and the pavement structure. A typical maintenance action on a seal is to spray diluted emulsion to increase and rejuvenate the existing binder before loss of aggregate occurs. Other maintenance actions would be patching of small areas where delamination/debonding of the previous surfacing occurred, or application of fine slurry to isolated areas where ravelling has occurred as a result of turning movements or concentrated water flow.

The role of maintenance capability in the selection of an appropriate surfacing is discussed in Chapter 4.

2.11 PHYSICAL AND SOCIAL ENVIRONMENT

Several factors related to the specific environment can adversely affect the performance of the seal and the pavement structure. The majority of these are inter-related with factors already discussed, but are worth mentioning.

2.11.1 Climatic conditions

The climatic conditions in the region where the seal is to be laid should be correctly evaluated to enable the appropriate grade and type of binder to be determined. These include:

- Extremely hot weather, which will reduce cohesion
- Cold weather, which can result in a brittle, hard binder and subsequent aggregate loss or cracking

- Variable weather and/or temperature
- Ultra-violet radiation, which accelerates ageing of the binder
- Humidity, which influences the evaporation of volatiles.

2.11.2 Drainage systems/kerbs

Roads are often used to carry storm water, especially in the urban environment. High flow speeds and volumes erode the seal. In this process soil particles and/or detergents are often carried in suspension which aggravates the situation. Research in South Africa has shown that single seals and thin sand seals or slurry seals are particularly vulnerable to erosion and should not be applied on steep gradients with urban-type drainage.[10]

2.11.3 Mechanical damage

Damage to seals is often caused during construction or by agricultural equipment crossing roads, by vehicle rims of flat tyres, or by cargo falling off vehicles at sharp corners. Damaged areas should be repaired as soon as possible to prevent rapid deterioration of the surfacing. Although the damage cannot be prevented by the road authority, in the selection of appropriate seals cognizance should be taken of the likelihood of the occurrence of mechanical damage, and maintenance strategies should be developed to ensure good seal performance.

2.11.4 Dust or wind-blown sands

Dust or sand covering a freshly applied bituminous binder has, in many cases, been the cause of poor aggregate adhesion and subsequent poor performance of seals.

2.11.5 Fuel spillage and organic matter

Intersections, steep gradients and access roads to fuel depots and filling stations are particularly vulnerable to fuel spillage, which softens up the bituminous binder and results in failures. Guidelines for selection of a suitable binder are given in Chapter 5.

The effects of animal droppings are often visible on surfaced roads in game parks and rural areas. Because of deterioration of the contaminated areas, particularly in the drier parts of the country, seal lives are markedly reduced. The presence of sugar cane, salt water or detergents also has a detrimental effect on the life of a seal.

2.11.6 Developing areas

Stresses induced on the seal can vary significantly from developing areas to developed areas. Building materials, such as stone, sand, bricks etc. are often found on streets in developing urban areas. These materials can damage the seal and result in poor performance of the surfacing.

3 PRE-DESIGN INVESTIGATIONS

3.1 GENERAL

The main purpose of a pre-design investigation is to acquire all available information which can be used to assist in the selection of the most appropriate surfacing type and pre-treatment, as well as to acquire sufficient information for the design of a surfacing that will perform under the prevailing conditions. Cognizance should, therefore, be taken of all factors which may influence the performance of the surfacing.

In this chapter the information required as part of pre-design investigations for both new construction seals and reseals is addressed and the requirements for

- Selection of seal and pre-treatment, and
- Design of seal and pre-treatment

are discussed separately.

Investigation for selection of appropriate pre-treatment and seal type requires different information than that needed for design purposes and is usually carried out long before the design stage. At least two investigations are, therefore, required.

A distinction is made between essential and desirable information for the selection and design process.

3.2 INFORMATION REQUIRED FOR SELECTION OF SEAL AND PRE-TREATMENT

In this section the essential and desirable information required to select appropriate surfacings is identified.

With regard to new roads, decisions with regard to the seal type are often made before the road is constructed and are based on the road authority's policies and experience of new construction seals in specific environments. However, decisions with regard to pre-treatment can only be finally decided upon after construction of the base layer and application of the prime coat.

With regard to resealing, information gathered in South Africa for network pavement management is used to identify problems and possible solutions. The information is usually gathered per road segment and therefore, does not always demarcate the exact beginning and end of the seal project. In most cases, therefore, project level investigations are carried out on all the candidate projects to identify the exact extent of the project and to enable final decisions to be made with regard to the most appropriate action (pre-treatment and/or seal type). If there is still any doubt as to whether it is necessary to reseal or whether structural rehabilitation would be more cost-effective, more detailed investigations are carried out to enable a final decision to be made.

In most cases visual assessment and observations on site can provide sufficient information to enable the most appropriate seal to be selected and to determine whether or not pre-treatment is required.

The type of information required for the selection of a seal and pre-treatment for both new construction seals and reseals is given in Table 3-1, Table 3-2 and Table 3-3.

3.3 INFORMATION REQUIRED FOR DESIGN OF SURFACINGS

For purposes of seal and pre-treatment design, uniform sections need to be identified along the length of the road and the start and end points of each section established.

Information obtained from the initial investigation to select appropriate treatments can be a valuable contribution to the designer. However, more detailed information is required to enable a lasting seal to be designed and accurate cost estimates to be prepared.

Apart from specific tests on site (described in paragraph 3.4), the visual assessment procedure recommended in TMH9[6] and TRH6[11] can be applied for each uniform section on the road.

Table 3-1, Table 3-2 and Table 3-3 contain the essential and desirable information required for design purposes.

Table 3-1 - Essential and desirable items for the selection of seal type and pre-treatment and for design purposes

RECOMMENDED INFORMATION	SEAL TYPE				PRE-TREATMENT			
	Selection		Design		Selection		Design	
	Initial	Reseal	Initial	Reseal	Initial	Reseal	Initial	Reseal
Client policies or requirements with regard to:								
- Skid resistance	E	E						
- Noise levels	D	D						
- Social needs (is street used as playground ?)	D	D						
- Environmental issues	D	D						
- Maintenance capability	E	E			E	E		
- Purpose of the seal (e.g. SAMI, skid improvement)			E	E				
- Standards and specifications			E	E			E	E
- Traffic control, limitations and time to opening	E	E	E	E				
Traffic expected:								
- Number of light and heavy vehicles per lane per day	E	E	E	E	E	E		
- Type of heavy vehicles and typical cargo	D	D	D	D				
- Typical axle loads	D	D						
- Typical axle loads (within three months)			D	D				
- Traffic speeds (required texture – skid resistance)	D	D						
- Actions and positions of occurrence (braking, stopping, turning)	E	E						
- Seasonal variation in traffic patterns and loads	D	D	D	D				

Note:

Parameters required : *ALD, Grading, Flakiness, Adhesion, Hardness, Absorption (refer to Chapter 8).*

D : Desirable *E : Essential*

Table 3-2 - Essential and desirable items for the selection of seal type and pre-treatment and for design purposes

RECOMMENDED INFORMATION	SEAL TYPE				PRE-TREATMENT			
	Selection		Design		Selection		Design	
	Initial	Reseal	Initial	Reseal	Initial	Reseal	Initial	Reseal
Existing surface condition:								
- Type		D	D	D		D		
- Texture (smoothness) and variability across the road width and length	E	E		E	E	E		E
- Voids to accommodate extra binder		E		D		E		E
- Surface cracking		E		E		E		E
- Aggregate loss or potential therefore		E		D		E		E
- Binder condition		E				E		
- Fattiness of existing surface		E		E		E		E
- Permeability		D	D	D	D	D	D	D
- Age of surfacing		D				D		
- Embedment potential (ball penetration)			E	E				
Existing structural condition:								
- Degree, extent and type of cracking	E	E	E	E	E	E	E	E
- Occurrence of pumping		E		E		E		E
- Failures, potholes and edge breaking								
- Patching (condition and age)								
- Occurrence of small irregularities influencing riding quality								
- Rutting	E	E	D	D	E	E	E	E
- Deflections - Measured		E		E		E		E
Estimated (seal flexibility)	D	D		D				
- Base type	D	E		D				
- Moisture condition in the base	E	D	E	D			E	E
- Crack activities			D	D			E	D
				D				D
Material availability, cost & availability of funds	E	E			E	E		
Aggregate properties *			E	E				

Note:

Parameters required : *ALD, Grading, Flakiness, Adhesion, Hardness, Absorption (refer to Chapter 8).*

D : Desirable *E : Essential*

Table 3-3 - Essential and desirable items for the selection of seal type and pre-treatment and for design purposes

RECOMMENDED INFORMATION	SEAL TYPE				PRE-TREATMENT			
	Selection		Design		Selection		Design	
	Initial	Reseal	Initial	Reseal	Initial	Reseal	Initial	Reseal
Road geometry and characteristics:								
- Gradients	E	E	E			E		
- Surface drainage		E	E			E		
- Profile and shape								
- Sharp curves	E	E		E				
- Intersections and access roads	E	E		E				
History of performance of seals, binders and aggregate in similar environments	D	D	D	D	D	D		
Climatic conditions	E	E						
This is not readily available								
Environment:								
- Possible surface temperature variations along the road (adjacent to trees, on/under bridge decks, etc)			E	E				
- Expected weather conditions during sealing operations			E	E				
Experience and capability of contractors (including labour-intensive) and availability of equipment	E	E	E	E	E	E	E	

Note:

Parameters required : *ALD, Grading, Flakiness, Adhesion, Hardness, Absorption (refer to Chapter 8).*

D : Desirable *E : Essential*

3.4 TESTS ON SITE

Tests required for design purposes are dependent on the type of surfacing decided upon. Tests required for control purposes are discussed in Chapters 7 and 8.

Essential tests on site are given in Table 3-4.

Table 3-4 - Essential tests on site

TEST	**METHOD**	**PURPOSE**
Ball penetration	ST4 in TMH6[12]	Possible embedment of seal aggregate into the base or existing surfacing, which affects the spray rate.
Texture depth	ST1 in TMH6[12] Texture meter	Adjustment of stone seals binder application rate and to confirm the appropriate seal type
Permeability	Marvil permeability test[13]	It is desirable to know the permeability of the existing surface to evaluate the need for pre-treatment or increase in binder application rate

Suggested reference road surface temperatures for correction of the ball penetration values are given in Figure 3-1. It should be noted that for northern KwaZulu-Natal and Zululand the KwaZulu-Natal Department of Transport uses 30 °C and 40 °C respectively as reference temperatures.

Notes:

The following comments from practitioners could assist in evaluating the embedment potential:

- *During testing, observe whether the steel ball has broken or displaced the existing surfacing aggregate, or whether it has indeed penetrated into the existing surface. If the measurement after one blow is the result of displacement or breaking of aggregate, the measurement value is taken as zero;*
- *Measurement should be taken preferably during the warmest part of the day and close to time of seal construction;*
- *Measurements inside and outside of the wheel tracks provide additional information regarding the variability of embedment potential;*
- *When sealing on newly constructed natural gravel or crushed stone bases, it is suggested that penetration values be used without correction for temperature;*
- *Some authorities report that they have had much success with the use of two-thirds of the corrected ball penetration values on primed G1 bases for design purposes;*
- *Some practitioners suggest measurement of penetration after a first and second blow using only the second measurement. Although the second set of results confirm embedment potential, the rational design method is based on results from only one blow in accordance with the standard test method.*

If there is any doubt with regard to skid resistance, crack activities and deflections and if the resources are available, the following tests will provide valuable information:

• Crack Activity Measurements (refer paragraphs 6.6.1 and 6.6.2)	*Crack Activity Meter*
• Deflections	*Benkelman beam, Deflectograph, Falling Weight Deflectometer*
• *Skid resistance measurements*	*SCRIM[14], British pendulum tester (method ST2 in TMH6)[11], Grip tester[15]*

3.5 SAMPLING AND LABORATORY TESTS

Laboratory tests can be grouped according to their purpose i.e:

- Suitability of materials for seals
- Design
- Quality control

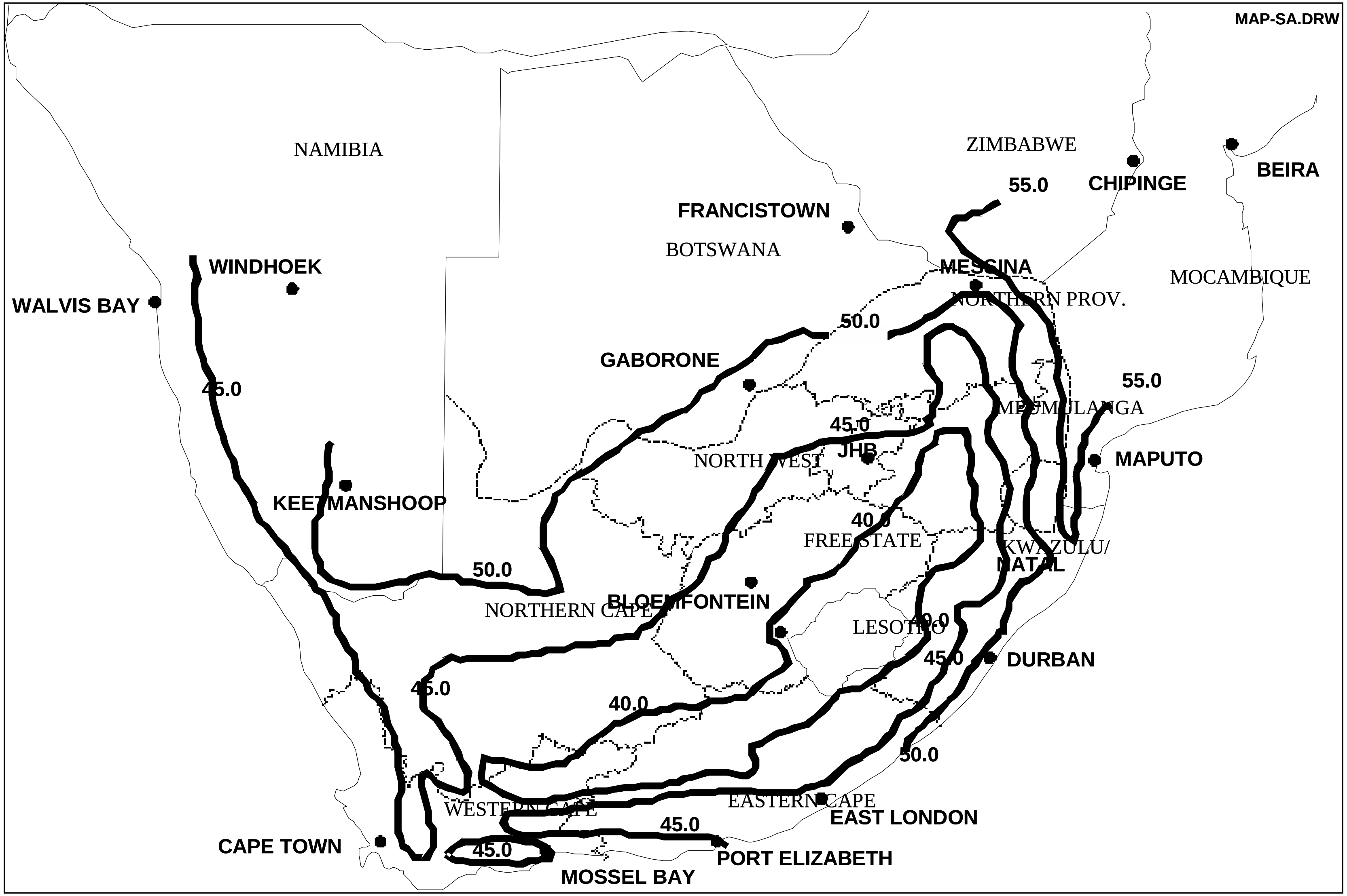


Figure 3-1 Road temperature isotherms for correction of ball penetration test results (After Marais, 1985)[16].

3.5.1 Tests to determine the suitability of materials for seals

During the process of selecting an appropriate seal type, it should be ensured that suitable materials are available at reasonable cost.

Material from existing crushers or natural sources (e.g. river beds) can be sampled and tested to determine the suitability of its application in specific seals. The following tests will provide sufficient information to evaluate the suitability of aggregate:

For large aggregate seals

• Gradation, Fines content and Dust content	TMH1 method B4[17]
• Hardness (10 % FACT)	TMH1 method B1 or method B2[17]
• Flakiness	TMH1 method B3[17]
• Polished Stone Value (PSV)	SABS method SM 848[18]
• Absorption	TMH1 method B14[17]
• Harmful minerals	SABS method SM 834[19]
• Durability (Weathering) (Durability Index)	HIGGS, 1976[20]
• Soundness	AASHTO method T104[21]
• Adhesion	*TMH1 method B11*[17]

For sand seals and slurry seals

• Sieve analysis	TMH1 method B4[17]
• Sand equivalent	TMH1 method B19[17]

Note:
In cases of large projects in remote areas, where there are no crushers, it might be worthwhile to investigate the local geology and the use of a mobile crushing plant.

3.5.2 Tests required for design purposes

3.5.2.1 Full TRH3 Rational Design method (pp 107-149)[22]

The charts in APPENDIX E are based on this method.

The design method is reproduced in APPENDIX K of this document and requires results from the following laboratory tests:

- Flakiness Index
- Average least dimension (ALD)
- Hardness - 10% FACT
- Modified tray test (TRH3, 1986, pp 149-150)[22] , provided in this document as APPENDIX L, to determine:
    - Effective layer thickness (ELT)
    - Void content in stone layer (V_1)
    - Void content in bulk aggregate (V_b)

- Practical and theoretical spread rates of aggregate (calculated from modified tray test and from ELT, V_1, Vb respectively.

3.5.2.2 Simplified TRH3 design method (APPENDIX C)[22] for single and double seals

The design method is dependent on the aggregates conforming to specifications as given in Chapter 8 and is based on assumptions with regard to ELT and V_1 . The method as described in Chapter 7 of this document requires results from the following tests.

• Average least dimension (ALD)	TMH1 method B 18(a)[17]
• Flakiness index (F1)	TMH1 method B18(b)T

Specifications for seal aggregates are given in Chapter 8 of this document. The following tests are required to check these specifications:

Single seals and double seals

• Grading, Fines content and Dust content	SABS method SM 829[23]
• Hardness	TMH1 method B1 or B2[17]
• Flakiness	TMH1 method B3[17]
• Polished stone value (PSV)	SABS method SM 84818

Slurry seals

• Hardness of parent rock	TMH1 method B1 or B2[17]
• Grading	TMH1 method B4[17]
• Sand equivalent	TMH1 method B19[17]
• Immersion index	TMH1 method C5[17]

Aggregates

• Aggregate crushing value (ACV)	TMH1 method B1[17]
• 10% FACT	TMH1 method B217
• Flakiness Index	TMH1 method B3[17]
• Sieve analysis	TMH1 method B4[(16)]
• Binder to aggregate adhesion	TMH1 method B11[17] Modified Vialit Adhesion Test (SABITA Manual 15, Test 9.6[24])
• Average Least Dimension (ALD)	TMH1 method B18(a)[17]

3.5.3 Tests required for purposes of quality control

The tests required for purposes of quality control are dependent on parameters specified. Recommended specifications are given in Chapter 8 of this document and will, therefore, not be further discussed in this chapter.

4 SELECTION OF APPROPRIATE SURFACINGS

4.1 GENERAL

The selection of appropriate surfacings for both new construction and reseals, based on the experience of road authorities and practitioners, is discussed in this chapter.

Although this document deals only with surfacing seals, it is important to understand the limitations of a surfacing seal. Recommendations with regard to the most appropriate surfacing type will, therefore, include asphalt surfacings. However, the most appropriate type of asphalt surfacing for given situations will not be discussed.

The factors influencing the performance of surfacings (discussed in Chapter 2) should be taken into account in the decision process.

The recommended process for selecting a surfacing or seal is as follows:

- Obtain all relevant information as discussed under pre-design investigation (Chapter 3).
- Divide the road into uniform sections of similar existing condition and required characteristics
- Identify appropriate surfacings for each situation.
- Compare initial and life-cycle costs.
- Compare the influence of other factors, e.g. knowledge, skills and available plant of potential contractors.
- Final selection.

For surfacings on new construction, the most important influencing factors, which identify those surfacings which will perform well under specific situations are provided in Table 4-1 to Table 4-4. A process is followed whereby inappropriate surfacing types are eliminated.

4.2 SURFACINGS SUITABLE FOR LABOUR-ENHANCED CONSTRUCTION

Surfacings suitable for labour-enhanced construction are discussed in Chapter 11.

4.3 SURFACINGS ON NEW CONSTRUCTION

A surfacing on new construction is defined as the first surfacing on a newly constructed road or street. Guidelines for the selection of appropriate initial surfacings are discussed under the following headings:

- Traffic volume
- Traffic actions
- Gradient
- Maintenance capability
- Surface texture required
- Construction techniques

- Environmental conditions
- Quality of the base
- Special conditions
- Initial cost basis for comparison.

The recommended surfacings are based on history of good performance. However, certain seals which are not recommended for specific situations may still perform reasonably well and their performance will depend largely on the skills and experience of local practitioners in the areas in which they are used.

Because of the simplified process incorporated in the tables below, the decision-maker is advised to study Chapter 2 and to incorporate additional information obtained during the pre-design investigation (Chapter 3).

4.3.1 Traffic volume

Traffic volume is expressed as the number of equivalent light vehicles (elv) per lane per day, as follows:

$$ELV = L + 40H$$

where

L = Number of light vehicles/lane/day
H = Number of heavy vehicles/lane/day

It is usual practice to use surfacing seals for roads carrying from about 125 to 20 000 equivalent light vehicles (elv) per lane per day. For roads carrying more traffic than this, an asphalt surfacing is usually recommended. However, there are surfacing seals, both in this country and elsewhere, which have performed well under much greater volumes of traffic (up to 60 000 elv). For roads carrying greater traffic volumes, all aspects relating to the materials, design and construction of the surfacing seal should be studied very carefully.

Lighter types of surfacing seals, such as sand seals, small aggregate seals and slurry seals should only be used as initial seals for roads carrying up to 2000 elv per lane per day. Where these seals are used for roads carrying greater volumes of traffic, it is possible that the polishing effect of the traffic may lower the skid resistance unduly. Larger sizes of stone should be used for roads carrying traffic near the top end of the range, since heavier traffic causes greater embedment of the stone.

Table 4-1 gives guidelines on seal types appropriate for different traffic categories.

The following abbreviations are used in Table 4-1 - Table 4-4:

S3	Sand seal
S7	Coarse slurry seal
S1	Single seal
S2(9)	Double seal with 9,5 mm aggregate and sand
S2(13)	Double seal with 13,2 mm aggregate and sand
S4(13)	Cape Seal with 13,2 mm aggregate and one layer of slurry
S2(13/6)	Double seal with 13,2 mm aggregate and a layer of 6,7 mm aggregate
S2(19/9)	Double seal with 19 mm aggregate and a layer of 9,5 mm aggregate
S2(19/6)	Double seal with 19 mm aggregate and one or two layers of 6,7 mm aggregate
S4(19)	Cape Seal with 19,0 mm aggregate and two layers of slurry
AC	Asphalt

Table 4-1 - Guidelines for initial surfacings for different traffic volumes

TRAFFIC VOLUME (elv/lane/day)	RECOMMENDED SURFACING TYPES FOR INITIAL SURFACING									
	S3	S7	S1	S2(9)	S2(13)	S4(13)	S2(13/6)	S4(19)	S2(19/9) S2(19/6)	AC
< 750	√	√	√	√	√	√	√	√	√	√
750 - 2000	x	√	√	√	√	√	√	√	√	√
2000 - 5000	x	x	√a	√a	√a	√	√	√	√	√
5000 - 10000	x	x	x	x	√a	√	√	√	√	√
10000 - 20000	x	x	x	x	x	√a	√	√	√	√
20000 - 40000	x	x	x	x	x	x	√a	√a	√	√
> 40000	x	x	x	x	x	x	x	√a	√a	√

Notes:

a - Good performance has been noted in several cases. The use of modified binders and trials on site can reduce risks in these situations. Typical problems expected are bleeding and loss of skid resistance

x - Not recommended

4.3.2 Traffic actions

Table 4-2 gives appropriate seal types for different traffic and road type combinations, based on experience in South Africa.

Table 4-2 - Guidelines for surfacing types for different traffic and road type combinations

TURNING ACTIONS	RECOMMENDED SURFACING TYPES FOR INITIAL SURFACING									
	S3	S7	S1	S2(9)	S2(13)	S4(13)	S2(13/6)	S4(19)	S2(19/9) S2(19/6)	AC
Rural with occasional heavy vehicles	√	√a	√	√	√	√	√	√	√	√
Residential - developed	x	√a	√b	√	√	√	√	√	x	√
Residential -developing	x	√a	x	x	x	√	x	√	x	√
Urban with occasional heavy vehicles	x	√a	x	x	x	√	√b	√	x	√
Urban with many heavy vehicles	x	x	x	x	x	x	x	x	x	√

Notes:

a - Only thick slurries (>10mm)

b - Preferably blinded with coarse sand

x - Not recommended

4.3.3 Gradients

On steep gradients, at traffic circles or in places where frequent stopping and starting occurs, traffic imposes such great stresses on the surfacing that a surfacing seal is liable to be damaged, particularly in its early life. For these special conditions the choice of surfacing type and the design are most critical. A normal single seal is likely to prove inadequate even for light traffic conditions. Under these conditions, surfacing seals in which binders with higher viscosity than normal (modified binders) are used, together with the use of precoated stone, or seals with a relatively fine texture finished off with a fog spray, or seals in which the stone particles are firmly held in place by slurry, will perform better.

Table 4-3 gives appropriate seal types for different road gradient categories.

Table 4-3 - Recommended initial surfacing types for different road gradient categories

GRADIENT	RECOMMENDED SURFACING TYPE FOR INITIAL SURFACING									
	S3	S7	S1	S2(9)	S2(13)	S4(13)	S2(13/6)	S4(19)	S2(19/9) S2(19/6)	AC
< 6 %	√	√	√	√	√	√	√	√	√	√
6 - 8 %	b,c	a,d	b,c,d	c,d	a,c,d	d	c,d	d	c,d	√
8 - 12 %	a,b,c	x	x	c,d,e	a,c,d,e	d,e	c,d,e	d,e	c,d,e	√
12 - 16 %	x	x	x	x	a,c,d	a,d	a,c,d	a,d	a,c,d	√
> 16 %	x	x	x	x	x	x	x	x	x	x

Notes:

a - *Not on stabilized base-courses constructed with fine material.*

b - *Not if channelling of water flow is expected because of soil wash - common in developing areas.*

c - *Not if urban drainage systems (kerbs) are present.*

d - *Not if communal water systems are present, since these result in detergents being washed onto the road with consequent erosion of the bitumen.*

e - *Not on gradients above 10 per cent if channelling of flow is expected because of soil wash - common in developing and hilly areas.*

x - *Not recommended.*

4.3.4 Maintenance capability

The majority of surfacing seals will normally lend themselves to simple maintenance techniques, such as the application of diluted emulsions or slurry seals. The application of diluted emulsions has been found to be cost-effective where the seal is beginning to ravel. If this is done before the seal starts to disintegrate, the life of the seal can be prolonged.

In Table 4-4 the maintenance capabilities of road authorities are categorized and recommendations on appropriate seals for different situations are made.

Table 4-4 - Recommended initial surfacings for different maintenance capabilities

MAINTENANCE CAPABILITY OF ROAD AUTHORITY	RECOMMENDED SURFACING TYPE FOR INITIAL SURFACING									
	S3	S7	S1	S2 (9)	S2 (13)	S4 (13)	S2 (13/6)	S4 (19)	S2(19/9) S2(19/6)	AC
High (Can perform any type of maintenance whenever needed)	√	√	√	√	√	√	√	√	√	√
Medium (Routine maintenance, patching and crack sealing on regular basis, but no MMS#)*	x	a	c	b	b	√	√	√	√	√
Low (Patching done irregularly, no committed team, no inspection system)	x	a	x	x	x	√	c	√	c	√
None	x	x	x	x	x	x	x	x	x	√

Notes:

a - Only thick slurries (>10mm)

b - Rural areas only

c - The performance of surface seals is sensitive to design and construction problems.

 # - It is not essential to have a maintenance management system (MMS), but its existence is indicative of a certain level of capability and sophistication.

x - Not recommended.

4.3.5 Surface texture required

Since the skid resistance of smooth-textured (fine) surfaces decreases much more rapidly with an increase in vehicle speed than that of rough-textured (coarse) surfaces, it is more important to provide a rough-textured (coarse) surface for rural high speed roads than for city streets. Smooth-textured surfaces are also desirable for city streets since they are both easier to clean and generate less noise.

There is a limit to the coarseness of texture of the surface because of the nuisance of tyre noise, its effect on riding comfort and the problem of windshield damage by large loose stones.

For single seals the largest size of stone generally recommended is 13 mm (19 mm in exceptional cases).

The higher the operating speed, the greater the texture depth required. Texture depths in excess of 0.7mm are recommended for operating speeds of more than 80 km/h. The greater the risk when braking, the higher the Sideways Force Coefficient (SFC) required.

4.3.6 Availability of aggregate

For seals to perform effectively on high volume roads, aggregate of good quality should be used. To increase the probability of a long maintenance-free life, consideration should be given to the importation of better quality materials if the stone available locally is of poor quality.

For lightly-trafficked roads consideration could be given to relaxation of some standards. Where suitable sand is available, it is usually worth considering one of the seals incorporating sand.

4.3.7 Construction techniques

Although seal construction techniques are basically the same, irrespective of the type of seal, the experience of the construction team should be taken into consideration in the selection of the seal to be used. Also, some types of seal are also more "forgiving" than others, lending themselves more readily to the construction of an acceptable quality wearing surface.

Conventional double seals (incorporating two layers of aggregate) or Cape Seals (incorporating a layer of aggregate followed by one or two applications of slurry) normally give good results. As the binder is applied in up to three applications, there is room for correction. Stone retention is good, since the lower layer of stone is wedged or grouted in by the succeeding layer. In a conventional double seal, retention of the second layer of stone can easily be brought about by the use of pre-coated chips or the application of a fog spray. In addition, its higher total binder content, by comparison with that of a single seal, makes the surfacing less permeable.

Single seals are more sensitive than double seals to the rate of application of binder, since there are less voids available and a small error in the application rate may have a significant effect on the percentage of voids filled. This is particularly true for single seals when small sizes of aggregate are used. Aggregate loss may also be greater, although this, to a certain extent, may also be overcome by pre-coating of the aggregate. It is essential not to apply too much or too little aggregate, but to achieve a shoulder-to-shoulder pattern in the completed seal. Careful brooming and rolling are necessary to ensure that the above-mentioned objective is met. It should also be ensured that the aggregate particles are properly orientated and embedded in the binder film.

Sand seals also require experience in rolling and back-brooming techniques.

The experience of the construction team in the application and spreading of slurry, especially in the proper use of squeegees, could make a substantial difference to the life of slurry seals and Cape Seals. Pneumatic rolling of slurry seals is recommended in order to provide a less permeable surface.

Note:

Construction guidelines are covered in detail in Chapter 7.

4.3.8 Environmental conditions

Although the temperatures prevailing in different areas of the country affect the choice of grade of binder and its rate of application, they have very little bearing on the choice of type of surfacing seal. In wetter areas it is desirable to use a surfacing which is as impermeable as possible, to prevent ingress of water into the underlying layers and to prevent the possibility of stripping of the binder in the surfacing itself. Well-constructed seals and Cape Seals will meet this requirement.

Several practitioners recommend the application of a fogspray and a blinding layer of coarse sand on single seals when sealing close to winter. This action reduces the risk of whip-off of the aggregate whilst the binder is still fresh.

Where roads or streets are used to carry storm water, single seals or thin seals are not recommended because of the risk of erosion. Table 4-3 may be used as a guideline for the selection of type of seal.

4.3.9 Quality of base

Since surfacing seals are relatively thin, any imperfections in the finish of the base will be reflected to the surface and will have an adverse effect on the riding quality of the road. This is particularly true of single seals (since the layer is only a single stone thick), and also of sand seals (which could be only 3 mm thick). In the case of multiple seals, minor undulations and depressions in the base may, to a small extent, be evened out. Some authorities have had good success in this regard, with the use of inverted double seals (smaller aggregate followed by the larger aggregate).

On relatively soft bases, such as those constructed with natural gravel or emulsion treated gravel where significant embedment of the surfacing stone is likely, good results will be obtained if inverted double seals or large-sized stone is used, for example if 19 mm stone is used in a Cape Seal or a double seal.

Where a satisfactory finish to the base profile cannot be assured, or where appreciable embedment of the surfacing stone is likely, a surfacing seal should not be used. Consideration should then be given to the use of an asphalt surfacing or to strengthening of the base, e.g. by stabilization.

4.3.10 Special conditions

In cases where the base has a high salt content, the surfacing seal should be designed to be as impermeable as possible and it should be placed as soon as possible after the base has been primed (Refer to TRH1).

4.3.11 Initial cost basis for comparison

4.3.11.1 Annual cost basis for comparison

The different types of surfacing seals vary in cost and have varying maintenance-free lives. One method of comparing costs is to calculate the annual cost over the maintenance-free period. This method of analysis is based on the assumption that the maintenance carried out is independent of the original type of surfacing seal used, which is not necessarily the case in practice.

To do this, use is made of the capital recovery factor, which gives an annuity which will return a given present payment plus interest on the unreturned portion in "n" receipts.

$$A = P \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right]$$

Where A = the annuity (or annual cost)

P = the present amount (or construction cost)

n = the maintenance-free period in years

i = the current discount rate

In the above equation the expression in square brackets is the capital recovery factor, which can be determined from standard tables for various periods and at various interest rates.

A sensitivity analysis should always be carried out to evaluate the influence of different possible scenarios, e.g. by using discount rates varying from 4 per cent to 10 per cent.

Example of the use of the method:

The annual costs of two surfacing seals, A and B, are to be compared. Type A costs R900 per unit length and gives an initial maintenance-free life of 8 years, whereas Type B costs R1 200 per unit length, but lasts 10 years.

Annual costs using an interest rate of 6 per cent

A =	900 x 0,161*	=	R145
B =	1 200 x 0,136*	=	R163

* Capital recovery factor calculated from the above formula or obtained from standard tables.

On the grounds of economy, Type A is preferred to Type B.

4.3.11.2 Relative costs of construction

Some relative costs of construction for different surfacing seal types are given as a guide in APPENDIX C. The initial maintenance-free life of these surfacing seals can vary considerably, depending on conditions; it has usually been found to be between 5 and 10 years. Where information on maintenance-free life is available, the two examples cited above illustrate one method which can be used to compare costs in practice.

4.3.11.3 Comparison of life-cycle costing

A more accurate approach to the economic evaluation of different seals would be to incorporate all expected costs and benefits over a specific analysis period. Costs would, therefore, also include maintenance costs of the seal (e.g. application of diluted emulsion) and increased maintenance costs of the pavement structure. The benefits can, to a certain extent, be quantified by the reduction in road user costs as a result of slower deterioration in road roughness and the effect on vehicle operating costs.

Note:

It should be noted that the results of such analysis are highly dependent on the assumptions made. This analysis should only be done on suitable seal types that have been pre-selected according to the parameters given in Table 4-1, Table 4-2, Table 4-3 and Table 4-4

4.4 RESEALS (MAINTENANCE)

4.4.1 The decision to reseal

The decision on whether or not to reseal depends mainly on whether the surfacing is achieving the purpose for which it was applied in the first instance, or on the risk of not achieving this. The basic purposes of a surfacing are:

- to provide a safe surface in all weather conditions (good skid resistance, no loss of aggregate, etc)
- to prevent or minimize vertical ingress of moisture into the pavement layers
- to prevent tyre contact with, or erosion of, the base layer.

It may not be necessary to reseal, as other maintenance strategies, such as patching or crack sealing, may be more cost-effective in certain cases to reinstate the surface to an acceptable condition.

Considering the first aim, the definition of a safe surface is related to the risk of collisions. It does not mean that all roads should have surfaces with high skid resistance, e.g. roads in dry areas, smooth textured roads with low traffic volumes and roads with alignments of a high standard may still have adequate skid resistance.

Provided the pavement layers are not moisture sensitive and the volume of heavy vehicle traffic is low, ingress of moisture can be tolerated to a certain extent before resealing is considered necessary. (For example: stabilization cracks tend to reflect through conventional binder surfacings within three to five years. Experience with stabilized pavements in South Africa indicates that the rate of pavement deterioration is slow until pumping of fines starts to occur. In such cases it is usually more cost-effective to do crack sealing than to apply a new seal.)

Visually assessable types of distress indicating the need for reseal are related to the basic purposes of a surfacing, as shown in Table 4-5.

Table 4-5 - Visually assessable attributes indicating a need for reseal

Basic functions of a surfacing	Surfacing failures	Cause of failure	Visually assessable distress
To prevent ingress of water	Porous surfacing	Dry binder Too little binder	Dry binder Voids Stone loss Poor surface drainage
	Surfacing cracks	Dry binder Premature cracking	Surfacing cracks Dry binder
	Structural cracks	Various mechanisms	Structural cracks Pumping
To protect base from traffic wear	Loss of stone/ravelling Potholes	Surfacing cracks Dry binder Structural cracks	Surfacing failures Surfacing cracks Dry binder Structural cracks
To provide skid resistance	Smooth surface texture	Flushing/bleeding Embedment	Flushing/bleeding Surfacing texture
	Polishing	Tyre abrasion/poor stone	Polishing
	Rutting	Densification of base or pavement failures due to water ingress	Rutting

Depending on the quality of the existing surfacing, some of the criteria for selecting a new seal could be of less importance when considering reseal types. The condition of the existing road structure and surfacing plays a major role in the selection of an appropriate reseal type. However, It is still necessary to consider the suitability of the various types of seals to particular conditions.

The following road surface conditions normally indicate that resealing or seal maintenance is required:

(a) Lean and dry appearance of an old seal caused by ageing of the binder, which has become hard and brittle.

(b) Loss of aggregate from the seal caused by ageing of the binder, insufficient binder, chemical decomposition of the stone or by the use of dusty stone during construction.

(c) A seal which is bleeding and has a smooth surface texture caused by excess binder. Such a seal will last a long time and will also have low permeability but, because of its low skid resistance, it may be a hazard to the travelling public. Where a road surface is rich in binder or is only bleeding slightly, the decision on whether or not to reseal should be based on the overall surface texture, skid resistance, geometry, traffic speeds and risk of accidents.

(d) A seal which is cracked and permits the ingress of water into the underlying pavement. There are several types and causes of cracking, and an understanding of the cause is essential to the selection of an appropriate remedial measure. For example, the road surface may exhibit crocodile cracking caused by fatigue of the pavement layers. In this case a reseal alone may not be effective and partial reconstruction or pre-treatment in the form of structural patching may be necessary. Cracks as such do not necessarily spell disaster, but their causes should be determined and crack development monitored.

(e) A seal with low skid resistance and a fine surface texture or aggregate which has polished under traffic.

4.4.2 Typical types of reseals

The seal types most commonly used for resealing, and the conditions under which these seals are used, are indicated below:

4.4.2.1 Single seals with 19 mm; 13,2 mm; 9,5 mm or 6,7 mm aggregate

The greater the traffic volume the larger the stone size used. When 19 mm ,13,2 mm or 9,5 mm aggregate is used with emulsion, a second spray of binder is added, followed by a thin layer of crusher sand if required to accommodate traffic immediately. This considerably reduces the risk of stone loss and hence the risk of broken windscreens. Precoating of the aggregate should be considered when hot binders are used.

4.4.2.2 Slurry seal

Slurry seals can be applied effectively to roads with a varying surface texture, for example where the aggregate has stripped in patches, where the road has been extensively patched, or where only the wheel tracks are fatty. A uniform texture results from a slurry application and it is, therefore, commonly used as a pre-treatment before a stone seal is applied.

Because of their thicker applications, rapid-setting slurry seals are often used to even out small irregularities and ruts.

Notes:

Care should be taken not to construct the reseal too soon after the slurry seal has been applied as punching of the aggregate will take place, which may result in bleeding of the surface.

Slurry seals should not be used on smooth-textured surfaces, especially in hilly environments with steep grades and sharp curves or at intersections because of the risk of shoving.

4.4.2.3 Surfacing enrichment

The life of a seal can be extended by the application of a surfacing enrichment spray in the form of a diluted emulsion or invert emulsion, provided the texture and voids in the surfacing are such that the mixture can penetrate into the seal and does not remain on the surface.

Note:

Rejuvenators have been used with success on lightly trafficked roads.

4.4.2.4 Diluted emulsion plus slurry

When a dry porous seal is treated with a slurry seal, the existing seal should be pretreated with diluted emulsion to prevent the trapping of air voids in the old seal or loss of binder from the new slurry. This could cause the binder to strip from the aggregate and could result in the failure of the seal.

4.4.3 The choice of the type of reseal

With all the possible pavement distress types, severity and extent of occurrence having been taken into account, a very large number of possible conditions could exist, making the selection of the most appropriate seal very complex.

In many cases one particular type of seal will provide the most effective solution. However, there is often at least one alternative which appears to be equally effective. The final choice will depend mainly on wide experience and mature judgement, economics and on the construction capabilities of the resealing unit or contractor.

The influence of some of the most important factors is discussed below and recommendations from the road authorities regarding actions currently considered to be the most cost-effective for the specific conditions are given.

4.4.3.1 Rutting

The typical crossfall of paved roads is 2 per cent. This implies that, for a rut width of 1 m, water will start to pond when the depression is deeper than 10 mm. However, roads may be found where the crossfall is inadequate, resulting in ponding of water in ruts less than 10 mm deep. A reduction in the risk of aquaplaning can be achieved by:

- Application of a coarse aggregate seal to dissipate water
- Application of a coarse slurry (not recommended by all road authorities because of bad experience with stripping in wet conditions).

Where rut depths are greater than 10 mm and there is little evidence of other types of distress, the following measures are considered to be the most appropriate:

- Application of coarse rapid-setting slurry - usually polymer-modified. (This is often done in two applications, firstly in the wheel tracks and then over the whole road width.)
- Application of an asphalt overlay or inlay. The use of asphalt is still regarded as a more reliable measure than that of slurry seals on more important roads with high volumes of traffic.

In cases where deep ruts and cracking occur, it is considered essential to apply a stone seal on top of the slurry as soon as the embedment potential allows it.

4.4.3.2 Surface texture

Fatty surfaces

The need to rectify fatty surfaces is dependent on skid resistance risks. If the risk is low it is not considered essential to improve this condition. Where the risk is high, a S1(13,2) single seal or a S2(19/6) double seal is often applied, with modified binders if necessary. In certain cases, especially where there is a significant amount of excess binder, some authorities prefer the application of double seals or inverted double seals. Modified binders are used with higher traffic volumes as this type of seal tends to be less sensitive to bleeding. On important roads asphalt is used at a much earlier stage if this type of problem occurs.

Medium to fine texture
Single stone seals are directly applied on this type of surface, the size of stone being dependent on the traffic volume and on the severity of the type of distress.

Medium to coarse textures
Depending on the type and severity of distress, various strategies can be followed, e.g.:

- Application of diluted emulsion
- Small stone single seal such as with 6,7 mm stone
- Texture treatments with sand seals, “Grit” seals or slurry seals.

The application of larger aggregate single seals is not recommended unless the surface is pre-treated or modified binders with high application rates are used. (The practical maximum binder application rate is usually insufficient to fill the voids in the existing surface and to bind the new aggregate.) This situation usually results in loss of stone.

Varying textures
In this case “varying texture” refers to a situation where the wheel tracks are fine textured or fatty and the area between the wheel tracks has a coarse texture.

It is not considered essential to reseal just because of this variation. When it becomes necessary to seal a road with varying texture, the choice depends on the ability of the type of seal selected to rectify this specific situation for a reasonable period of time. The choice is highly dependent on the traffic volume and on the risk of low skid resistance.

One strategy is to prepare the surface for the next stone reseal with a texture treatment such as a sand seal or slurry. In this regard the following may be recommended:

- Application of a sand seal where traffic volumes are low, if this is cheaper than a fine slurry
- Application of a medium or fine slurry on roads with higher volumes of traffic if the risks associated with low skid resistance are not great
- Application of a coarse slurry where skid resistance risks are high
- Application of a coarse, rapid-setting slurry on high volume roads, roads with little room for deviations or on roads with small irregularities, such as rutting or small undulations.

Depending on the structural condition of the pavement, these texture treatments may act as seals for several years before further action is required.

4.4.3.3 Loss of aggregate
Three different situations are identified. If very little loss of aggregate has occurred and the situation is stable, there is no real need to improve the current condition. If the situation is not stable, or if there is a potential for loss of aggregate, e.g. because of dry binder or voids in the surfacing, diluted emulsion is applied to prevent further deterioration. In cases of severe loss of aggregate (coarse texture) the situation

can be rectified by the application of a texture treatment as discussed previously.

4.4.3.4 Pavement condition

As the severity and extent of cracking and patching increase, more binder is needed to prevent reflection of the distress. Single seals with large aggregate, or double seals, are used on more lightly trafficked roads with severe pavement distress to extend the life of these pavements. The use of modified binders to deal with this type of situation is becoming more common.

The choice of a reseal as a holding action is often considered by road authorities when major rehabilitation cannot be executed immediately. There are many examples on South African roads where holding actions have extended the service life of pavements by more than ten years. The tendency in recent years is to make use of modified binders and/or geotextile seals for this purpose.

4.4.3.5 Traffic

There is general agreement among road authorities that seals have an upper traffic limit, below which seals can be applied cost-effectively. A traffic volume of 40 000 equivalent light vehicles per lane per day is regarded the upper limit, beyond which asphalt surfacings are usually applied. This limit is not rigid and may be influenced by factors such as road importance, construction quality and sophistication, time delays and the funds available.

In addition, the volumes and types of heavy vehicles, as well as their speed and turning actions, determine whether a seal would be appropriate. Asphalt surfacings are often used on roads with much lower traffic volumes, particularly at intersections with stopping and turning actions, or on climbing lanes.

The use of modified binders has improved the performance of stone seals on highly trafficked roads, especially because of their tendency not to bleed and their ability to reduce stone loss.

The general trend with lower traffic volumes is to reduce the aggregate size to 6,7 or 9,5 mm. This has the effect of reducing the binder application and thus of reducing the costs of the reseal.

Here again other factors often contribute to a final decision of whether or not to use a 13,2 mm aggregate such as:

- the availability and cost of smaller stone
- pavement condition (the greater the severity of the distress, the greater the quantity of binder needed)
- embedment potential
- the risk of a sudden increase in traffic volumes
- difference in cost effectiveness for the specific conditions.

4.4.3.6 Construction experience

The reseal teams of some road authorities, as well as those of some contractors, have built up experience in the construction of specific types of seal only. In cases where various alternatives are considered, those types of seal with the least risk of construction problems are recommended.

4.4.3.7 Noise levels

High noise levels are not acceptable in urban areas. It is, therefore, recommended by some road authorities that the maximum size of stone used in the top layer should not exceed 9,5 mm. Because of the high traffic volumes on some provincial or national routes in urban areas the application rate required for a 9,5 mm single seal is too low to be sprayed accurately with conventional binders and the only alternative is to make use of double seals, normally with modified binders. This alternative also reduces the risk of windscreen damage on these roads.

Selection diagrams

Figures D-1 to D-5 in APPENDIX D can be used to select the appropriate types of reseal for different situations.

Note:

The appropriate stone size is not provided in these figures. Although the general rule is to increase the stone size with higher traffic volumes, the purpose of the new seal must also be taken into account e.g. a 6,7 mm seal could be applied on an open textured existing 13,2 mm seal, even if the traffic volumes are high.

5 CRITERIA FOR CHOOSING A BINDER

5.1 GENERAL

The purpose of this chapter is to identify those factors influencing the selection of a specific type and grade of binder and to discuss the benefits of the appropriate application of specific binders, as well as the potential problems resulting from wrong decisions.

Recommendations are given for different traffic categories and climatic conditions. In addition, guidelines for the cutting back of bitumen on site are given.

5.2 FACTORS INFLUENCING BINDER SELECTION

The choice of the type of bituminous binder depends on:

- Type and purpose of seal
- Climatic conditions
- Durability of binder and long-term performance
- Price of binder at time of application
- Convenience of application
- Compatibility with aggregate
- Traffic
- Road geometry

5.2.1 Type and purpose of a seal

The purpose of a seal can govern the selection of a binder, for example:

- Hot modified binders allow for a thicker film of binder, which enhances the ability to retard crack reflection and ensures rapid adhesion with the aggregate when traffic has to be accommodated immediately after resealing. They are less sensitive to bleeding under high traffic volumes than unmodified binders and have better elastic properties, enabling them to accommodate high deflections and low temperatures.
- Texture treatments with slurry require the use of emulsions.

Practical hints

Bitumen emulsions should be used for **fog sprays** since they penetrate better than other types of binder, thus ensuring that the binder lies between the aggregate particles, with only a very thin film of binder on top of the aggregate. This reduces the possibility of pick-up when the road is opened to traffic.

In the case of **sand seals**, the binder should be a penetration grade or cut-back bitumen, depending on temperature conditions, or a bitumen emulsion. If emulsion is used, care should be taken to avoid the formation of a wave of emulsion in front of the curtain of sand being spread when a mechanical spreader is used. This can be done either by travelling at low speed when spreading the sand, or by waiting until the emulsion has started to break before applying the sand.

When a layer of **coarse aggregate** is **followed by slurry**, penetration grade bitumens will be suitable as a tack coat. Because emulsion has a low viscosity, it penetrates better into the voids of the underlying aggregate layer than penetration grade or cut-back bitumens and does not leave a thick film of bitumen covering the top of the aggregate. Bitumen emulsion should therefore be used for the penetration coat.

Cut-back bitumens are not recommended for use in the lower layers of seal construction, as the volatile constituents may take considerable time to evaporate.

For the **manufacture of slurry** the choice is between cationic or anionic stable-mix type bitumen emulsion. In most cases anionic stable-mix type bitumen emulsion should prove to be satisfactory for the production of slurry. Cationic stable-mix type bitumen emulsion is usually preferred when the aggregate for the slurry is prone to premature stripping, as is often the case when the aggregate blend has a high proportion of natural sand and/or when the road has to be opened to traffic shortly after the application of the slurry.

5.2.2 Climatic conditions

The selection of binder will depend on the climatic conditions pertaining, e.g. in South Africa there is the hot summer rainfall area with dry cold winters in the central parts of the country, while in the southern part of the country cold wet winters and hot dry summers prevail.

Penetration grade bitumens can be modified to accommodate most of the temperature conditions in South Africa by being cut back in the field. Alternatively emulsions can be used.

For successful seal work the most advantageous weather conditions are those which are "settled" and which allow relatively accurate predictions to be made of the minimum temperature for the ensuing 24 hours after spray operations. Hence dry winter or dry summers can be more readily accommodated in the seal design.

Note:

Although the surface may look dry, moisture can be trapped in the underlying layers if these are sealed during the rainy season. This can result in higher moisture conditions in the base layer and in the softening thereof, which will permit "punching" of the seal aggregate, resulting in bleeding.

Table 5-1 shows the types of binder recommended for different traffic and climatic conditions. In some cases other types of binder have been used with success. These, however, require specific knowledge and experience of materials used and of local conditions.

Because of their quicker breaking action, cationic emulsions perform better than anionic emulsions in humid or cold weather, or when moist aggregate has to be used from the stockpiles.

5.2.3 Durability and long term performance of binders

Penetration grade bitumens, cut-back bitumens and bitumen emulsions are durable and consequently are suitable for single and double seals.

Experience in South Africa has shown that polymer-modified binders are superior to conventional binders. In this regard a further distinction should be made between homogeneous and non-homogeneous modified binders, as there is a marked difference between the ability of homogenous binders and that of non-homogenous binders to retain their superior properties. (Refer to APPENDIX B for life expectancy.) The type of binder used can dictate the time required before the road is opened to traffic.

5.2.4 Price of bitumen at time of application

Although the life-cycle cost of a seal strategy using a more expensive binder may be less than that when a less expensive one is used, sufficient funds are often not available at the time of construction to allow the best product to be selected. A typical example is the use of a modified versus a conventional binder.

In many instances the decision to reseal (even with a conventional binder) is more important than selection of the type of binder.

5.2.5 Convenience of application

All the types of binder used in seal construction require heating to bring them to a suitable spraying viscosity. Bitumen emulsions are convenient to apply, since they require less heating than other types. With bitumen emulsions there is also less risk of damage by overheating than there is with binders containing volatile inflammable constituents. Furthermore there is no fire hazard.

5.2.6 Compatibility with aggregates

The properties of the aggregates used for sealwork in South Africa vary a great deal. A binder should be selected to ensure good adhesion with the specific aggregate to be used. For example: cationic bitumen emulsions will be found to be more suitable than anionic emulsions when aggregates such as granites or quartzites are used. Precoating of aggregate is also used to improve adhesion. (Refer to test methods - Chapter 8.)

Practical hints

Dusty aggregates should not be used. However in low-risk situations where only dusty aggregate is available, it is recommended that the material be washed or re-screened. If aggregate containing more dust than is normally acceptable has to be used, then a bitumen emulsion or even a cut-back bitumen rather than a penetration grade bitumen should be used; with bitumen emulsions the aggregate should be damp before application. Alternatively, when penetration grade bitumen is used, aggregate can be precoated to offset the influence of the dust.

5.2.7 Traffic

The type and volume of traffic are the main criteria to be considered during the selection of the binder. On high-volume roads with heavy traffic the amount of penetration grade bitumen, or of residual binder if emulsion is used, is too little to allow sufficient structural strength to develop to hold the aggregate in place during the critical 24 to 48 hour period immediately after spraying. An alternative binder may have to be selected which will allow sufficient binder to be sprayed to hold the aggregate without possible "bleeding" taking place, e.g. polymer-modified binders will meet this requirement.

5.2.8 Road geometry

Polymer-modified binders, especially non-homogeneous binders, are often selected to minimize the risk of bleeding on steep gradients or at intersections.

The spillage of fuel at corners, intersections and parking areas can cause severe bleeding or ravelling of the bituminous surfacing. In the past tar products have been used with great success. However, as discussed in paragraph 2.7.2, tars are no longer used in this country. Currently, the trend is to use bitumen binders and to seal the surface with protective agents, of which several are commercially available. These protective agents may be either sprayed on at approximately 0,6 ℓ/m² or applied with a squeegee (if manufactured as a creamy mix, similar to slurry).

Recommended binders are given in Table 5-1.

Table 5-1 - Recommended Binders

Traffic (elv/l/d)	**Winter : Dry**	**Summer: Dry**	**Winter and Rain *(c)**	**Summer and Rain *(c)**
<10 000	(i) 80/100 pen bit + cutter *** (b)** (ii) MC 3000 (iii) Emulsion (80/100 pen base bitumen) (iv) Lowveld - 80/100 pen bitumen (v) Modified hot binder or emulsion ***(d)**	(i) 80/100 pen bitumen (ii) 65% emulsion (80/100 pen base bitumen) (iii) Highveld -80/100 pen bitumen (iv) Modified hot binder or emulsion ***(d)**	(i) Cationic emulsion (quick setting) (ii) MC3000 (iii) Modified hot binder ***(d)**	(i) 80/100 pen bitumen + 2% cutter *** (a)** (ii) Cationic emulsion (iii) Modified hot binder ***(d)**
10 000 - 20 000	(i) 80/100 pen bitumen + cutter ***(b)** (ii) Modified hot binder or emulsion ***(d)**	(i) 80/100 pen bitumen (ii) Modified hot binder or emulsion ***(d)**	(i) Modified hot binder or emulsion ***(d**)	(i) 80/100 pen bitumen + 2% cutter ***(a)** (ii) Cationic emulsion (iii) Modified hot binder ***(d)**
20 000 +	(i) Modified hot binder ***(d)**	(i) Modified hot binder ***(d)**	(i) Modified hot binder ***(d)**	(i) Modified hot binder ***(d)**

*(a) When surfacing is carried out in wet summer months during a period when the weather is unpredictable, e.g. with possible showers in the afternoon, it is advisable to add 2 per cent of approved cutter to the binder and to use precoated aggregate.

*(b) During the dry winter months it is possible to predict the approximate minimum temperature to be expected for the ensuing 24 hours and to estimate the appropriate amount of cutter to be added. This could vary from 1 to 10 per cent, depending on the minimum temperature. In temperatures lower than 5℃, the use of winter grad e modified binders is recommended.

Expected short and medium term temperatures can be obtained from the South African Weather Service.

*(c) When surfacing is carried out in the rainy season, both summer and winter, there are periods of dry spells when surfacing can be done. In such cases the binder selected should preferably be quick setting and the binder should have good adhesion properties.

*(d) Specific formulation of polymer-modified hot binder (homogeneous or non-homogeneous) or emulsion, designed for local conditions.

5.3 FACTORS INFLUENCING SELECTION OF THE GRADE OF BINDER

The appropriate grade of binder depends mainly on:

- Purpose of the binder, i.e. precoating, tack coat, penetration spray etc.
- Road surface temperature
  - minimum temperature at time of application and shortly afterwards - early loss of stone could occur as a result of inadequate adhesion of hard binders
  - minimum temperature during the life of the seal - brittle fracture could occur later in the life of the seal due to the use of a hard binder
  - maximum temperature during the life of the seal - this could cause softer binders to become too soft, with consequent loss of stone, particularly in the early part of the life of the seal
- Road geometry
  - steep gradients could cause softer binders to run off during construction
  - curves and intersections could lead to traffic-induced damage on seals with softer binders when hot or on those with harder binders when cold. Recommended maximum gradients for different types of binder are given in Table 5-2.
- Traffic
  - in the early life of the seal traffic actions, particularly turning actions, could result in stone loss when softer binders are used
- Pavement deflection
  - high deflections could lead to cracking of hard binders, particularly at low temperatures
- Aggregate characteristics
  - the better the adhesion of the binder to the aggregate, the harder the binder can be
  - pre-coated aggregates will adhere to harder binders.

Table 5-2 - Recommended maximum gradients for application of binder types

Binder type		Application viscosity	Maximum gradient
Bitumen grade:	80/100 pen 150/200 pen	40 - 100 cSt 40 - 100 cSt	12% 10%
Cutback bitumens:	MC3000 MC 800	3000 - 6000 cSt 800 - 1600 cSt	8% 6%
Emulsions:	60% 65%	20 - 50 Saybolt Furol secs 51 - 200 Saybolt Furol secs	6% 8%

Note:
These values are only approximate and highly dependent on road temperatures, texture and the permeability of the existing surface. The operator's own experience should be added to this table to obtain more reliable values.

The maximum gradient refers to the maximum gradient resulting from the vertical alignment and camber/elevation of the road, and not only to the vertical alignment.

5.4 CUTTING BACK OF BITUMEN

The effective viscosity of the bitumen at time of application may be changed to accommodate local conditions during construction.

Before the bitumen is cut back, the expected maximum and minimum temperatures for the ensuing 24 hours should be ascertained. During the summer months, i.e. November, December, January and February, temperatures are usually most accommodating but work can be affected by sudden drops in temperature due to rain and hail. It is not advisable, therefore, to do any surfacing work if wet weather is anticipated (continuous rain). Thunderstorms are usually unpredictable and allowance should be made by introducing 1 - 2 per cent aromatic paraffin into the bitumen as a safety precaution.

Guidelines for cutting back 80/100 pen bitumen are provided in APPENDIX I.

Note:
Only petroleum-based cutters should be used with bitumen. (Power paraffin, Illuminating paraffin)

6 SURFACE PREPARATION/PRE-TREATMENT

6.1 INTRODUCTION

The performance of a seal is highly dependent on proper preparation and, if necessary, on pre-treatment of the existing surface and pavement structure. The purpose of this chapter is to discuss the importance of scheduling repairs and pre-treatments and to give some guidance as to how repairs and pre-treatments should be done, both in the case of new construction and reseals.

6.2 SCHEDULING AND COORDINATING REPAIRS AND PRE-TREATMENTS

6.2.1 General

Provision of a seal necessitates proper management of the total works involved. This includes scheduling of all activities prior to surfacing, which include the following:

- Repair of potholes, pavement and/or surfacing failures and edge breaks
- Crack sealing
- Smoothing out of undulations to improve the riding quality
- Filling of ruts
- Treatment of dry or porous areas or the addition of a tack coat
- Treatment of fatty areas, e.g. by rolling in chips (elementary *in situ* armour plating)
- Texture treatments to provide a uniform texture
- Cleaning of existing surfaces
- Reconstruction of small areas if required, replacement or provision of culverts
- Provision of sub-surface drainage
- Reinstatement of service trenches
- Regravelling of shoulders.

Planning and scheduling of these activities are of the utmost importance. For example, services such as the provision or repair of cable ducts, piping, sub-surface drainage etc, should be completed <u>before</u> surfacing operations begin. Scheduled road-marking should be postponed until the new surfacing has been laid.

6.2.2 Timing and opening to traffic

Repairs and pre-treatment usually require time to settle before a reseal can be applied, for example:

- All continuously graded asphalt work, whether it be skim coat applications or repair of road failures, should be open to traffic for at least 8 - 10 weeks before any seal work is carried out. Premature sealing will result in excessive embedment of aggregate.
- Roads on which any pre-treatment was done using slurry seals should be open to traffic for at least 4 - 6 weeks (preferably 12 weeks) before any seal work is carried out.
- Any new services which have to be installed, such as extra culverts, service ducts, water main ducts, etc., should be programmed for installation well ahead of any rehabilitation work. When trenches are backfilled, the upper 300 mm of backfill should be constructed with carefully selected material. Possible treatment of this material could include, for example, the addition of emulsion (1,5 per cent

residual bitumen) and 1,5 per cent cement, if proven to be satisfactory in testing or in previous works. This emulsion-treated base (ETB) may be taken to the same level as the surrounding existing surface levels. Alternatively, on roads with high traffic volumes, the upper 150 mm may be backfilled with a bitumen-treated base (BTB).

Practical hint

Conduct ball penetration tests at regular intervals. When the ball penetration values during the warmest part of the day become fairly constant less than 2 mm, then seal work may be carried out. Should ball penetration values stay above 2 mm and seal work cannot be postponed, the implications of fattiness or bleeding and reduced skid resistance must be evaluated.

6.3 TREATMENT OF NEWLY CONSTRUCTED BASE MATERIAL PRIOR TO SURFACING

6.3.1 General guidelines

Before a newly constructed base is primed, the following aspects should be checked and rectified if necessary and there should be an appropriate time interval before sealing:

- The shape of the road should conform to longitudinal and transverse levels as specified.
- Any slacks which may have been built into the road should be rectified. These slacks often occur at the joints between adjacent sections, and where deviations cross over new work.
- Any loose layers which may have occurred during the cutting of final levels should be removed and rectified with asphalt after priming. These loose layers often occur on stabilized bases and on G1 bases which have been slushed.
- All loose material should be properly broomed off the newly constructed base prior to priming, leaving a sound hard base ready for priming. (This also applies to slushed fines from a crushed stone base, which is not necessarily loose.) Care should be taken during surfacing of a natural non-plastic gravel base not to over-broom the surface, or to destroy the specified shape or surface texture of the road. In the latter case it would be more appropriate to spray water onto the base and roll the surface with a steel-wheeled roller just prior to priming, ensuring that a smooth, tightly knit and uniform surface is obtained.
- Depending on the type of surfacing to be applied, any areas of the road which would detract from the riding qualities of the road should be rectified with coarse slurry or asphalt after the road has been primed. This rectification specifically applies to roads which are to receive a single or double seal or, to a lesser extent, a Cape Seal. Asphalt surfaces are more accommodating of small inadequacies in the final surface of the newly constructed base than are seals.
- All dust and deleterious matter should be removed from the primed surface before any tack coat is sprayed. Where the primed surface has been used by construction vehicles and/or by public traffic, it

will be necessary to wash off any clay or other contamination of the primed surface.

- Where sand seals are to be applied, it is recommended that the surface be watered, broom-dragged and rolled with a steel wheel roller. This process should continue until a smooth, well-knit surface has been achieved, free of roller track marks, irrespective of whether or not the specified densities were achieved with the initial compaction. The road should be primed before the surface has dried out completely (at about 50 per cent of optimum moisture content).

- After all the loose material has been broomed off the base and just before the prime is applied, a light spray of water is applied to break the surface tension of the base material and to settle any loose dust.

Note:
The base should not be flooded with water - only a very light application of water is required.

Practical hints for base finish

After the base has been compacted in the normal manner and when the final levels are being cut, there is often a problem of the grader dragging the larger aggregate along the surface, forming minor longitudinal grooves. At this stage, the blade of the grader should be adjusted to the spreading position, i.e. not at a right angle to the surface but as flat as the adjustments will allow. Then, if the surface is watered and the minor windrows are swept longitudinally backwards and forwards across the road, the coarser material will roll free and the finer material will fill the voids in the surface. While the grader is "sweeping" the surface, a heavy pneumatic-tyred roller should follow in tandem. It should be ensured that the material has sufficient moisture for the compaction effort to be effective and that lamination does not occur. Care should also be taken to ensure a true cross section.

In order to obtain the final finish, the surface should be kept damp and then broom-dragged, with a heavy steel-wheeled roller following in tandem.

If this method is used it is possible to achieve an extremely smooth and satisfactory surface.

Note:
The following alternative procedure can only be used if the P.I. of the base is less than 8.

Instead of a prime, consideration could be given to the following alternative method of preparing the final surface before sealing:

- Once the normal compaction has been completed and just before final levels are cut, the "mulch" or ± 25 mm of loose material in the surface is sprayed with a diluted emulsion. Stable grade anionic emulsion is diluted with 10 parts of water to 1 part emulsion. The loose material is moved by grader in small windrows across the road surface and back, with the pneumatic roller following in tandem. The surface is kept continuously "wet" with the diluted emulsion until a smooth compact surface is obtained, free of ruts or holes caused by the cutting of final levels.

- The road can be opened to slow-moving traffic as soon as final rolling has been completed and when the surface has been allowed to dry for ± 1 hour. After a day or two, depending on the condition of the base surface, a “final” spray of the 1 to 10 diluted emulsion can be applied to the road.

- The road can be left open to traffic until a sufficient length of road has been completed to accommodate a full tank load of bitumen for the application of the “final” spray.

The advantages of this process are that there will be no areas of uncompacted material in ruts or holes and that it is a relatively easy operation. Small irregularities can be rectified during this period with hand-mixed materials of the same composition as that used for the finish.

6.4 REPAIR AND CLEANING OF EXISTING SURFACES PRIOR TO SEALING

6.4.1 Cleaning of surfaces

Cleaning of the existing road surface is important and sometimes difficult, but has to be carried out meticulously.

- Dust and loose material can generally be removed by hand brooming and/or by rotary brooms. However, on surfaces which are open textured, it may be necessary to use compressed air.

- Clay and animal droppings. This can be a problem and it may be necessary to use water, brooms and spades. It is essential that this work be done meticulously. Clay contamination is often more serious at the edge of the road, on curves and at traffic crossings. Where deviations have been used and they cross over the pavement, care should be taken to remove all dirt from the pavement, especially if a double seal is being applied and the first layer has been trafficked.

- Road studs should be removed and the resultant patches repaired.

6.4.2 Repairs to Existing Surfaces

Before an existing surface is resealed, it is strongly recommended that the road be inspected and all failures repaired, as this will extend the life of the road. Sealing over failed areas is a waste of valuable road funds and is regarded as a short-sighted policy.

A visual assessment of road failures is a prerequisite before repairs of the failures are undertaken. In addition to the information contained in Table 1-1, the following information will assist in the selection and design of appropriate repair measures:

- Type of failure, viz: surfacing, base or subbase.

- Extent of the failure. If the area which has failed exceeds 15 to 20 per cent of the total area, particularly in the wheel paths, it may be more economical to reconstruct the road, or specific sections of the road.

- The causes of the failure should be established as these will determine the kind of repairs required.

- The original specifications and construction details should be known, as these will determine what kind of material is required for repairs.

- The most effective method of repairing bleeding surfaces is to roll in additional stone without applying binder. However, as bitumen loses its ‘tackiness’ shortly after application, the aggregate will not bond with the bleeding area unless this “tackiness’ is restored by rejuvenation of the binder.

This is achieved by one of the following methods:

- Power paraffin is applied to the bleeding surface by means of a broom or a hand-held sprayer. As soon as the bitumen becomes tacky, precoated stone (6,7 or 9,5 mm) is spread on the surface and rolled in with a pneumatic-tyred roller.
- 6,7 mm aggregate is thoroughly precoated with power paraffin or Sacresote/Petrosote at 9 to 12 ℓ/m3. This is then spread over the affected area and rolled in with a pneumatic-tyred roller.
- Where there are large areas of bleeding, a light application of bitumen emulsion could be applied on a hot day. This is diluted with water in a 50:50 ratio and applied by a distributor at an application rate of between 0,7 and 1,0 ℓ/m3. This is then followed by an application of 6,7 or 9,5 mm aggregate, which is then rolled in with a pneumatic-tyred roller.

These measures only apply to the repair of bleeding areas. If the road is to be resealed, a suitable sized (13,2, 9,5 or 6,7 mm) is spread shoulder-to shoulder directly onto the bleeding surface prior to the application of any binder. The size of aggregate to be used depends on the softness of the bleeding areas, i.e. on the severity of the bleeding, and hence on the penetration of the stone. The tack coat is then sprayed over this layer of stone and the construction of the seal is completed.

This method, which is currently used by the Gauteng Department of Transport, was used for many years by the former Transvaal Roads Department and has given excellent results.

6.5 SURFACE PREPARATION/PRE-TREATMENT

There are sound and logical reasons for pre-treating an existing surface before the road is sealed with a single or double seal. The following serve as practical guidelines:

- If the surface is porous, this porosity can be reduced by spraying a diluted emulsion or applying a sand seal to choke the voids in the surface. If this is not done, the binder of the seal will slowly soak into the existing surfacing during warm weather, resulting in loss of aggregate.

- If the surface is not uniform, it is almost impossible to design for correct application rates, resulting either in a bleeding surface in parts or loss of aggregate in others. Uniformity of the surface can be assured by applying a thin (texture) slurry seal or a fogspray plus slurry to the existing surface, depending on the age and dryness of the surface. Alternatively, and on low volume roads (less than 750 elv per lane per day), sand seals may be used to create a uniform texture.

- If the road surface is uneven and/or has ruts in the wheel paths, these should be rectified, possibly by the application of a skim coat of continuously graded fine asphalt. The smoother the surface, the longer the life of the road. Rapid-setting slurries have been used with success for this purpose.

- If the road is cracked, with either crocodile cracks or transverse/longitudinal cracks, the causes of the cracking should first be established and the cracks rectified by sealing or patching before treatment is effected. See Table 6-1 for recommended treatments.

Table 6-1 - Recommended treatments for defective surfacings

Condition of Surface	Recommended Treatment
1. Non-uniform Surfaces e.g. Richness in wheel paths and dryness on edges and centre line of road occurring non-uniformly throughout the road section.	Fog spray dry areas with diluted emulsion and slurry seal the section. If the surface is uneven the texture slurry should preferably be applied by hand squeegees - not by machine.
2. Porous Surfaces e.g. Old continuously graded asphalt surfaces.	Spray a diluted modified emulsion to inhibit seepage of the binder. Blind with clean, washed sand to prevent pick-up (if necessary).
3. Uniform Dry Surfaces At edges and centre line of road.	Fog spray only the widths which are dry. This process only applies if the affected areas are uniformly distributed along the road.
4. Uneven Surfaces Causing ponding on the road or poor riding qualities. Corrugations.	Fog spray and apply a skim coat of hot bitumen fine graded asphalt. Corrugations can be taken out with a quick-setting cationic modified emulsion slurry.
5. Rutting in Wheel Paths	Fog spray the area containing the rutting and apply a hot bitumen asphalt skim coat OR Depending on the depth of the rut a modified emulsion (cationic) slurry can be applied. If the rut is deep, coarse slurry should be used (either anionic or modified cationic slurry, depending on intensity of traffic.) Alternatively, a rapid setting slurry can be applied. OR Apply a diluted emulsion (if dry and porous) and cover with slurry seal. OR In case of varying texture and fattiness in the wheel tracks, apply 6,7 mm or 9,5 mm aggregate with or without a very light binder application, only in the wheel tracks before resealing
6. Existing Repaired Areas (a) Repairs which are open graded and probably showing some signs of ravelling. (b) Unstable or uneven asphalt repairs.	Remove the existing patch and 150 – 300 mm of the adjacent existing surface. Tack with diluted emulsion. Apply hot bitumen asphalt.
7. Service Ducts (both existing and new) (a) Existing service duct crossings which are showing signs of “slumping” or are in poor condition	Remove 150 mm layer of the backfill and replace with ETB (1,5% residual bitumen – 1,5% cement) and enrich the final 25 mm with diluted emulsion. A premanufactured Bitumen/Rubber patch can be applied if the road is to be resurfaced OR remove 25 mm of the ETB and replace with hot bitumen asphalt when convenient.

Condition of Surface	Recommended Treatment
	Alternatively, removed 150 mm and replace with BTB.
(b) New Services	Carry out compaction in normal manner and apply 2 x 150 mm layers of ETB as above or a 150 mm layer of BTB.
8. <u>Major Slacks in Major Roads</u>	(i) Determine the extent of slack. (ii) Stringline the slack to determine the quantity of material required to rectify the slack. (iii) Tack the affected area with 20 – 30% diluted emulsion. (iv) On a hot mid-summer day spread a continuously graded asphalt with a grader, using a heavy pneumatic-tyred roller in tandem to compact the material. (v) The binder to be used can be an 80/100 pen bitumen in a hot climate and 150/200 pen bitumen in a cool climate. (vi) If the slacks are in excess of 100 m, carry out the same exercise as above with ETB prepared and mixed off site using 2% emulsion in the ETB or use a BTB. (vii) Use the normal method of applying asphalt i.e. with an asphalt paver, in layers not greater than 25 mm in thickness. In the case of BTBs, layer thicknesses should not exceed 75 mm.
9. <u>Bleeding Surfaces</u>	(i) Apply power paraffin to the bleeding surface by means of a broom or a hand-held sprayer. As soon as the bitumen becomes tacky, spread precoated stone (6,7 or 9,5 m) onto the surface and roll it in with a pneumatic-tyred roller. OR (ii) Thoroughly precoat 6,7 mm stone with power paraffin or precoating fluid at 9 to 14 ℓ/m^3. Spread this over the affected area and roll it in with a pneumatic-tyred roller. OR (iii) Where there are large areas of bleeding, apply a light application of bitumen emulsion on a hot day. This should be diluted with water in a 50:50 ratio and applied by a distributor at an application rate of between 0,7 and 1,0 ℓ/m^3. This is then followed by an application of 6,7 or 9,5 mm aggregate, which is then rolled in with a pneumatic-tyred roller.

6.6 CRACK SURVEY, IDENTIFICATION OF PROBLEMS AND TREATMENT OF CRACKS

Cracks will occur in the surface of any road sooner or later, depending on the degree and intensity of maintenance by the road authority concerned.

The type of cracking will, to a large extent, depend on sub-surface conditions, the method of construction and on the materials initially used for construction.

Broadly speaking, and for purposes of crack treatment, cracks can be classified as active cracks and passive cracks. The treatment of cracks will depend on the type of crack.

A question that may be asked is - whether cracks should be treated and repaired. In general, the sooner cracks are treated/repaired, the longer the life of the road will be.

6.6.1 Active Cracks

Most cracks have some activity between the crack walls. Active cracks in this case refer to the typical block/stabilization cracks which occur on a large number of South African roads. Active cracks generally occur as reflection cracks on the surface of semi-rigid pavements, i.e. in pavements which have one or two layers stabilized with lime and/or cement. The initial cracking is caused by shrinkage of the system after curing, after which movement is generated by expansion and contraction resulting from temperature changes. The passage of traffic will add to this movement in both horizontal and vertical directions, especially if the subbase does not give adequate support.

In wet weather this movement will cause "pumping" to take place, resulting in the transportation of fines from the lower layers of the system to the surface, where they will be visible. There could also be an uneven build-up of the coarser material between the layers close to the crack, causing secondary cracking of the system.

These stabilization cracks occur both transversely and longitudinally and allow the ingress of water into the system. Longitudinal cracks, however, although not subject to pumping to the same extent as transverse cracks, act almost like a "catchwater drain" for collecting water in the system. They normally occur along the construction joints in the system. If these active cracks are sealed timeously, i.e. after one wet season, when the tell-tale evidence of pumping is observed, the system can be kept intact for an extended period. If this crack treatment is deferred for 2 or 3 wet seasons, the excessive transportation of fines and the build-up of the coarse material (lesser fines) will result in secondary cracking, block cracking and in the formation of potholes.

Once secondary cracking has taken place, care should be taken to establish whether or not the resultant "blocks" are loose or rocking. No purpose will be served by sealing cracks round "loose" blocks. These blocks should preferably be removed/replaced.

Where a road has been kerbed and guttered or where a concrete side drain abuts onto the asphalt surfacing, the longitudinal joint acts as an active crack because of the differential coefficient of expansion of the two materials. This joint tends to open up with time and to act as a catchwater drain and will divert water into the system. This water will accumulate at the low points of the road, causing hydraulic pressures to develop in the system.

A similar phenomenon will occur to a greater or lesser extent at the interface between plastic shoulder material and a stabilized or unstabilized non-plastic base. It should be noted that sealing of the cracks without attending to the source of the water entering the system will only partially solve the problem. If water enters the system and there is no drainage/exit of the water, a major problem may arise. If the rate of entry of water into the system is greater than the exit/drainage rate, the passing of heavy truck traffic over the system will generate sufficient hydraulic pressure to burst through any seal placed over the section.
See Table 6-2 for the treatment of active cracks.

6.6.2 Passive Cracks

Passive cracks can include all other cracks, such as fatigue cracks, surfacing cracks, longitudinal cracks and parabolic cracks caused by slippage of the fill. Before any treatment is carried out on the cracks, it is essential to establish the cause of the cracking and whether the resultant "blocks" or segments are loose or rocking and whether these cracks are surfacing cracks or deeper. The extent of the area which has degraded to a cracked surface should also be established.

See Table 6-3 for the treatment of passive cracks.

6.6.2.1 Fatigue cracking (crocodile cracks)

Fatigue cracking is related to high deflections, repetitive loading and type/quality of the surfacing. Fatigue cracking usually occurs after a passage of time and is usually confined to the wheel paths. It has been observed that the occurrence of these cracks may be due to the presence of a soft, thin layer between the base and the surfacing, usually associated with an absence of rutting.

If cracking occurs in isolated areas, further investigation should be done to establish the quality of the material(s) below the surface. It may be necessary to replace the layers in the pocket failure. These local failures may, however, be caused by ponding of water on the road, resulting in degradation of the road structure and surfacing, the material itself being adequate and similar to the adjacent material. Any defect in the shape of the road should also be rectified before it is surfaced.

6.6.2.2 Shrinkage/ageing cracks (surfacing cracks) and secondary cracks

Crocodile-pattern cracks often occur as a result of ageing of the binder in the surfacing caused by UV radiation and by oxidation of the material. Also, thermal shrinkage of the surface may cause cracking as can a lack of binder in the surfacing. Such a surface will show no signs of depressions/failure in the lower layers. It will have a uniform "level" surface. These cracks will deteriorate with time and with the ingress of water in conjunction with increases in traffic volumes. Here again, it is important to know the age of the road and surfacing. There could, therefore, be an overlap in the designations of fatigue and shrinkage cracks.

If this crack pattern occurs over most of the road, if the shape of the road is sound and if the age of the road is known to exceed 6 or 7 years, these cracks may, with confidence, be designated as shrinkage/ageing cracks and a definite system of repair proceeded with.

6.6.2.3 Deep longitudinal/parabolic cracks

Typical parabolic cracks can occur on high fills or on low fills on "unstable" subgrade. Before the slip on a fill is treated it might first be necessary to establish whether the whole fill is stable enough or whether any (dangerous) complete slippage is possible. The resources for doing any major earthworks may not be available and the crack treatment would then be regarded as a holding operation which should be monitored regularly. Slippage can be distinguished from differential settlement by the shape and extent of the crack line.

Longitudinal cracks are often caused by active subgrades and moisture movements or by poor shoulder support. These cracks should be sealed as soon as possible to prevent the ingress of moisture.

Table 6-2 - Recommended treatments on active cracks (stabilization cracks)

Information Required/Investigations	Recommended Treatment
PRIMARY CRACKS	
1. Establish whether base is cement treated (CTB) or lime treated (LTB). CTB cracks occur at 1,5 - 3,5 m intervals. LTB cracks occur at 4 - 7 m intervals.	**Note:** Large slabs are normally not loose and do not rock. It is when these slabs break up forming secondary and tertiary cracks that they should be inspected for their integrity.
2. Establish the number of points at which pumping is taking place and the reasons for the ingress of water apart from the cracks, as well as the source of water.	
(a) Dense shoulders built with clayey (high PI) gravel boxing in the base and inhibiting free drainage.	(a) Special sub-surface drains in the centre line of the road and/or herringbone drains may be required.
(b) Water ponding on the shoulders and seeping into the base via cracks or between surface and base or base and subbase.	(b) Repair shoulders to slopes, giving a free flow of water away from the surface.
(c) Side drains not deep enough to cut off water from higher ground which is forced by hydraulic pressure under the drain into the centre of the road system.	(c) Repair, deepen side drains. Line the side drains with weepholes in wall of side drains remote from the road.
(d) No sub-surface drains through cuttings, ditto (c).	(d) Construct sub-surface drains if drainage is a problem.
(e) If the road is kerbed and guttered - the longitudinal joint between surfacing and the gutter collects water and directs it into the system - resulting in a build-up of water pressure at low points in the system.	(e) Clean the joint properly and seal. Widen the new seal to overlap this joint.
(f) Porosity of the surface should be established.	(f) This condition can be rectified with a seal.
(g) Establish the width and extent of cracks.	(g) Repair as described in Table 6-4.
SECONDARY CRACKING Primary cracks deteriorate into secondary cracks with the transportation of fines when pumping occurs.	
1. Are the secondary cracks pumping? Establish the number of points which are pumping.	1. Treat drainage as above in (2).
2. Are the blocks loose and rocking?	2. If blocks are loose or rocking, they should be removed.

Information Required/Investigations	Recommended Treatment
3. Establish the origin of the water which is causing the pumping.	3. The source of the water should be established as for the primary cracks and treated as above in (2).

Table 6-3 - Recommended treatments for passive cracks

Investigation Information Required	Recommended Treatment
Crocodile cracks	
1. Determine the extent of the affected area. 2. Determine whether there is deformation of the surface. 3. If pumping is evident, determine source of water. 4. Establish whether the "blocks" are loose or firmly in place.	Treat drainage as in (2) under Primary Cracks in Table 6-2. See Table 6-4 for method of repair.
Longitudinal and parabolic cracks	
1. Determine the extent of the crack. 2. Determine the cause of the crack. 3. Determine the depth of the crack. 4. Determine the width of the crack.	See Table 6-4 for method of repair.

Table 6-4 - Recommended methods of crack repair

Type of Failure/Crack	Method of Repair
1. Active Primary Stabilization Cracks which are less than 3 or 4 mm wide	1. Remove all loose material in cracks by means of compressed air. 2. Using a pressurized insect spray can (4 Bar pressure), spray into the cracks an approved water soluble weed killer if necessary. 3. Allow crack to dry out. 4. Prime the crack with an inverted emulsion prime, using the same type of pressurized spray can. (A modified 10 litre insect spray can is most suitable if the lance is extended and the nozzle replaced with a 3 mm nozzle - spraying a thin jet and not a flare). 5. Allow prime to cure for 48 hrs or sufficiently long to allow the subsequent application to adhere.
	6. Spray into the crack a modified emulsion containing 4 to 5% of nett rubber in nett bitumen. This can be mixed on site using an emulsified rubber (anionic) with a 60 to 70% anionic emulsion. 7. The application of the modified emulsion may have to be repeated twice or three times to fill the crack. 8. Excess binder on the surface should be smoothed out so that it does not form a ridge. Precautions (i) Cleanliness and neatness of operation is essential. Over-spraying of the surface should be avoided. (ii) The modified emulsion should be screened into the spray can to avoid blockages. (iii) The equipment should be thoroughly cleaned at the end of the working day by washing with water and dieseline.
2. Secondary Stabilization Cracks (Block sound)	Treat as above, ensuring that the blocks are not rocking. Loose blocks should be removed.
3. Stabilization Cracks (primary) - wider than 4 mm.	1. Hot bitumen rubber (BR) sealant can be obtained from commercial sources and applied but, if it is decided to use the BR method, it is advisable to carry out steps 1 - 6 above, using only one application of modified emulsion. 2. Hot BR is not always available and the following process can be used (follow the supplier's instructions): Repeat steps 1 - 6 as above and fill the crack with a slurry made with crumb rubber as follows: SABITA specifications for rubber crumbs from pneumatic tyres are to be used, viz. Grade 2, Type 3, mixed in the following proportions: 20 litres of rubber crumb 5 litres of modified stable grade 60% anionic bitumen emulsion ½ litre of cement Water as necessary to improve workability of the mix.

Type of Failure/Crack	Method of Repair
	Note: *Several products are available on the local market which can be used for crack sealing as recommended by the manufacturers.*

Table 6-5 - Recommended methods of crack repair

Type of Failure/Crack	Method of Repair
4. *Crocodile Cracks* on sound base and there is no block movement. (Only applies when cracks are spalled).	
4.1 Isolated small areas (5 – 10 m²)	Tack coat of emulsion + patch (premanufactured bitumen rubber – commercial supply).
4.2 Medium areas (10 – 20 m²)	Fog spray with diluted emulsion 1 : 3 + slurry seal.
4.3 Large areas.	Fog spray with diluted emulsion 1 : 3 + slurry seal.
Note: If the crocodile cracks on a sound base are still fine and there is no spalling, the section can be resealed without pre-treatment.	
5. *Crocodile Cracks* on sound base but where the blocks are loose.	Neatly remove the loose blocks, tack the excavation with 1 : 3 diluted emulsion and apply hot asphalt, (continuously graded fine, or medium, depending on the depth of excavation), applied in one or two layers, depending on the thickness. (25 mm = 1 layer; 100 mm = 2 layers). Roll with small pedestrian vibratory roller. **Note:** *When the surface is tacked, the vertical sides of the excavation should also be tacked.*
6. *Crocodile Cracks* on unsound base and subbase	1. Excavate the failed/unsound base and subbase and treat with ETB in separate 100 mm layers. The sides of the excavation should be treated with diluted emulsion. Compact the layers up to the level of surrounding existing surface. Enrich the top of the base with diluted emulsion. Tack with emulsion and apply premanufactured bitumen rubber patch. This treatment is recommended if the road is to be resealed or overlaid. OR

Type of Failure/Crack	Method of Repair
	2. Treat as above up to 25 mm from final surface and apply hot asphalt, *OR* take base to the level of surrounding surface and excavate when suitable to depth of 25 mm below surrounding levels. OR
• *Deep Longitudinal Cracks* These often occur on fills or where the road passes over heavy clays. They tend to be wide and deep.	3. Tack excavation and apply black base under special circumstances – e.g. when rapid repair is required under heavy traffic conditions. **Notes:** *Do not repair base or subbase failures with concrete.* *Do not use cement stabilised material to repair unstabilised base layers.* *Do not use expensive black base to repair unstabilised layers.* *Do not use open-graded asphalt material for repair patching.* *Do not use asphalt containing volatiles where the road is to be resurfaced in the near future. Alternatively, the asphalt should settle under traffic for a minimum of 8 weeks before it is sealed.* 1. Caulk the crack with a 50 / 50 lime / fine sand slurry to within 100 mm of the surface. 2. Allow the water to evaporate until the slurry is just damp. 3. Prime and apply modified emulsion as above. 4. Apply / introduce rubber crumb slurry. **Note:** *The above only describes one method. Other methods and commercially available products can be used.*

7 DESIGN AND CONSTRUCTION OF SEALS

7.1 INTRODUCTION

In this chapter the purpose is to guide the reader in the design and construction of typical seals used in South Africa. Important aspects relating to the design and construction of common types of seals are addressed under the following headings:

Seal types not commonly used in South Africa are briefly discussed in paragraph 7.10.
These are:

- Choked seals
- Split seals
- Geotextile seals
- Inverted Double Seals
- Otta seals and graded aggregate seals
- Stress-absorbing membrane interlayers (SAMIs)
- Ultra-thin asphalt

Note:
The recommendations regarding the construction of Cape Seals and single and double seals, with both conventional and modified binders are similar. These are given in paragraph 7.11.

7.2 PRIME COATS

Recommendations for prime coats and bituminous curing membranes are discussed in detail in the companion documents DRAFT TRH1 and SABITA Manual 26 and are summarized below:

- Prime coats are not essential but reduce the risk of failures resulting from small imperfections in the upper part of the base. In addition, they:
  - promote adhesion between the base and the surfacing;
  - help to seal the surface pores in the base;
  - help to strengthen the surface of the base by binding the finer particles, and
  - provide the base with a temporary protection against the effects of weather and traffic.

- Curing membranes are used to:
  - prevent loss of moisture in cementitious stabilized materials ;
  - prevent carbonation of, or salt migration in, the base, and
  - provide a waterproof membrane to protect the base from the damage caused by surface water.

- The main aspects to be taken into consideration in the selection of the type and grade of prime or curing membrane are the weather conditions, the absorptive characteristics of the base and whether or not the base is chemically stabilized.

- The use of quick-drying primes should be limited to special circumstances, such as when the road has to be surfaced as soon as possible, when cold, wet conditions occur, or when the base is very dense.

- Suitable spray rates vary between 0,65 and 1,0 ℓ/m^2 for both prime coats and curing membranes.

- Priming should not be carried out when the surface temperature is below 10 °C, in strong wind or when rain threatens.

- Priming should be done when the base has dried to approximately 50 per cent of optimum moisture content.

- If traffic has to be accommodated on the road before the prime or curing membrane has dried out, the surface should be covered with a blinding layer of small aggregate (6,7 mm nominal single size).

Commonly used primes are: Inverted bitumen emulsion prime
MC 70 or MC 30

7.3 SAND SEALS

7.3.1 General

The success of sand seals depends on the quality of the finish of the base. A brief description of ways of attaining the required quality is given in paragraph 6.3 as a practical hint, as this is regarded as a most important aspect for a long-lasting surface.

Generally sand seals are not recommended as initial seals for roads on which the traffic exceeds 750 ELV per lane per day. However, as a reseal or texture treatment numerous examples exist where sand seals have performed exceptionally well on roads carrying up to 3000 ELVs per lane per day. The success of sand seals on higher volume roads relates to a coarse grading (2.0 mm - 4.75 mm) with a low dust content (minus 0.075 mm). The material falling into this category is often referred to as “Grit”.

Should a sand seal be selected as the initial seal, experience indicates that provision must be made to reseal the road within three years. Timeous reseal, even with another sand seal, could result in a service life of the second seal in excess of ten years.

- **Design**

There is no specific design method for sand seals. A nominal bituminous binder application rate of 1,0 ℓ/m^2 residual binder is recommended.

As a rule-of-thumb the binder is applied at the following rates:

Penetration grade bitumen 1,1 - 1,3 ℓ/m^2

Cut-back bitumen	1,2 - 1,4 ℓ/m^2
Emulsion	1,4 - 1,6 ℓ/m^2

The selected application is a function of the purpose of the seal, the porosity and texture of the existing seal, the grading of the sand, the prevailing temperature and the expected traffic

Thereafter the sand is applied at a rate of between 200 and 100 m^2/m^3 and rolled. For one to two weeks, depending on the traffic, the excess sand is swept back towards the wheel tracks to prevent fattiness and pick-up.

Notes:

A sand texture treatment differs from a conventional sand seal in that the minimum quantity of binder is applied and the sand application rate is reduced to approximately 300 m^2/m^3

Excellent performance on roads carrying up to 3000 ELVs per lane per day has been recorded using coarse graded sands and precoated coarse sand. Precoating eliminates dust during construction, reduces the need for back sweeping and requires a lower rate of binder application.

Moist aggregate reduces dust during construction and improves adhesion when using emulsions or cut-back bitumen.

A higher application rate of aggregate (120 – 100 m^2/m^3) is normally required when applied by hand.

7.3.2 Aggregate

Normally river sand or crusher dust is used for sand sealing. The sand should be screened to eliminate pebbles larger than 6,7 mm. These pebbles are often quartzitic with large crystals and when applied and rolled, although they partially penetrate the surfacing, they tend to shatter under steel wheel rollers and to form incipient potholes.

The recommended grading of the sand is given in Chapter 8; Table 8-4

7.3.3 Binder

Typical binders used for sand seals are given in Table 7-1.

Table 7-1 - Binders used for sand seals

Summer	Winter
65% or 70% Cationic Emulsion (Base bitumen - 80/100 pen.) 80/100 pen. bitumen 150/200 pen. bitumen MC 3000 cut-back bitumen	65% or 70% Cationic Emulsion (Base bitumen 150/200 pen) 150/200 Pen. bitumen MC 3000 cut-back bitumen MC 800 cut-back bitumen

Note:

Sand seals are highly sensitive to rain within hours of construction. Coarse graded precoated sand seals with cut-back bitumens are sensitive during and immediately after construction to road surface temperatures above 50 ℃. MC 800 cut-back bitumen should only b e used on very low volume roads.

Several products are marketed in South Africa as bituminous dust palliatives and have been used with success to provide dust-free surfaces. These products are often mixtures of hydrocarbons or tar and cut-back bitumens, applied at approximately 1,4 ℓ/m^2 and blinded with sand. The average effective life of these surfacings is 3 years on lightly trafficked roads.

7.3.4 Construction

The success of a sand seal is dependent on the finish of the base and on the construction technique employed. The recommended construction procedure is described below.

The primed base should be swept clean of all loose and foreign particles. The bituminous binder should be applied at the required rate and sand should be applied immediately to obtain maximum wetting of the sand by the binder. If a mechanical spreader is used, care should be taken to avoid the formation of a wave of emulsion in front of the curtain of sand being spread if the binder used is a bitumen emulsion. This can be done either by the mechanical spreader travelling at low speed while spreading the sand, or by waiting until the emulsion has started to break before the sand is applied.

As soon as a complete layer of sand has been applied, rolling with a 6 to 10 ton pneumatic-tyred roller should commence. After the entire surface has had four passes of the roller(s), the road should be opened to traffic and any loose sand should be swept back onto the road. This should be repeated over a period of one to two weeks. This is particularly important on curves and on gradients. If a second seal is required, work should not commence until the road has been trafficked for eight weeks. All loose sand on the existing surface should then be removed, and the application of binder and sand and after-care treatment should be resumed as described above.

All areas showing signs of distress should be repaired before the second seal is applied.

Proper maintenance of a sand seal will result in an extension of the functional life of the seal. Scouring of the road shoulders and the growth of vegetation on the road shoulders should be prevented.

Note:

Please also refer to paragraph 6.3 - Practical hints for base finish. Although initial rolling with a 5 to 8 ton steel wheel roller is recommended by several practitioners, excellent performing sand seals have been constructed using only light steel wheel rollers (3 tons)

7.4 SLURRY SEALS

7.4.1 General

A slurry is a homogenous mixture of fine aggregate, stable-mix grade emulsion (anionic or cationic) or a modified emulsion, water and filler (cement or lime). Slurry seals are used as maintenance treatments and for new surfacing on roads and airfields. They are also used to provide a homogenous texture to the existing surface prior to resealing.

The design of the slurry is such that:

- The mixture is easily applied by hand by rubber squeegees or by mechanical spreaders i.e. the mixture will have a creamy consistency, which will allow it to flow readily into surface voids and interstices
- The hardened product will have sufficient binder not to ravel but stable enough to carry the wheel loads without bleeding or deformation.

7.4.2 Materials

7.4.2.1 Aggregates

The most suitable aggregates are crusher dusts. The grading of the material depends on, and is determined by, where the slurry is to be applied and on its purpose. Table 8-5 and Table 8-6 give some guidance on suitable aggregate gradings.

On account of their generally rounded particles, natural sands should be used with caution, preferably with a maximum of 50 per cent in a blend with crusher dust. As sands also contain large amounts of quartzitic material, it would be advisable to test for stripping by using test TB 115 of the International Slurry Surfacing Association[25] or the Immersion Index Test (TMH1, test method C5)[17].

7.4.2.2 Fillers

Cement or lime acts as a catalyst to keep the mix consistent and to improve the flow and workability of the slurry. Cement or lime should be added to all slurries, as with most aggregates there is a tendency for diluted emulsion to segregate from the larger sized particles. This emulsion then tends to float upwards to the surface of the spread slurry.

7.4.2.3 Water

The addition of water is necessary in order to obtain the correct slurry consistency. As a guide 160 litres of water per cubic metre of dry aggregate should be added. This, however, will vary with the type of aggregate and the prevailing temperature on site. On hot days extra water will be required to obtain the correct consistency for uniform spreading.

The pH of water used for the dilution of anionic bitumen emulsion should be between 7 and 9 and for that of cationic bitumen emulsion between 4 and 7. Water with a pH value outside these limits should be checked for compatibility with the emulsion. In addition to the pH requirement, if the total dissolved solids count is greater than 500 ppm, the water should be tested for compatibility with the emulsion. Generally the water content is about 10 per cent by mass of dry aggregate. The use of excess water should be avoided.

7.4.2.4 Emulsion

The following types of emulsion are used extensively in South Africa for slurry seals:

EMULSION TYPE BASE BITUMEN

Stable grade anionic emulsion	-	using 80/100 penetration grade in summer
	-	using 150/200 penetration grade in winter
Stable grade cationic emulsion	-	using 80/100 penetration grade in summer
	-	using 150/200 penetration grade in winter

Quick setting cationic emulsion

Quick setting modified cationic emulsion

Note:

In hot climates it is recommended that 80/100 penetration grade bitumen be used in all the emulsions.

As regards modified emulsions, various polymer modifiers are available and the supplier of the binder is advised to select the modifier compatible with his bitumen and certify the percentage modifier introduced. The addition of modifiers improves the strength (initial stiffness) of the mix as well the aggregate/binder adhesion. Improvement of flexibility resulting from the addition of polymers is not noticeable in slurry seals.

In general, three per cent of polymer solids (by mass of bitumen) is regarded as the minimum amount of modifier to be added. This, however, should be established by the laboratory doing the mix design.

7.4.3 Design of Slurry Seal

The design of slurry mixtures is based on semi-empirical methods or on experience. The different applications of slurry seals have lead to different design approaches. These applications can be summarised as follows:

7.4.3.1 Texture treatment

The purpose of a texture treatment is to pre-treat an existing coarse or variable texture surfacing to obtain a uniform fine texture before a single seal is applied. A 2 - 3 mm thick layer of fine slurry is applied, preferably by hand. The ideal emulsion content is dependent on the aggregate type and on the grading, the time before the single seal will be applied, the traffic conditions on the road and on the thickness and method of application.

Typical emulsion contents used are given in Table 7-2.

Note*:*

The construction of small experimental sections, trafficked for a week, usually provide sufficient information to enable the appropriate emulsion content to be selected.

7.4.3.2 Slurry seal

Medium and coarse slurries are often used as seals on sound pavement structures. One semi-empirical method which has yielded useful results is to determine the residual bitumen content of the slurry according to the hot-mix Marshall design procedure[26]. The binder mixed with the aggregate is a 80/100 penetration grade bitumen and the optimum bitumen content is taken as the value which gives maximum stability. The residual binder content of the slurry should be selected in terms of:

- traffic, and
- aggregate grading and apparent maximum relative density of combined aggregate.

Table 7-2 may be used as a guide in respect of traffic.

Notes:

When the Marshall approach is used, it should be borne in mind that the optimum bitumen content is established on a compacted sample. All the slurry seal calculations are based on uncompacted material, e.g:

- *If the optimum bitumen content is 8 per cent obtained at a density of 2415 kg/m³, then the quantity of residual binder would be 193,2 ℓ/m³ compacted.*

- *If the material were loose and a bulking factor of 1,4 were applied, the quantity of residual binder in 1 cubic metre would be 138 litres, i.e 193,2/1,4. This would give 230 litres of 60% emulsion per cubic metre of aggregate (loose).*

The moisture content of the aggregate should be checked daily so that the emulsion content in the mix may be adjusted if required

Table 7-2 - Binder content of slurry

ELV/lane/day	Percentage of residual bitumen in mix by mass of aggregate	Typical emulsion contents for texture treatments
> 10 000	6 - 8	180 - 200 ℓ/m^3
1000 - 10 000	8 - 10	200 - 220 ℓ/m^3
. 1000	10 - 12	220 - 260 l ℓ/m^3
Cape Seal (new construction)	10 - 12	

Note:

Percentages given are by mass of loose dry aggregate and not by mass of the total mix.

The residual bitumen contents given in Table 7-2 are based on the aggregate having a maximum relative density of 2,65. Adjustments to the percentages of residual bitumen can be made for aggregates with different maximum relative densities by multiplying the given bitumen contents by a ratio of (2,65/X), where X is the maximum relative density of the aggregate to be used.

Variation in the grading of slurry aggregate delivered often result in uncertainty regarding the required binder content. A practical method to determine the appropriate binder content in a site laboratory is as follows:

- Several slurry mixtures are made up, varying the emulsion content from 180 ℓ/m^3 to 240 ℓ/m^3
- The slurry mixtures are poured into Marshall briquette moulds to approximately 15 mm in depth
- Samples are heated overnight at 60 ℃ to allow wa ter evaporation
- Samples are then compacted using the Marshall hammer - 150 blows (only one side)

The ideal binder content would result in:

- No plastic deformation at the edges (between the hammer and the side of the mould)
- Dark grey to black coloured specimens, slightly pliable when broken in two

A dull brown colour indicates too low binder content.

This method is currently referred to as the “Colas method”

7.4.3.3 Slurry for Cape Seals

A mix consisting of 100 parts aggregate to 20 parts stable grade emulsion (60 per cent) by mass is recommended, irrespective of traffic density. Only in exceptional circumstances should consideration be given to a reduction in the emulsion content. The cement content should be between 1 and 2 parts. The water content may be varied, but it will normally be about 15 parts to give a flow of 30-40 mm using ASTM test method D 3910[27] or Western Cape Provincial Administration Method CPA C1[28].

Note:

The appropriate binder content in the slurry used with a Cape Seal depends on whether the traffic will drive directly on the slurry or on the top of the large aggregate (single seal - first layer). If the slurry is applied using hand tools, it will flow between the large aggregate particles, irrespective of the shape of the road. In this case the slurry will be able to accommodate a high binder content without any risk of bleeding. However, if the slurry is applied with a spreader box on an uneven surface, there will be areas where the slurry will cover the large aggregate and will, therefore, be in direct contact with the tyres. In this case, it is recommended that a lower binder content be considered, similar to the binder content of a slurry applied as a slurry seal.

7.4.4 Batch mixing

Batch mixing can be done in a concrete mixer, of either the tilt or non-tilt type. Small quantities may be mixed in a wheel-barrow.

For large quantities where thick layers of slurry are required, i.e. in excess of 3 mm, mechanical equipment and spreader boxes are used. (This does not apply to true Cape Seals.)

The sequence of filling the concrete mixer is:

a) Aggregate is put in first.
b) Active filler is added slowly, care being taken to ensure that no lumps of cement/lime are added. Mixing continues until a uniform mix of aggregate and filler is obtained.
c) Water is added until all the particles have been coated with water - there should be no dry fines in the mix. If this is done efficiently, the risk of balling of the mix is avoided.
d) Lastly, the emulsion is added. It may be prudent to dilute this emulsion before it is introduced to the mixer.
e) If necessary, water is added to obtain the required consistency.

The resultant slurry should be a smooth, creamy, uniform free-flowing mix, free of lumps and balling. There is a simple test which can be carried out to determine the correct consistency[29]. (See APPENDIX G.)

7.4.5 Preparation of Surface

Before the slurry can be applied to an existing road surface, all failures, potholes and crack treatment should be carefully and efficiently attended to. The road surface should be cleaned of all deleterious material and, if necessary, washed and broomed. Edge failures should also be repaired.

Once the road has been cleaned, the surface is dampened slightly just prior to application of the slurry. There should not be any pools of free water in depressions or in minor cracks which have not been sealed.

7.4.6 Tack Coat

Under normal conditions, a tack coat is not required unless the slurry is being applied to an old porous or oxidised surface. If it is decided to apply a tack coat, a diluted emulsion spray consisting of 1 part of emulsion to 3 parts of water may be applied at the rate of ± 0,7 ℓ/m². This may be applied either by hand or by a distributor. The use of a motorised hand-sprayer is very useful, especially where extra emulsion is obviously required in particular areas.

7.4.7 Adjustment of emulsion content due to expansion of moist sand

Ideally, the sand used for the slurry seal should be dry before the required volume of emulsion is mixed in. The volume of sand conforming to the grading specifications as shown in Table 8-5 and Table 8-6, typically expands by up to approximately 5 per cent of its dry volume as the moisture content increases, after which, when saturated, it decreases again to approximately its original dry volume. This phenomenon creates a risk of too much binder being added to the slurry mixture.

A practical method of determining the approximate moisture/volume expansion of sand is as follows:

a) Fill a container of known volume with sand from the stockpile. Dry the sand and determine its volume. Calculate the moisture content and volume expansion.

b) A moisture/volume expansion curve can be derived in a laboratory for a specific sand, by adding water to dried samples and measuring the change in volume.

c) Fill a container of known volume with sand from the stockpile. Saturate the sample with water and determine the reduced volume of sand. Although not necessarily correct, the saturated volume is taken as being similar to the dry volume for calculation of the required amount of emulsion.

Note:

The method of filling the container is not defined and the packing of the moist sand may be different in the slurry machine.

7.4.8 Weather Limitations

Limitations to be observed are:

a) Minimum temperatures and time of opening to traffic

Slurry type	Min. Road Temp.	Opening to traffic
Normal anionic or cationic slurry	7 ℃	Min. 3 hrs . after laying **
Rapid setting slurry	4 ℃	Min. 45 - 60 mins. after laying

Note:

*** Cold weather affects the time taken for the emulsion to break and may cause segregation of aggregate and migration of the emulsion to the surface. Generally speaking, it should be applied during dry periods and, if these periods occur in winter months, the process should cease 3 hours before the late afternoon drop in temperature, (in the case of normal anionic slurries). Quick setting slurries are more accommodating to lower temperatures.*

b) High temperatures

Special measures to reduce the road temperature will be required during hot weather, e.g. a light spray of water could be applied, or work could be carried out in the cool part of the day.

c) Rain

Care should also be exercised when slurry seals are applied when inclement weather conditions are likely, i.e. rain.

7.4.9 Precautions

- The grading selected should be appropriate for the work/problem the slurry is intended to cover.
- If a slurry is too wet it will tend to run off and, if it is too dry, it will be difficult to spread the material uniformly. (Refer to APPENDIX G - Consistency test.)
- The addition of 1 - 2 per cent of filler (cement or lime) should be carefully controlled and monitored. If too little filler is added, problems of segregation and flotation may occur.
- Fine-graded slurries should not be used for thick applications, or coarse-graded slurries for thin applications.
- The source of the water to be added to the mix should always be checked before work commences.
- The moisture/volume expansion should be checked daily so that the emulsion content can be adjusted if necessary.

7.4.10 Rapid setting slurry

Rapid setting slurries are preferable to conventional slurries in the following cases:

- Where the surface is uneven because of bumps, slacks, etc, i.e., where the riding quality is poor or where rut depths exceed 10 mm. The required thickness will influence the choice of maximum aggregate size.
- Where traffic has to be accommodated on the road soon after application. The material should be capable of carrying traffic within 60 minutes of laying.
- Unpredictable weather conditions.

Some design aspects to consider:

The slurry system should be a process whereby a modified bitumen emulsion with rapid-curing characteristics, independent of ambient temperatures required for evaporation of the water phase, is combined with high quality aggregate in a purpose-designed machine to apply a continuous cold mix.

The combined aggregate gradings should comply with the requirements given in Table 8-5 and Table 8-6.

Samples of aggregate should be submitted to the supplier of binder well in advance of the start of operations so as to enable the compatibility of the proposed source to be assessed.

- Marshall Criteria

The modified Marshall test (ASTM D 1559)[27] could be used to determine the optimum binder content. This test should be used with caution as the microsurfacings are 10 mm thick and behave differently from a 63,5 mm thick standard Marshall specimen. However there is a school of thought which believes that a minimum Marshall stability of 7 kN is acceptable. The voids in mix may range from 6,0 - 8,0 per cent.

- Immersion Index

This provides an indication of water sensitivity and stripping (minimum 75 per cent).

- Mineral Filler Content

1 - 2 per cent Portland cement or lime (by mass of dry aggregate) should be incorporated in the mixture.

Notes:

If the dust content (< 0.075 mm) is less than 7 per cent - 1 per cent of filler should be added.

If the dust content is greater than 7 per cent - 1,5 per cent of filler should be added.
Although the ideal dust content range is considered to be between 5 and 12 per cent, successes have been achieved with dust contents of up to 20 per cent.

- Bituminous Binder Content

Ultimately, the accepted bituminous binder content of the microsurfacing which is in accordance with the grading categories and type of application should be decided on after the mix has been designed and approved, following the placing of an acceptable trial section.

7.5 CAPE SEALS

7.5.1 Design

Cape Seal consists of a single seal of 13 mm or 19 mm aggregate, penetrated with a binder and covered with a slurry seal. If 19 mm aggregate is used, the slurry is applied in two layers.

The total quantity of binder required for the 13 mm or 19 mm aggregate is calculated according to the single seal design method using the minimum binder requirement to hold the aggregate.

The binder is split in two applications as follows:

Tack coat: Either a hot binder or bitumen emulsion is used. Hot binder is often preferred as this is normally the most economical.

Penetration coat: A mixture of equal parts of 60% stable grade emulsion and water applied at a rate of 1,0 ℓ/m^2 is recommended.

Notes:
The stable mix grade emulsion used in the slurry seal may also be used for the cover spray. If available, this may be the most desirable.
Compatibility of the water to be used with the emulsion for the cover spray should be checked. Water which is fit for drinking is usually suitable for the dilution of cationic (spray grade and stable mix) and anionic stable mix emulsions. In all cases the water should be added gradually to the emulsion. Anionic spray grade emulsion should never be diluted on site.
Where emulsion is used for the tack coat, it is possible that the calculated spray rate will exceed the maximum permissible spray rate of 1,5 ℓ/m^2 if the cover spray remains at 1,0 ℓ/m^2 using 1 part emulsion to 1 part water. In such cases the first spray should be 1,5 ℓ/m^2 and the rest of the binder should be sprayed in the second spray in the ratio of 2 parts emulsion to 1 part water.
The maximum spray rate should be reduced with steep gradients and smooth surface textures.
In exceptional cases, where diluted emulsion cannot be used for the cover spray, undiluted emulsion may be used.

7.5.2 Selection of Aggregate

The quality of the aggregate should conform to SABS Standard Specifications[31] as given in Chapter 8.

The size of the aggregate will depend on the traffic using the road and on the texture required for appropriate skid resistance. The following is given as a guide:

< 10 000 elv/lane/day	13 mm
> 10 000 elv/lane/day or situations requiring high skid resistance	19 mm

The 19 mm aggregate allows more binder to be applied with less risk of bleeding. It is also more accommodating with high volume turning actions or when used on a natural gravel base course (allowing more penetration of the larger aggregate into the base course).

7.6 SINGLE AND DOUBLE SEALS USING CONVENTIONAL BINDERS

7.6.1 Basic design principles for single and double seals

Most of the seal design methods used in South Africa evolved from Hanson's concept of partially filling the voids in the covering aggregate and that the volume of these voids was controlled by the Average Least Dimension (ALD) of the sealing chips. Through formal and informal experiments and experience, different institutions have refined their methods over a period of 30 years to provide guidance to designers in the design of seals within their areas of jurisdiction.

For various reasons, the recommended application rates for apparently similar situations, calculated according to the different methods, are different. During the compilation of this document, several logical reasons were found for these differences. The main reasons are:

- Most design methods recommend only one application rate for a given situation, whereas theory and practice indicate that a range of application rates could suffice.
- Perceptions of the ideal aggregate matrix differ. The more open the aggregate matrix, the more binder can be accommodated (in case of low flakiness aggregate).
- Perceptions of the ideal texture depth differ, which may be related to the maintenance strategy of the authority, the risk of bleeding and poor skid resistance.
- Climatic differences.
- Different sources of binders.

To a large extent the design method described in this section satisfies the requirements of the major road authorities.

The principles applied are as follows (see also Figure 7-1):

a) The minimum amount of voids to be filled with binder to prevent stone loss when there is no embedment, is 42 per cent for single seals and 55 per cent for double seals.

(Wetting 30 per cent of the aggregate height, as shown in Figure 3-1, requires approximately 42 per cent of the voids to be filled.)

b) The amount of void loss due to traffic wear is dependent on the hardness of the stone and traffic as given in APPENDIX K, Table K-5. For purposes of simplification it is assumed that the hardness is not less than 210 kN (10% FACT).

c) The required texture depth to provide adequate skid resistance is taken as 0,7 mm. However, design charts are available for seals with low ALDs and for texture depths of 0,3 mm and 0,5 mm.

d) The degree of embedment during construction may vary but, for simple design purposes, it is taken as 50 per cent of the embedment with time.

e) The total embedment potential is determined from corrected ball-penetration tests (test method ST4 in TMH6)[12].

f) The effective layer thickness (ELT) of a single seal is a function of the average least dimension (ALD).

g) ELT = 0,85679 x ALD + 0,46715 mm.

h) The effective layer thickness of a double seal is a function of the sum of the ALDs of the two aggregates.

i) (ELT_d) = 0,86028 x (ELT1 + ELT2) + 0,19188 mm.

(The ELT and percentage voids for any aggregate/binder combination may be determined by the modified tray test). (See APPENDIX L.)

j) The percentage void content in the aggregate layer is a function of the ELT.

k) Estimated void content for a single seal (%) = 45,3333 - 0,333 x ELT.

Estimated void content for a double seal (%) = 63,01263 + 0,04743 x ELT_d^2 - 2,41172 x ELT_d.

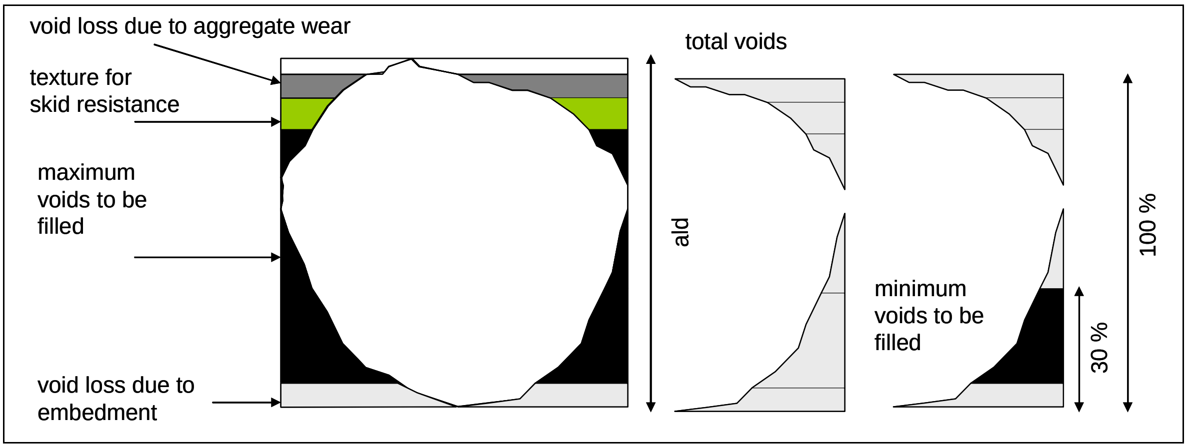


Figure 7-1 Principles applied for design of the binder application rate

7.6.2 Design process for single seals

The following procedure is given as a guideline:

a) Equivalent light vehicles (ELV)

Obtain or determine the most probable traffic scenario for each unique section per lane. (Recent traffic counts should be used.)

Total ELV/lane/day = Number of light vehicles + (Number of heavy vehicles x 40).

b) Potential embedment

Calculate the average corrected penetration from at least ten ball penetration tests (TMH6 - Method ST4)[12] per road section. (Refer to Figure 3-1 for suggested road temperatures, T_0 as described in Method ST4)[12].

Note:

Additional guidelines on interpretation are provided in paragraph 3.3.

c) Minimum and maximum binder application rates

Use the average least dimension (ALD) and the required texture depth, together with the average corrected ball-penetration value and read off the theoretical minimum and maximum residual binder application rates (net cold binder) from the relevant charts in APPENDIX E.

Note:

Aggregate samples should be taken on site and not from stockpiles at the crusher.

One of the major reasons for differences in application rates by various road authorities lies in the required texture depth after the service life. *The design charts (*APPENDIX E*) make provision for texture depths of 0,3 mm, 0,5 mm, 0,7 mm and 1,0 mm where appropriate.*

Use straight line interpolation if the ALD falls between those supplied on the charts.

d) Adjustments (refer to paragraph 7.6.3.3)

Existing texture

- Measure the average texture depth (TMH6 - Method ST1)[12] and use Figure 7-2 to determine the quantity of extra binder required to prevent whip-off on coarse textures.

Climate (See Figure 1-3).

- The design curves are appropriate for moderate climates.
- Subtract up to 10 per cent of the net cold binder for wet or humid areas (Weinert N-value < 2).
- Add up to 10 per cent to the net cold binder for dry areas (Weinert N-value > 5).

Slow-moving and channelised traffic

- Obtain information regarding the typical speed and actions of heavy vehicles for specific uphills, downhills, stopping places, turning places and sections where heavy vehicle speeds are low and reduce binder content with up to 10 percent to prevent bleeding and fattiness.

Note:

Sections where binder application should be reduced relate to the speed of heavy vehicles and not the gradient. Reduction of the binder application rate is normally required when the speed of heavy vehicles reduce to below 40 km/h

Aggregate spread rate

- Decide on the appropriate matrix of aggregate by referring to APPENDIX F and add up to 10 per cent binder for the medium-dense or up to 20 per cent binder for the open "shoulder-to- shoulder" matrices.

Note:

This adjustment is only valid for aggregates with low flakiness indices (guideline < 10%) and only if there is a specific need for these type of aggregate spread.

e) Sensitivity analysis

It is important to note that variations of input parameter values will occur and that different assumptions used in the design process may be valid. It is, therefore recommended that the sensitivity of these parameters to the minimum and maximum application rates be analysed. Extreme scenarios would result from the following:

Minimum:	Highest expected traffic
	Highest ball penetration (Average corrected ball penetration + 1 Standard deviation)
	Smoothest texture (Average texture depth - 1 Standard deviation)
	Lowest design ALD (Average texture depth - 1 Standard deviation)
Maximum:	Lowest expected traffic
	Lowest ball penetration (Average adjusted ball penetration - 1 Standard deviation)
	Coarsest texture (Average texture depth + 1 Standard deviation)
	Highest design ALD (Average texture depth + 1 Standard deviation).

f) Practical minimum and maximum binder application rates

- Select possible binders from Table 5-1 (Chapter 5).
- Convert to hot spray rates of the appropriate binders using Table 7-3.
- Check for practical minimum spray rates (accuracy) = 0,7 ℓ/m^2 (hot).
- Check for practical maximum spray rates to prevent run-off by evaluating the maximum gradient/cross fall combination, texture and binder viscosity (approximately 1,75 ℓ/m^2 for hot conventional binders and 1.5 ℓ/m^2 for emulsions).

Note:

Each type of binder has its own minimum practical spray rate. Cognisance should be taken of this. In the case of polymer-modified binders, it should be borne in mind that the use of minimum spray rates will tend to defeat the object for which the polymer-modified binder was selected in the first place.

g) Final decision and specification of a target spray rate.

It is essential that the contractor be given a specified application rate for each unique road section.

In selecting the target application rate cognisance should be taken of the 5 per cent permissible variation in binder application rates (See COLTO specifications[4]).

The final decision should be supported by documentation stating the input parameters and the rationale for adjustments.

h) Policy and maintenance strategy

Evaluate the policies and strategies of the road authority concerned with regard to maintenance (risk of aggregate loss) and required skid resistance (risk of fattiness) as well as the level of uncertainty with regard to traffic. If there is a high level of uncertainty with regard to traffic and the ability exists to add binder (application of diluted emulsion) when necessary, a strategy can be followed of applying the minimum amount of binder.

i) Select appropriate binder application rates for each unique road section.

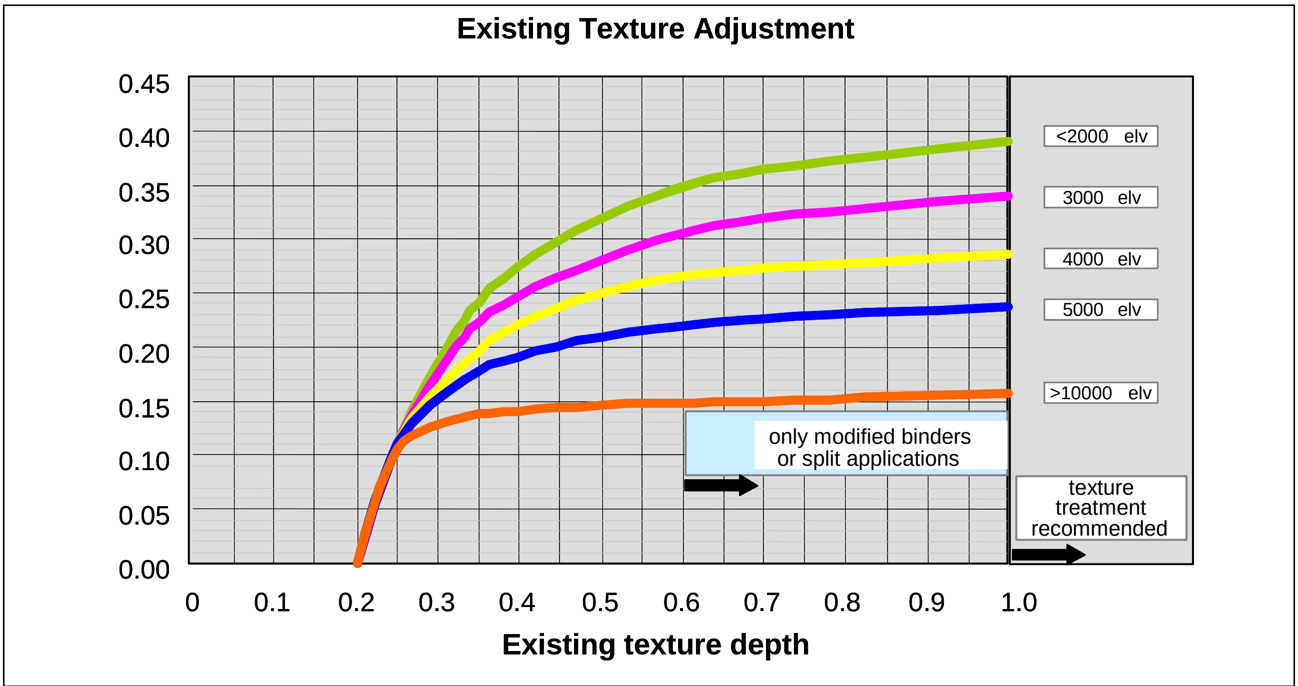


Figure 7-2 Binder adjustment for existing texture

7.6.3 Design process for double seals

7.6.3.1 Application rate

The steps are similar to those taken for the determination of application rates for single seals except for the following:

a) The design ALD of the double seal is calculated as follows:
Design ALD (double seal) = ALD of first layer + ALD of the second layer.

b) Use the relevant charts in APPENDIX E to determine the total binder application rate required for the double seal.

c) Binder distribution

Current practice differs from one road authority to the next with regard to the split in binder between the tack coat and penetration coat. However, it is generally agreed that this split is governed by the minimum application rates required for each layer to prevent whip-off or by the minimum rate that can be sprayed accurately (in the case of a fog spray).

The following guidelines may be used:

- Determine the total net cold binder required for the double seal.
- Subtract half of the binder required for the fog spray e.g. 0,33/2 = 0,17 ℓ/m^2 (if a fogspray will be applied). It is assumed that only half the binder will flow down - the remainder will stick to the top and sides of the aggregate, i.e. will be non-effective in terms of filling the voids.

The minimum quantity of net cold binder required for the penetration coat depends on the aggregate size of the second layer. (Table 7-4 may be used as a guideline.)

If traffic has to be accommodated on the first layer (this is not recommended), it is advisable to design the next layer separately as a second single seal.

The minimum quantity of residual binder required for the tack coat depends on the size of the aggregate used in the first layer. (See Table 7-5.)

The concepts of adjustment and sensitivity analysis of application rates, as used in the single seal design, should also be used in the design of double seal. They are not repeated here.

Concept of risk

Areas are indicated on the design graphs where the use of the curves constitutes a risk. Theoretically, in these areas the application rate is too low to prevent whip-off but is also too high to ensure the required texture depth. Therefore, the probability of the seal having a shorter life than normal is very high.

Table 7-3 - Factors for converting net cold residual binder to hot spray rates and storage and spraying temperatures

Type of binder	Conversion *** factor	Spray temperature (℃)	Max. storage temperature (℃)
Cutback bitumen			
MC 3000	1.19 – 1.27	130 - 155	100
MC 70	1.63 – 1.72	60 - 80	Ambient
MC 30	1.88 – 1.99	45 - 65	Ambient
Penetration grade bitumen			
150/200 pen	1.09	145 - 185	115
80/100 pen	1.09	160 - 200	125
Polymer modified bitumen			
S-E1	1.08	165 - 190	150
S-E2	1.06	165 - 190	150
Bitumen rubber (S-R1)	1.07	195 - 205	-
Bitumen emulsions			
60% emulsion	1.68	60	Ambient
65% emulsion	1.55	60	Ambient
70% emulsion	1.44	70	Ambient

Note:

**** Binders from different sources have different temperature conversion factors. The user should refer to the manufacturer.*

Table 7-4 - Minimum quantity of net cold binder required for penetration coat

Aggregate size in top layer	4,75 mm or less	6,7 mm	9,5 mm
Minimum net binder required	0,3 ℓ/m^2	0,6 ℓ/m^2	0,7 ℓ/m^2

Table 7-5 - Minimum quantity of net cold binder required for tack coat

Aggregate size	9,5 mm	13,2 mm	19,0 mm
No traffic	0,5 ℓ/m^2	0,7 ℓ/m^2	1,0 ℓ/m^2

Notes:

These figures should be adjusted to hot spray rates with a suitable binder type to ensure that a minimum hot spray rate of 0,7 ℓ/m^2 is achieved.

If sufficient binder remains after deduction of the minimum residual binder required for each layer, a decision has to be made as to whether this remainder should be added to the tack coat or to the penetration coat. Guidelines in this regard are based on the shape of the second layer aggregate and are as follows:

Rounded aggregate	-	*Add remainder to penetration coat*
Flaky aggregate	-	*Add remainder to tack coat*
Intermediate	-	*Divide the remainder 50:50 between the tack coat and penetration coat.*

Rule of thumb: *Some experienced seal designers recommend the following split for double seals (percentage of total net binder):*

	Precoated stone	**Non-precoated stone**
Fog spray	*0*	*(0,8 – 1,1 ℓ/m^2) hot diluted emulsion*
Tack coat	*55%*	*50% of remaining net binder*
Penetration coat	*45%*	*50% of remaining net binder*

7.6.3.2 Aggregate spread rate

The optimum binder application rate is highly dependent on the spread rate of the aggregate. In theory, with cubical aggregate, the more closely the particles lie together, the less binder the aggregate can accommodate before flushing will occur. The general belief is that the first layer of single sized aggregate should lie shoulder-to-shoulder. However, the interpretation of "shoulder-to-shoulder" differs between road authorities.

The flakiness of the aggregate also influences the ideal spread rate. Theoretically, the more flaky the aggregate, the less aggregate is required per unit area to obtain a "shoulder-to-shoulder" mosaic. However, if the flaky aggregate is allowed to lie flat, there will be less voids available to accommodate the binder. Therefore, in order to obtain sufficient voids and texture in the seal, some authorities believe in increasing the aggregate spread rate as the Flakiness Index values increase.

The spread rates in Figure F-1 of APPENDIX F are based on a Flakiness Index of 15 per cent. The recommended spread rates for lower and higher Flakiness Indices vary by between 2 and 4 per cent for each 5 per cent difference in the Flakiness Index value. The higher the Flakiness Index, the higher the recommended spread rate.

Notes:

Aggregate spread rates are expressed in m^2/m^3. Lower values therefore imply greater aggregate volumes per unit area.

The ideal spread rate will depend on the specific aggregate and should finally be determined on site by spreading the aggregate to obtain the required matrix and by measuring the bulk volume used to cover a specific area.

7.6.3.3 Adjustments

Adjustment for existing surface texture

Additional binder is required on coarse-textured surfaces to ensure that there is sufficient tack coat on the aggregates in new seals to prevent whip-off. However, very coarse-textured surfaces should be pre-treated as described in Chapter 6 before single seals can be constructed with success.

Figure 7-2 may be used as a guideline to adjust the net cold binder based on the texture depth of the existing surface.

Notes:

Adjustment of binder content because of surface texture is only applicable to hard surfaces (surfaces with a corrected ball penetration of 3 mm or less).

In cases of texture depths of >0,63 mm, a texture treatment is recommended when conventional binders are used with single pre-coated aggregate seals.

If a modified binder is used, the maximum texture depth may be increased to 1 mm. (This is based on experience with improved adhesion and higher possible application rates)

If the binder is applied in two applications, (tack coat and penetration coat), e.g. double seals or single seals with a fog spray, the maximum allowable existing texture depth may be increased to 1 mm.

Establish whether upward adjustment is indeed required by spreading the seal aggregate on the existing surface. Should the new aggregate fit into the old seal e.g. new 6,7 mm on existing coarse 13,2 mm seal or 9,5 mm on existing 19,0 mm Cape seal, no adjustment is required.

Adjustment for climate

Experience in the northern parts of South Africa indicates that seals in similar situations and with similar application rates in different climates will perform differently. For example, seals in the north-western parts tend to become dry and brittle whilst seals in the hot humid areas of Mpumalanga Province tend to become fatty. As stated in Chapter 1, South Africa is divided into three zones, namely dry, intermediate and humid. The climatic factors influencing the performance seem to be closely related to temperature and humidity and coincide with areas defined by certain Weinert N-values[8].

$$N = 12Ej/Pa$$

where Ej is the calculated evaporation during January and
Pa is the total annual precipitation

When using conventional binders, the minimum application rates determined in paragraphs 7.6.2 and 7.6.3 may be reduced by up to 10 per cent in areas with N-values of less than 2 and increased by up to 10 per cent in areas with N-values greater than 5. (Refer to Figure 1-3.)

Notes:

Experience indicates that this adjustment is not applicable to modified binders.

Adjustments for steep gradients and slow speeds.

Steep gradients (typically climbing lanes) tend to become fatty. This is probably because of slower heavy vehicle speeds and the effect of higher traction of the vehicle tyres. Downward adjustments, up to 10 percent should be considered based on heavy vehicle speeds, volume and channelised trafficking due to limited lane widths.

The movements and speeds of heavy vehicles should be determined on site. In rolling terrain, vehicle speeds are usually still high at the bottom of steep grades due to the momentum gained on the downhill, and are usually low past the crest. Reduction is typically required on sections with heavy vehicle speeds of 40 km/h or less.

Notes:

Downward binder adjustment might also be required on downhills as a result of braking actions.

In urban environments where frequent stops occur, heavy vehicles tend to stay in the lower gears. In these situations binder application rates should be reduced by 5 to 10 per cent.

It should be borne in mind that asphalt surfacings are more suitable than seals in areas with severe turning actions, acceleration and deceleration. (Refer to Chapter 1.)

Adjustments for aggregate spread rate

A more open "shoulder-to-shoulder" matrix, as recommended by the Provincial Administration of the Western Cape, can theoretically accommodate up to 30 per cent more binder in a single seal than the dense matrix recommended by the Gautrans Department of Transport, provided that the aggregate has a low flakiness index. (Refer to APPENDIX F).

The appropriate aggregate matrix must be decided upon. In this regard Figures F-3 to F-4 (APPENDIX F) can be used as a guide.

Although the binder application rate may be increased by up to 10 per cent for the "medium dense" and by up to 20 per cent for the open "shoulder to shoulder" matrices, the flakiness of the aggregate, the use of steel wheeled rollers for initial rolling and the viscosity of the binder at application temperature may reduce the need for additional binder quantities.

Notes:

This adjustment only applies to single seals and only if very low flakiness aggregate is used (<10%)

Over chipping or even dense chipping prevents orientation of the aggregate to its ALD and would require more binder than a dense shoulder-to-shoulder matrix (after rolling) to prevent whip-of

On highly trafficked roads, the final recommended binder application rate and stone spread rate should only be established on site after construction of a trial section.

Adjustments for porous surfaces

Porous or dry surfacings tend to absorb binder, often resulting in loss of aggregate from the new seal. Depending on the type of binder used and other factors, this absorption may occur over a period of time. Increasing the application rate for the reseal may result in excess binder and bleeding. It is therefore recommended that porous and dry surfacings be treated with diluted emulsion prior to sealing and that no adjustments be made for loss in binder on account of porosity. (Refer to Chapter 6).

Adjustments for fatty surfaces
Although there is a tendency to reduce binder application rates on fatty surfaces, it is believed that the corrected ball penetration value already makes provision for this phenomenon. High ball penetration values would indicate that larger aggregate should be used.

Notes:
Areas with excess binder should rather be pre-treated as describe in paragraph 6.4.2

Adjustment for no traffic
Newly constructed roads are often not trafficked for some time after construction. The recommended practice in such cases is to evaluate the situation just before the road is opened to traffic by driving over the section and observing any loss of aggregate. Application of a diluted emulsion spray will assist in preventing loss of aggregate.

Notes:
Care should be taken to differentiate between excess aggregate (over-application) and true aggregate loss.
Seals on surfaced shoulders should be designed as separate lanes, in which factors such as potential traffic, gradients and whether the shoulders are used as climbing lanes, are taken into consideration.
As areas on the outside of curves usually carry less traffic than those on the inside, the application rates may be adjusted upward to prevent loss of aggregate.

Adjustment for cold micro areas
Shady or cold areas (under/on bridges or next to trees) are prone to aggregate loss. Current practices to reduce the risk of aggregate loss in these areas are:

- Sensitive areas are constructed separately, close attention being paid to temperatures, application rates and immediate extra rolling.
- Application of emulsion fogspray and sand blinding.
- Selection of different binder. Penetration grade binders are not recommended unless they are cut back or modified.
- Increase of binder application rates by between 15 to 30 per cent.
- Tight traffic control.

Notes:
In cases where emulsion is used, sufficient time should be allowed before these areas are opened to traffic.

Adjustment for porous seal aggregates
Aggregate which meets the requirements of TRH14[32] usually has low binder absorption properties. Where absorptive aggregate is used (water absorption greater than 2 per cent), it is recommended that the aggregated be precoated rather than that the binder application rate be increased.

Adjustment for construction traffic
A particularly severe condition is encountered when a newly laid surfacing seal is trafficked by heavily loaded trucks engaged in the construction of other parts of the road. This situation should be avoided if possible. However, if construction traffic cannot be kept off the new surfacing, the expected traffic should be incorporated in the calculation of the design traffic.

Adjustment for stone and sand seal combinations

Single seals are often blinded with a coarse sand or "grit" to prevent initial aggregate loss. Experience indicates that the total binder content, calculated for the single seal, may be increased by between 20 and 40 per cent. The penetration coat usually consists of an emulsion or diluted emulsion.

7.7 SINGLE AND DOUBLE SEALS USING MODIFIED BINDERS

7.7.1 Introduction

Experience with modified binder single seals over twenty years has shown that considerably higher binder application rates can be tolerated in modified binder seals than in seals with conventional bituminous binders.

The previous version of the TRH3 (1998) suggested an approach towards the design of modified binder application rates, assuming less embedment of aggregate and an increase in voids due to less orientation of the aggregate. Based on specific studies, the ring and ball softening point and equivalent traffic volumes were used to quantify the increase in binder application rate. The results compared well with appropriate application rates determined from field experiments and ten years experience using 13,2mm and 9,5mm aggregates and mainly non-homogenous binders.

Where the non-homogenous modified binders were favoured from 1985 to 1995, the use of homogenous modified binders has increased dramatically over the past decade. Experience gained through design, application and performance monitoring resulted in the following important conclusions regarding the TRH3 (1998) modified binder designs namely:

- Design application rates for non-homogenous modified binder single seals are still appropriate.
- Design application rates for homogenous modified binder single seals are too low (in the order of 10 - 15%).
- Design application rates for homogenous modified binder double seals are too high (in the order of 10 %).

Due to insufficient experience at that stage, no guidelines were provided regarding the design of seals making use of a combination of conventional and modified binders.

The purpose of this section is to address the mentioned shortcomings and to ensure more appropriate designs.

7.7.1.1 Single seals with modified binders

The majority of practitioners in South Africa are of the opinion that the appropriate application rate for a particular modified binder is a function of the appropriate conventional binder application rate and specific properties of the selected modified binder.

In addition to all factors incorporated in the conventional design application rate, experience in various parts of the country indicates that the shape of the aggregate, the spread rate, rolling type and effort as well as temperatures within a few days after construction could drastically impact on the initial performance of modified binder seals.

It is acknowledged that much research work is still required to perfect the theory of application rate design, taking into account all factors influencing initial and long term performance.

Therefore, the decision has been made, for purposes of this version of TRH3, to document best practice from experience without substantiating the methodology in terms of current theory.

In order to utilise the rational application rate design curves for conventional binders a single function is applied to increase the calculated application rates for each of the hot homogenous and non-homogenous modified binders. These functions are based on experience and opinions of a panel of current practitioners.

7.7.1.2 Conversion factors for hot modified binders

a) Non-homogenous modified binder (Bitumen Rubber)

Typical conversions from net cold conventional binder to net cold non-homogenous modified binder vary from 1.4 to 2.0 with a typical value applicable to 8,0 mm ALD aggregate of between 1.5 and 1.9 times the application rate appropriate for a conventional binder. Some practitioners hold the opinion that the lower conversion factor should apply for high heavy vehicle volumes.

This relates to approximately 1.65 and 2.1 times the minimum net cold conventional binder to obtain the appropriate hot application rate for Bitumen Rubber (Non-homogenous binder).

The absolute minimum practical application rate is 1.8 ℓ/m^2 for the summer grade products and 1.6 ℓ/m^2 for winter grade products (Suppliers generally recommend a minimum of 2.0 ℓ/m^2)

Although non-homogenous binders have been applied at rates of more than 5 ℓ/m^2 for 13.2 mm seals, the general consensus is than a 3.2 ℓ/m^2 maximum hot application rate is sufficient, even for 19.0 mm seals to perform well.

Notes:

Due to the sensitivity of fattiness during the first hot season, the use of winter grade products are not recommended by several road authorities.

Due to the minimum application rate of 1.8 ℓ/m^2, small aggregate e.g. 6,7 mm cannot be applied in a single layer without bleeding. The smallest aggregate recommended is 9.5 mm.

Aggregate used with non-homogenous modified binders are normally precoated to improve adhesion.

Based on the experience of practitioners and in order to utilise the rational design procedure for single seals with conventional binders the following procedure is recommended:

- Calculate the minimum net cold application rate for a conventional binder
- Adjust the application rate by multiplying the net cold conventional application rate by the relevant adjustment factor in Table 7-8
- Convert to hot application rate (Typical adjustment = 1.07 x net cold binder)
- Allow for allowable tolerance (i.e. add 5% to minimum application rate)
- Limit the maximum application rate to 3.2 ℓ/m^2, regardless of traffic volumes

Should the calculated rate be less than the minimum practical application rate either:

- Adjust to the minimum application rate (1.8 – 2.0 ℓ/m^2) dependent on supplier, but take into account the risk of bleeding or that the surfacing life might be reduced due to insufficient texture depth, or
- Specify a larger aggregate size that would result in application rates higher than the practical minimum

b) Homogenous hot modified binders (Polymer modified)

Initial experiments with 13.2 mm single seals in the Northern parts of South Africa applying polymer modified binders at application rates between 1.2 ℓ/m^2 and 1.8 ℓ/m^2 indicated a low sensitivity to variation. The best results on medium to fine textured roads were obtained with application rates varying between 1.4 ℓ/m^2 and 1.6 ℓ/m^2.

Since then numerous roads have been resealed using both SBR and SBS polymer modified binders, mainly with precoated aggregate. Feedback from practitioners indicated that the application rates as calculated through the suggested process in TRH3 (1998) are too low, resulting in several cases of early aggregate loss.

Through back calculation of documented guidelines and rationalization of several opinions, conversion factors from conventional to homogenous modified binder of between 1.1 and 1.4 as recommended in Table 7-6 and Table 7-7 provided more appropriate design application rates.

The simplified process of calculating the design application rate for a modified binder single seal is as follows:

- Calculate the minimum net cold application rate for a conventional binder
- Adjust the application rate by multiplying the net cold conventional application rate by the relevant adjustment factor in Table 7-6 or Table 7-7
- Convert to hot application rate (Typical adjustment = 1.08 x net cold binder)
- Allow for tolerance (i.e. add 5% to minimum application rate)
- Limit the maximum application rate to 2.6 ℓ/m^2
- Should the calculated hot application rate for a 13,2 mm single seal be less than 1.3 ℓ/m^2 adjust to 1.3 ℓ/m^2

Note:

Application rates obtained through the multiplication factor are applicable only if the rational design method is applied.

Table 7-6 Adjustment for S-E1 binder application

S-E1 ADJUSTMENT (Conventional to modified binder)			
Traffic (ELV)	Single seal	Double Seal	Split application double seal
< 5000	1.3	1.1	1.2
5000 - 20000	1.2	1.0	1.1
> 20000	1.1	1.0	1.0

Table 7-7 Adjustment for S-E2 binder application

S-E2 ADJUSTMENT (Conventional to modified binder)			
Traffic (ELV)	Single seal	Double Seal	Split application

			double seal
< 5000	1.4	1.2	1.3
5000 - 20000	1.3	1.1	1.2
> 20000	1.2	1.0	1.1

Table 7-8 Adjustment for S-R1 binder application

S-R1 ADJUSTMENT (Conventional to modified binder)			
Traffic (ELV)	Single seal	Double Seal	Split application double seal
< 5000	2.0	1.8	-
5000 - 20000	1.9	1.7	-
> 20000	1.8	1.6	-

7.7.2 Modified binder double seals

Following the publication of TRH3 (1998) several modified binder double seals have been constructed. Results and feedback from practitioners indicate that the application rates as calculated using the 1998 version are too high resulting in bleeding and fattiness on the higher trafficked roads.

Current opinions are that the design charts used for conventional double seals are suitable for determining the appropriate application rates for modified binder double seals and that very little further adjustment is required.

The only difference from the current conventional binder design practice is that the design ALD for the modified binder double seal is taken as the sum of the ALDs of the two aggregate sizes.

Note:

Current practice applied by various practitioners with the design of the conventional binder double seals is to:-

- *add half of the top layer ALD to the bottom layer ALD to obtain the design ALD for the typical 1 ½ seal*
- *add the ALDs of both aggregates to obtain the design ALD for the typical double seal (refer Figure 7-1).*

7.8 COMBINATION BINDER DOUBLE SEALS

7.8.1 Background

Various approaches have been applied with the design of seals using more than one type of binder. The most common procedure applied is to design the double seal as two individual single seals ignoring the increase in binder required for the second layer as a result of the texture created by the first layer.

Notes:

Although good performance has been observed on low volume roads, the application rates calculated are considered too high for highly trafficked roads.

The results obtained for application of inverted seals e.g. 6,7mm + 13,2 mm are too low.

7.8.2 Recommended approach

Recent experience suggests that the total binder calculated for the conventional binder double seal is appropriate with slight adjustments for homogenous modified and combination binder seals (Conventional binder and homogenous modified binders).

The design process is summarised as follows:

- Add the ALDs of the two aggregate layers
- Determine the appropriate total binder application rate (conventional double seals)
- Distribute the net cold binder between the tack coat, penetration coat and, if required, half of the fog spray
- Apply a single factor adjustment when homogeneous modified binders are used (Refer to Table 7-6 and Table 7-7)

The minimum recommended hot application rates for each coat is as follows:

Table 7-9 - Minimum recommended application rates

Aggregate size	Binder	Coat	Minimum hot application (ℓ/m^2)
19,0mm	Polymer modified	Tack	1,1
13,2 mm	Polymer modified	Tack	1,0
9,5 mm	Polymer modified	Tack	0,9
9,5 mm	Polymer modified	Penetration	0,8
9,5 mm	Conventional	Penetration	0,8
6,7 mm	Polymer modified	Penetration	0,8
6,7 mm	Conventional	Penetration	0,7
4.75 mm	Conventional	Penetration	0,7
Fog spray	Conventional	Fog spray	0,8

Note:

The first layer of aggregate is normally precoated. A diluted (30% or 40%) conventional 65% Cationic Spray grade emulsion is recommended as a fog spray.

7.8.3 19 + Double 6,7 Seal

This seal, consisting of a closely knitted 19,0 mm layer and two 6,7 mm layers has become popular as a reseal measure on relatively high volume roads e.g. 5000 – 40000 ELVs.

The first 6,7 mm aggregate layer is either applied as a dry layer or adhered to the 19,0 mm aggregate with a light binder application e.g. 0,8 ℓ/m^2 Cationic spray grade emulsion.

Note:

Current practice suggests that the surface is rolled with a five to eight ton steel wheel roller after application of the first 6,7 mm aggregate.

Typical designs for three traffic scenarios are provided in Table 7-10. Corrected ball penetration = 1,5 mm and existing texture depth adjustment = +0.2 ℓ/m^2 .

Table 7-10 - Typical designs for the 19.0 + double 6,7 mm seal

	Dry method			Wet method		
ELV	5000	10000	20000	5000	10000	20000
SE-2 tack coat	1,4 hot	1,3 hot	1,1 hot	1,4 hot	1,3 hot	1,1 hot
19,0 mm	70 m^2/m^3	70 m^2/m^3	70 m^2/m^3	70 m^2/m^3	70 m^2/m^3	70 m^2/m^3
Cat 65% penetration cost				1.1 hot	1.1 hot	1.0 hot
6,7 mm choke	300 m^2/m^3	300 m^2/m^3	300 m^2/m^3	250 m^2/m^3	250 m^2/m^3	250 m^2/m^3
SE-2 penetration coat	1,1 hot	1,1 hot	1,0 hot	1,0 hot	1,0 hot	1,0 hot
6,7 mm	155 m^2/m^3	155 m^2/m^3	155 m^2/m^3	155 m^2/m^3	155 m^2/m^3	155 m^2/m^3
Fog Spray (50/50 Cat 65%)	1,1 hot	1.0 hot	1.0 hot			
Total net binder	2.45	2.35	2.1	2.45	2.35	2.1

Notes:

The "Wet Method" refers to the process whereby the first 6.7 mm aggregate is applied after a slight application of binder.

The total net cold binder rates suggested relate well to the calculated values using the rational design method for double conventional binder seals with total ALD (16 – 18 mm).

The ideal aggregate spread rates of the 6,7 mm layers are dependent on the shape, spread rate and rolling strategy on the 19,0mm layer.

The first (dry layer) spread rate typically varies between 220 and 350 m^2/m^3 while the second (final) layer spread rate varies between 150 and 170 m^2/m^3.

Care should be taken NOT to over-apply the dry layer aggregate as this will result in insufficient binder to hold the final layer of 6,7mm aggregate.

7.8.4 Non-homogenous modified binder seals

Double seals with non-homogenous binders as well as non-homogenous binder in combination with homogenous binders have been constructed with success. At time of this publication, no formal guidelines were available, mainly due to differences in the properties of available non-homogenous binders.

Notes:

Several 19,0 + 9,5 mm double seals have been constructed with success using non-homogenous modified binders as well as combinations of non-homogenous and homogenous modified binders. The non-homogenous binder is normally applied as the tack coat.

The typical recommended application rate of the tack coat varies between 2.3 and 2.6 ℓ/m^2 and compares well with a single seal design for the relevant ALD and traffic situation.

The appropriate application rate of the penetration coat is highly dependent on the size, shape spread rate and rolling strategy of the 9,5 mm aggregate. Good performing seals have been constructed with:

large cubical 9,5 mm aggregate (ALD = 7 mm) applying a penetration coat of non-homogenous modified binder at 2.5 ℓ/m^2 using only pneumatic rollers on both layers *smaller and more flaky 9,5 mm aggregate (ALD = 5.5 mm) applying a penetration coat of non-homogenous modified binder at 1.8 ℓ/m² using a steel wheel roller for the initial roll on the 19,0mm aggregate followed by pneumatic rollers*

Appropriate homogeneous modified binder penetration coat application rates for this double seal type vary between 1.0 and 1.5 l ℓ/m², dependent on how well the smaller aggregate fits into the available texture/voids.

7.9 DILUTED EMULSIONS/ FOG SPRAYS

7.9.1 Application

Diluted emulsions are typically used for the following purposes:

- Cover spray on newly constructed single or double seals.
- Prevent/stop/ reduce aggregate loss on a newly constructed seal.
- Enrichment of dry/porous surfacings, often as a pre-treatment before resurfacing operations
- Finishing of natural gravel base layer on low volume roads prior to surfacing as discussed in paragraphs 6.3 and 7.3.

7.9.2 Cover spray on newly constructed single or double seals

On new construction double seals, the fog spray is usually applied one day after the application of the second layer of aggregate. Excess aggregate should be broomed off before application of the fog spray.

Wetting of the surface before application of the binder improves the penetration of the emulsion. However, care should be taken that ponding of the water does not take place during this wetting process.

Application rates are in the order of 0,8 - 1,0 ℓ/m² of a 50:50 emulsion/water mix. Some practitioners believe that half of the nett cold binder applied here should be subtracted from the total binder content of the seal before the distribution between the tack coat and penetration coat is calculated. This is because approximately half the total binder does not penetrate into the interstices between the chips and is not part of the effective binder content, but remains as a coating on the surface.

A split application of binder in single seals is common in certain parts of South Africa, especially when using emulsions.

7.9.3 Prevent/stop/ reduce aggregate loss on a newly constructed seal

Aggregate loss sometimes occurs soon after construction due to various reasons such as:

- Too low application rates
- Faulty binder
- Cold temperatures
- Excessive delay in application of aggregate (especially Modified Binders)

One of the most cost-effective ways to prevent stripping could be to add a final application of binder to the seal in the form of a diluted emulsion.

Due to the fairly coarse texture of the new seal and the need to create a bond between the aggregate as shown in Figure 7-3, a rapid setting emulsion is considered appropriate for this situation.

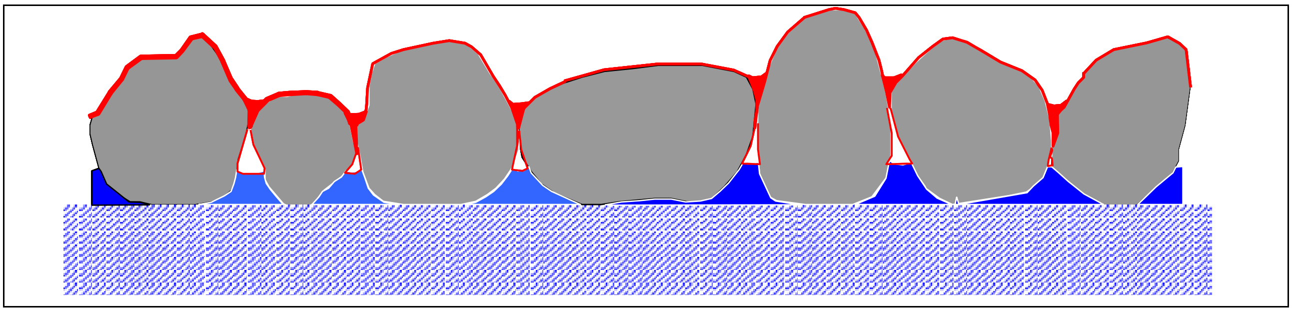


Figure 7-3 Bond created between aggregate particles with rapid setting emulsions

Recent experience favours the application of fog sprays on precoated modified binder seals when sealing close to winter.

7.9.4 Enrichment sprays on dry/porous surfacings

The life of a seal and of certain asphalt surfacings can be extended by the application of diluted emulsion. The number of possible applications during the life of the seal is dependent on the required texture depth and on the voids within the seal but could be applied up to three times during the life of a single 13,2 mm seal, each time extending the effective life of the seal with up to three years.

The general opinion with enrichment sprays is to get as much as possible new binder as deep into the existing seal as possible. Experience indicates that diluted emulsion applications:

- rejuvenate the existing binder;
- drastically reduced permeability of the existing surfacing;
- improve the performance of follow-up resurfacings (slurry seals and stone seals)

With reference to the above, the appropriate type of binder would be a low viscosity stable binder that could flow around the existing particles, penetrate and fill up from the bottom. Refer to Figure 7-4.

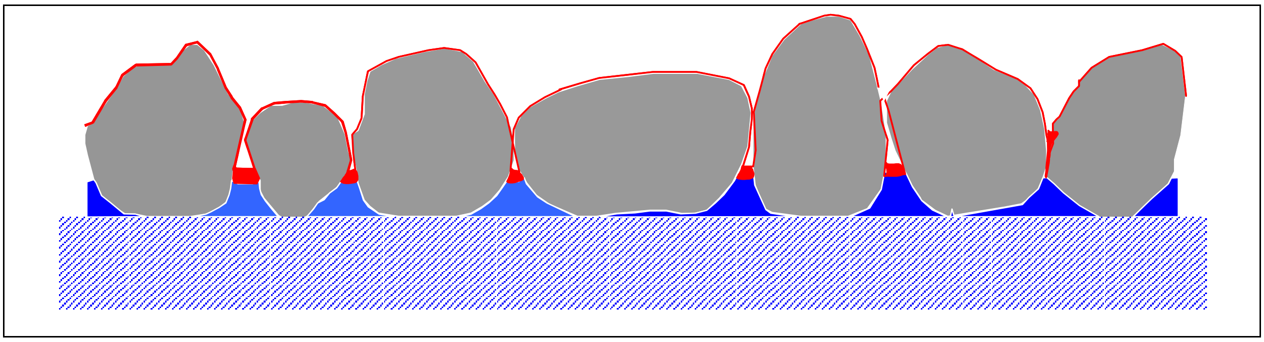


Figure 7-4 Penetration of low viscosity stable emulsions

There is no formal design procedure to determine the required application rate or water/emulsion ratio. However, the following procedure can be used/applied to ensure good results.

- Dilute a 60 per cent emulsion with an equal amount of water (i.e. to make a 30 per cent emulsion) and apply on a 500 m section at 0,8 to 1,0 ℓ/m^2.

- Observe to what extent penetration of the mix takes place and adjust the application rates, and if necessary, the mix ratio (minimum 25 per cent net binder). Maximum application rates depend on the geometry of the road.
- After the emulsion has broken (but only if penetration has taken place) another application can be sprayed the following day.

7.9.5 Finishing of natural gravel base layers

The use of diluted emulsion to improve the surface of granular base layers before sealing is described in Chapter 6.

7.9.6 Materials

7.9.6.1 Emulsion

The following grades of bitumen emulsion are available and can be diluted with water for use as fogsprays:

- Anionic or Cationic Stablemix 60%
- Unfluxed Cationic Spray 60, 65 or 70%
- Unfluxed Cationic Spray 65 or 70% modified with SBR latex
- Latex modified cationic microsurfacing emulsion

The decision on which type of emulsion to use will depend largely on the most desirable flow characteristic of the emulsion which is most critical to the application of the enrichment spray, namely the low viscosity characteristics of stablemix for maximum penetration into surface voids versus the quick breaking action of spray grades.

Care should be taken when latex-modified emulsions are diluted. These products should preferably be diluted by the manufacturer.

Products marketed in South Africa as “rejuvenators” are inverted emulsions manufactured from a binder containing bitumen, aromatic oil and a cutback medium. These products are specifically designed as surface enrichment or rejuvenating agents. Once sprayed, it penetrates into dried and aged bituminous surfaces, and rejuvenates the binder, thus extending the time required before resurfacing.

7.9.6.2 Water

Water used to dilute emulsion on site should be fit for drinking and should be added gradually to the emulsion. Clear water with pH = 7 should not yield problems.

If premature breaking or scum is observed, the manufacturer of the emulsion should be consulted.

7.9.7 Selection of appropriate product

Factors influencing the selection are:

- Purpose
- Add binder and additional bond to prevent stripping
- Add binder and rejuvenate existing surfacing
- Only rejuvenate existing binder

- Presence of sufficient voids and or texture to accommodate the additional binder
- Geometry of the road increasing the risk of "runoff"
- Weather conditions influencing the breaking time of emulsions
- Traffic accommodation
- Transport distance
- Presence of cutters

Cationic spray grades will tend to break quicker than anionic and cationic stable mix emulsions, which are more stable. Thus with spray grade emulsions the binder will tend to be deposited on top of the stone chips whereas stable mix emulsions will tend to flow into the voids more easily. Cationic grade emulsions will render improved binder/aggregate adhesion due to the chemical reaction, which takes place between the positively charged bitumen droplets in the emulsion (and latex if used) and the free negatively charged ions of the aggregate. A light water spray is often applied in advance to reduce surface tension and/or to cool down the road surface.

Several examples exist where diluted emulsions have been applied with success on slurry seals and asphalt mixes. However, this practice could result in pickup, damage to vehicles and poor skid resistance.

The prevailing weather conditions will affect the 'breaking' of a diluted emulsion. In the case of colder weather and in shaded areas, the lower temperature retards the breaking action of the emulsion. In the latter instances quicker breaking Cationic spray grades should be used.

During hot weather, latex modified emulsion will tend to form a skin which could create a false perception that the emulsion has broken. When this phenomenon occurs, total breaking of the emulsion can be delayed for several hours. The emulsion must be checked by scratching with a knife to ensure that it is uniformly black under the skin.

In hot weather, the residual binder film tends to become tacky resulting in pick up on the tyres. When the expected road surface temperature is above 50 °C then a higher softening point binder such as 60/70 penetration base bitumen must be considered. As a general guideline the following closure times should be allowed after spraying, based on prevailing weather conditions:

- Hot, windy day: 2 hours
- Overcast, cool day: 4 hours

There are some time and drying constraints to be considered when selecting candidate pavements for treatment with inverted emulsion rejuvenators, particularly in cool climates.

These "rejuvenators" are ideal for hot, dry climates. In cool climates, the drying time will be extended, and traffic control on roads could be a problem, although it will be less of a problem on areas such as airport secondary runways. When applied on coarse surfaces such as chip seals, traffic can be allowed onto the surface within 4 hours, whilst the drying/penetration time on dense asphalt surfaces could be up to 36 hours.

This limits the application to roads that:

- can be closed for a period
- roads with several lanes, of which one can be closed

- where the traffic can be diverted
- airport pavements
- very light traffic, 2 lane roads, where single lane operation can be put in place for several kilometres. In practice this might mean executing the work over a weekend.

The presence of cutter in emulsion is not desirable when used as an enrichment spray, as the residual binder tends to remain tacky after breaking. It must also be noted that all standard spray grades of emulsion are formulated with between 2% to a maximum of 5% cutter to improve the cohesion development of the residual binder when applied in stone seals. It is therefore important that the binder supplier be requested to omit the cutter in the emulsion formulation, when ordering spray grade emulsions for fogspraying purposes.

The bitumen emulsion is normally diluted in a 1:1 ratio with water. This ratio can be varied to overcome certain constraints. However the lowest recommended binder content is 25% m/m of the diluted emulsion. Diluting the emulsion further will weaken the electrochemical charges thus rendering the end product unstable causing “Foaming”.

In the event of steep grades and/or cambers it is recommended that a spray grade be used with a lower dilution of 70:30 to prevent runoff.

If the emulsion has to be transported long distances from the source then consideration must be given to using a higher binder content emulsion such as a cationic spray grade 70 and to rather dilute on-site to reduce the effective transport costs.

7.10 SEALS NOT COMMONLY USED IN SOUTH AFRICA

7.10.1 Choked seals

A choked seal can be described as an open single seal, choked with a smaller aggregate, without the application of a binder penetration coat (refer to Figure 1-2). Several roads have been successfully resealed with choked seals consisting of 13,2 mm and 6,7 mm aggregate.

The 13,2 mm aggregate should be placed open and not shoulder-to-shoulder in order to leave room for the 6,7 aggregate.

The quantity of binder is calculated by normal methods, using the ALD of the 13,2 mm aggregate and adjusting the quantity for the percentage of 6,7 mm aggregate that is anticipated to be used.

It is suggested that a sample be made up of the ideal mix required by placing the 13,2 mm stone in a pan, opening up the 13,2 mm stone sufficiently to enable the 6,7 mm stone to be applied.

- The ALD of the mixture can then be determined.
- The sample may be screened and the application rates of the two aggregates determined.
- The application rates may be compared with those obtained in the field by adjusting the gates of the chip spreader for a dry run.

From observations, the following comments might be of value:

- If binder is under-sprayed, loss of 6,7 mm aggregate will be excessive.

- The judgement of opening up the 13,2 mm aggregate in the field to accommodate the 6,7 mm aggregate is arbitrary and may either cause loss of 6,7 mm aggregate or flushing.
- It is alleged that the noise level of a choked seal is lower than that of a single seal.
- It is very difficult to place a double seal on a single lane road under traffic without deviations. It is also very difficult to place a double seal under heavy traffic using penetration grade binders, as the quantity of binder to be sprayed is low and the risk of bleeding is greater than if a bitumen emulsion were used. However, if an emulsion is used, the time element for the emulsion to break comes into play.

Modified binders may be used if there are little or no volatiles in the binder.

7.1.1. Split seals

A split seal is defined as a double seal in which the top layer of aggregate is split into two applications (refer to Figure 1-2). The first application of the top layer is usually done without a penetration coat.

Because of problems regarding the availability of 13,2 mm aggregate, 19,0 mm + 6,7 mm double seals were constructed on several roads, but these resulted in fairly coarse-textured surfaces. By splitting the 6,7 mm layer (and increasing the total aggregate spread rate), a fairly smooth surface was obtained, with a texture similar to that of a 6,7 mm single seal. Refer to par. 7.8.3.

7.1.2. Geotextile seals

7.1.2.1. General

Geotextile seals are defined as bituminous surfacings consisting of a bitumen saturated geotextile and a conventional seal (Refer to Figure 1-2).

A geotextile is adhered to the existing surfacing by spraying a bituminous binder tack coat and rolling with a pneumatic roller. Dependent on the application rate of the tack coat and the preference of the engineer, a conventional seal could be constructed directly on the geotextile, adding additional binder to compensate for absorption into the geotextile. Alternatively, a saturation coat could be sprayed onto the geotextile and covered with small aggregate e.g. crusher dust before the conventional seal is constructed.

Experience in South Africa consists mainly of seals constructed on polyester, non-woven fabric (140g/m^2).

Although some experiments are documented[33], sufficient information regarding the long term performance on the full traffic spectrum does not exist. Therefore, information provided should only be considered as guidelines for good practice.

7.1.2.2. Design guidelines

Experience indicates that the required total application is a function of the construction procedure. Lower total application rates could suffice if the seal is constructed in stages allowing traffic compression of the saturated geotextile before application of a large aggregate seal.

a) Geotextile tack coat

- The purpose of a tack coat is to properly adhere the geotextile to the existing surfacing.
- A variety of binders have been used worldwide with hot application rates varying from 0.6 ℓ/m^2 to 1.2 ℓ/m^2. This relates to approximately 0.5 – 1.1 ℓ/m^2 residual bitumen.

- The ideal application rate is dependent on the texture and permeability of the existing surface, the viscosity of the binder used for the tack coat, the grade of geotextile used and the traffic. The ideal tack coat application rate is considered one where the geotextile would be saturated, without being tacky, after rolling with a heavy pneumatic roller and 6 - 8 weeks trafficking.
- Based on experience the following application rates are suggested
- High traffic (ELV > 15000) and fine existing texture 0.5 ℓ/m^2 residual bitumen
- Low traffic (ELV < 5000) and coarse existing texture 1.1 ℓ/m^2 residual bitumen
- Any binder could be used provided there is sufficient time for volatiles to evaporate before application of the stone seal and the application temperature is below the recommended temperature provided by the geotextile supplier. A SBR polymer modified emulsion (SE-1) is preferred by several practitioners

b) Saturation coat

Trafficking the road for 6 - 8 weeks would show whether there is a need for additional binder to saturate the geotextile. Areas exhibiting dry/clean geotextile should be sprayed with a diluted emulsion and, if necessary, covered with a washed coarse sand or "Grit" (low fines, minus 4.75 mm coarse sand).

Note:

If the probability of rain is high, the geotextile must be saturated and covered with a coarse sand

c) Aggregate seal application rates

The seal is designed in the conventional way using TRH3.

In the case of stone seals:

- Corrected ball penetration is taken as 1mm (only if not saturated)
- No provision is made for additional binder due to texture depth
- Do not use the minimum application rate
- Add 30% additional binder to compensate for the vertical movement of the stone on the geotextile (only if not saturated already) Better to ensure that patches are saturated.

Notes:

Should circumstances not allow for trafficking of the geotextile e.g. concern for low skid resistance or contractual aspects, additional binder would be required to prevent whip-off. Experience indicates an additional 0.3-0.4 ℓ/m^2 net binder required to prevent whip-off.

Due to the movement of the aggregate layer on the geotextile, it is recommended that the total binder calculated is distributed to make provision for a cover spray (minimum hot application rate of 1.0 ℓ/m^2 diluted emulsion)

d) Construction aspects

- Rut filling and patching must be done prior to placing of the geotextile
- The geotextile should be placed as quickly as possible after application of the tack coat, even if emulsion is used.
- Geotextile width should be equal to the lane width plus the overlap width/s
- Overlap on the joints should be 100mm – 200mm
- Overlap on the transverse joint should be in the direction of traffic flow.
- Do not overlap geotextile in wheel paths
- Complete lay of tack coat and geotextile over full width before sealing
- Rolling with a heavy pneumatic roller should commence immediately after placing of the geotextile

- Four to five passes with a heavy pneumatic roller (17 ton or heavier) is recommended
- Additional hand spray on the overlap might be required

e) Additional comments and concerns from South African practitioners

- Rapid setting slurries applied on geotextiles tend to delaminate
- Tack coats without cutters are recommended
- Concerns regarding milling of geotextile seals are only valid on new geotextiles. These products tend to deteriorate within 10 years to such an extent that it could be torn by hand
- Minimum fabric grade recommended is140g/m^2
- Thicker grades might be required with larger aggregate seals e.g. 19 mm
- The use of steel wheel rollers is not recommended

7.10.2 Inverted Double Seals

Inverted double seals are constructed by first applying the smaller aggregate and then the larger aggregate. Reasons quoted for the reverse operation are:

- Armour plating of a soft substrate (punching less with 6,7 mm)
- Base protection during half-width construction. Sealing the new half surface width first with a 6,7 mm aggregate is considered a lower risk than immediate construction of a double seal or a single 13,2 mm layer.

The current approach is to design the two layers as individual single seals. However, experience indicate that additional binder might be required to fill up the voids in the first seal e.g. 6,7 mm or that provision must be made for an additional emulsion cover spray.

7.10.3 Otta seals and graded aggregate seals

Following excellent performance of Otta seals in Botswana using marginal quality material, several road authorities in southern Africa have introduced the practice of graded aggregate seals. Although the design, construction and maintenance is well described in a recent publication(1), it has been decided to incorporate the basic information of the Otta seal and some local experience with graded aggregate seals into the TRH3 document.

7.10.3.1 Otta seal summary

a) General

The Otta seal was developed by the Norwegian Roads Research Laboratory during the early 1960's and refers to the Otta valley where it was first used.

The seal consists of graded aggregates (natural gravel or crushed rock) in combination with soft (low viscosity) binders. From experience, three different aggregate gradings have been defined namely "Open", "medium" or "dense".

Dependent of the circumstances a single or double layer of aggregate is constructed after which a sand cover seal is generally applied. The total thickness of a single Otta seal is approximately 16mm. A single Otta seal with a sand cover layer is normally used with ADT < 1000vpd.

b) Key aspects

- Maximum particle size (Preferred 16mm - Maximum 19mm)
- Fines content (<0.075mm) (Preferred <10% - Maximum 15%)

c) Recommended material properties

Material properties	Requirements	TMH test method
Plasticity Index	Maximum 10	A3
Flakiness Index *	Maximum 30	B3T
Sieve sizes (mm)	Grading requirements (% passing)	
19 16	100 80 – 100	A1
13.2 9.5	52 – 100 36 – 98	
6.7 4.75	20 – 80 10 – 70	
2.0 1.18	0 – 48 0 – 38	
0.425 0.075	0 – 25 0 - 10	

Note:

Only applies for crushed rock. The weighted Flakiness Index is determined on the following fractions:
9.5 – 13.2 mm
6.7 – 9.5 mm
4.75 – 7.6 mm

Sand for cover seals should be clean, non-plastic and passing through the 6.7mm sieve

Aggregate strength requirements	Vehicles per day at time of construction	
	< 100	> 100
Min. Dry 10% FACT	90 kN	110 kN
Min. Wet/Dry strength ratio	0.6	0.75

d) Appropriate binders

Medium cut back binders are preferred e.g. MC 3000. However, it has been stated that cut back bitumen manufactured in Botswana lacks long-term durability. Cutting back base bitumen on site is preferred. Blending proportions are provided in the Table.

Required product	Cutter (Power paraffin) in percent of total mixture	
	80/100 base bitumen	150/200 base bitumen
150/200 Pen	3-5% flux oil is used instead of cutter	
MC 3000	8 – 10 %	*5 – 8 %
MC 800	18 – 20 %	*15 – 18 %
*The durability of the binder can be improved by replacing 3% of the cutter with flux oil where 80/100 penetration grade is used as base bitumen.		

Experience indicates that priming is normally not required unless calcrete material is used in the base layer.

Grading envelopes				
Sieve sizes (mm)	Open Grading (% passing)	Medium Grading (% passing)	Dense Grading (% passing)	TMH test method
19 16	100 80 – 100	100 84 – 100	100 93 – 100	A1
13.2 9.5	52 – 82 36 – 58	68 – 94 44 – 73	84 – 100 70 – 98	
6.7 4.75	20 – 40 10 – 30	29 – 54 19 – 42	54 – 80 44 – 70	
2.0 1.18	0 – 8 0 – 5	3 – 18 1 – 14	20 – 48 15 – 38	
0.425 0.075	0 – 2 0 - 1	0 – 6 0 - 2	7 – 25 3 - 10	

Choice of binder			
	Type of Bitumen		
AADT at construction	Open grading	Medium grading	Dense grading
> 1000		150/200 pen	MC 3000 MC 800 in cold weather
100 - 1000	150/200 pen	150/200 pen. In cold weather	MC 3000 MC 800 in cold weather
< 100	150/200 pen	MC 3000	MC 800
Notes: *80/100 pen. bitumen should only be used if cut back to meet viscosity requirements* *Binder for sand cover seal shall be:* *MC3000 for crusher dust of coarse river sand* *MC800 for fine sand*			

Hot bitumen spray rates for un-primed base course (ℓ/m^2)					
		Grading			
				Dense	
Type of Otta seal		Open	Medium	AADT <100	AADT >100
Double	1st layer	1.6	1.7	1.8	1.7
	2nd layer	1.5	1.6	2	1.9
Single with sand cover seal	1st layer	1.6	1.7	2	1.9
	Fine sand	0.7	0.7		0.6
	Crusher dust or coarse river sand	0.9	0.8		0.7
Single		1.7	1.8	2	1.9
Maintenance reseal (single)		1.5	1.6	1.8	1.7

Notes:

Reduce application rate by 0.2 ℓ/m^2 for the first layer on a primed base course

Increase application rate by 0.3 ℓ/m^2 if the aggregate water absorbency is more than 2%

Aggregate application rates			
Type of seal	Aggregate spread rates (m^2/m^3)		
	Open grading	Medium grading	Dense grading
Otta seals	77 – 63	77 – 63	63 – 50
Sand cover seals	100 – 83		

e) Caution

Although excellent performance has been achieved in Botswana, practitioners should take note of the following:

- The Otta seal is suited mainly for low volume roads < 1000 AADT.
- Skid resistance could be suspect.
- Rolling

On day of construction:

- 15 passes with a 12 ton or heavier pneumatic roller and one pass with a 10-12 ton static tandem steel roller are recommended

Each of two days after construction:

- 15 passes with a 12 ton or heavier pneumatic roller

- Maximum traffic speed of 40 – 50 km/hour for 2 – 3 weeks after construction and even longer (4 – 6 weeks) if natural gravel with high fines content is used.
- Allow for a minimum period of 8 – 12 weeks between the construction of the first and second layers.

- Accept that bleeding will occur and blinding and additional rolling might be required. Provision must also be made in contracts to establish a team for blinding during the first hot season after construction for up to 8 weeks.
- Back brooming of the sand cover should be repeated regularly until the sand is fully embedded in the first layer of the surfacing. This could be required for up to 4 weeks.
- The surfacing could be sensitive to heavy vehicle turning and breaking actions during the early life. Harder binder and reduced application rate required for these situations.
- If possible permanent road markings must be delayed for as long as possible. For safety reasons pre-marking or temporary lines might be required.

7.10.3.2 Additional information on graded aggregate seals

a) South African experience

Although numerous graded aggregate seals have been constructed in South Africa over the past thirty years and some case studies have been documented, insufficient information exists to provide guidelines for all traffic spectrums.

General recommendations:

- Softer binders are recommended (e.g. MC3000)
- Recommended binder application rates vary between 1.4 – 1.6 ℓ/m^2 residual binder
- Preferred aggregate (max 13,2mm)
- Dust (max 5% preferred 2%)
- Aggregate spread rate (0.015 m^2/m^3) or 67 m^3/m^2
- Max traffic (ADT = 1000 vpd in both directions)

7.10.4 Stress-absorbing membrane interlayers (SAMIs)

SAMIs are not, strictly speaking, seals. They are designed and constructed as single seals with modified binders (usually bitumen-rubber). As their name implies they are applied on an existing surfacing as an interlayer, prior to the application of an asphalt overlay. Their purpose is to accommodate and attenuate stresses in the existing pavement and prevent or minimise their transfer to the new asphalt surfacing.

7.10.5 Ultra-thin asphalt

Ultra-thin friction course (UTFC) could be described as a paver-laid seal. Although good performance has been observed, products applied are generally proprietary products with the result that designs are treated as confidential. The reader is referred to the latest relevant Agrement Specifications.

7.11 CONSTRUCTION OF SEALS

7.11.1 General guidelines for construction of chip seals

Once all the checks have been meticulously carried out as described in Chapter 9, and the distributor correctly placed on the road to be sealed, operations can commence.

a) The distributor should not commence spraying until it has reached the required speed for the specified application rate for the binder.

b) Immediately after the distributor has passed over the reinforced paper joint, the two edges of the paper strip at right angles to the edge of the road are folded over to prevent any spillage of the binder, and the extreme edges of the paper parallel to the centre-line of the road are rolled over towards the centre of the section, picked up in total and placed in a truck or L.D.V. to be disposed of in a suitable place.

c) The chip spreader follows immediately after the jointing material is removed. The reason for this is to avoid holes being punched in the jointing material by the aggregate, which would result in leakage of the binder through the jointing material onto the existing primed surface, which would cause unsightly fatty patches in the surface at a later stage.

d) The chip spreader and the truck supplying it should be closely followed by trucks full of aggregate.

e) As each truck loading the chip spreader is emptied, it pulls out to face the oncoming traffic. Flagmen are required to control this operation. An experienced truck driver can connect up with the chip spreader in motion, without stopping, and this speeds up the process.

f) The distributor could spray out its whole load in one operation, provided all the equipment is sound, the operators are experienced and there is sufficient aggregate already loaded in the trucks to cover the whole section. Due to the risks related to equipment problems, this practice is not recommended.

g) Immediately behind the loaded trucks, the heavy pneumatic-tyred rollers give the surface one completed pass of the roller. One pass of a steel-wheeled roller is often applied to the first layer of a double seal.

h) The brooms(2) are then brought on in tandem, the second broom overlapping the first broom by ± ½ metre and the rollers follow the brooms systematically. The brooms continue to broom the surface from the centre of the road to the edge and back again. The brooms should be set so that the bristles just touch the aggregate and do not disturb the aggregate in contact with the binder.

Note:
If emulsion is used, brooming should not take place until the emulsion has broken.

i) The process of lightly brooming and rolling should continue until all the loose aggregate has been placed shoulder-to-shoulder and in contact with the binder in a single layer of stone aggregate.

j) If the gates of the chip spreader have been properly adjusted, very little if any back chipping will be required.

k) Where the connection of the trucks with the chip spreader occurs, some over-application of aggregate may occur. This over-application of aggregate should be removed by hand brooming the surface before the rollers pass over the area and lock the excess aggregate in the bottom layer of stone.

l) The joint on the centre line of the road should be given special attention. A 3 mm twine on the centre line is used as a guide for spraying. The width of the spray should overlap the line by 100 mm. This width can be controlled accurately by fitting fish plates next to the end nozzle.

m) Immediately after application of aggregate and brooming, the 100 mm overspray should be cleaned of aggregate spillage while the road is still warm and before the binder has set. It is advisable for the rollers to keep within the surfaced area and not to roll across the string line. Once this operation is complete, the string line should be removed.

7.11.2 Specific aspects applicable to single seals

a) Rolling with the heavy pneumatic rollers should continue from the time the binder and aggregate are applied for a minimum of 8 passes per roller width. As a guide, 2½ hrs rolling with one heavy pneumatic-tyred roller is required for every km of single lane 3,7m wide surfaced roadway. (i.e. approximately 8 - 10 passes over each "width of roller" of surfaced width of the roadway). It is recommended that the initial rolling (first roll) be completed within 15 min of spreading the aggregate. A minimum of two rollers is recommended for each chip spreader.

b) Before the road is opened to traffic, all loose stone should be removed from the surface. The surface should be broomed the day following surfacing to ensure there are no "flying chips" on the road. For wide surfaces exceeding 7,4 m it is advisable to use self-propelled brooms or (preferably) vacuum brooms to remove the unattached chips. Back-rolling the following day can further improve binder/aggregate adhesion.

c) The rollers should be ballasted (20 ton unballasted) and there should be sufficient rollers for the work envisaged. Efficient use of the brooms and rollers makes a significant improvement to the quality of the final finish.

d) The quality of the aggregate should be checked before it is delivered to site. The precoating of the aggregate should be uniformly done and the aggregate should be stockpiled at least 48 hrs before it is used. These stockpiles should be covered with tarpaulins if the operation is done in the rainy season.

e) Stockpile sites should be carefully selected and prepared vis-à-vis drainage, access and possible contamination of the aggregate (e.g. by mud).

f) The minimum temperature which may be expected for the ensuing 24 hours should be checked.

Note:

*If cutting back is allowed, the appropriate cutback material should be added and the cutback bitumen circulated for 20 - 30 minutes before it is sprayed. (Refer to **APPENDIX I**.)*

g) It is not advisable to use steel-wheeled rollers on single seal reseal projects if the road is deformed, as these will damage the aggregate, riding the high spots and missing the aggregate in the cusps.

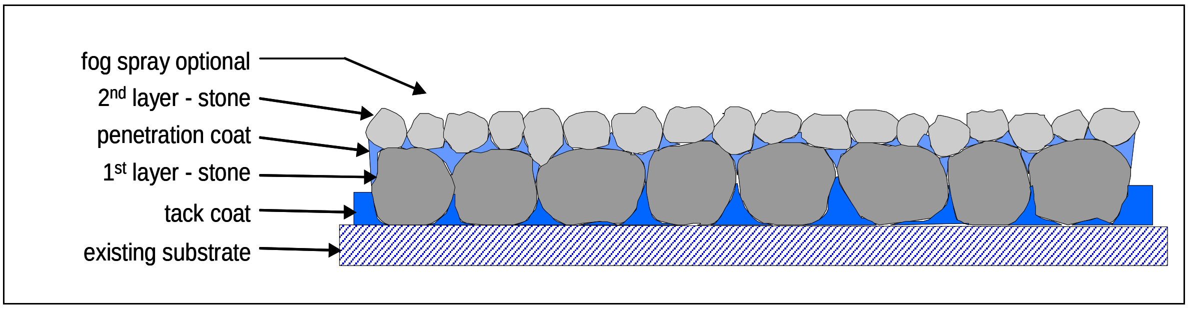
h) In a hot climate it may be necessary to keep the road closed until sunset and even to spray the surfacing with water to cool the surfacing down before it is opened to traffic. If possible, the road should only be opened to traffic the next morning, while the binder is still stiff.

i) Traffic speeds should be controlled for two to three days to allow the seal to settle.

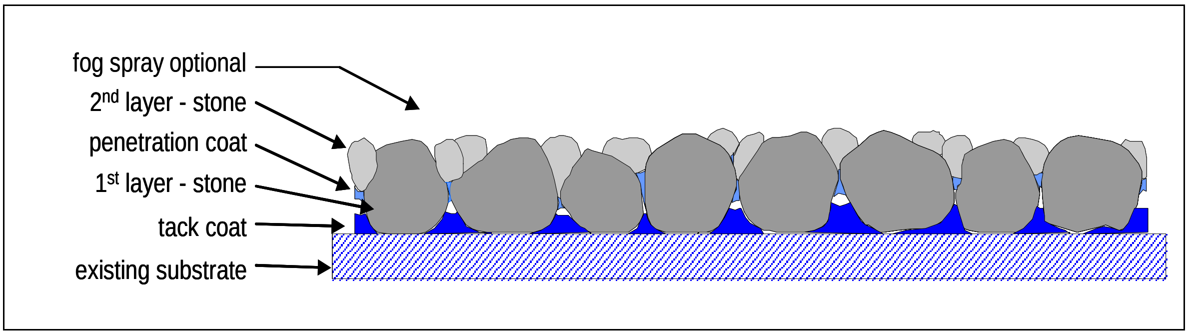
7.11.3 Specific aspects applicable to double seals

There are two different basic design approaches to the construction of the standard double seal, viz:-

7.11.3.1 Proper double seal (shoulder to shoulder application of both stone applications)



7.11.3.2 One and a half seal (open application of coarse stone and flaky small stone)



In the "one and a half seal" the first application of aggregate does not lie shoulder-to-shoulder and only part of the second application of aggregate is locked into the voids between the coarse aggregate. The balance of the fine aggregate is lost through whip-off as there is not enough binder on the top of the coarse chips to hold the second application. There is a significant cost factor regarding payment for the surfacing, which is affected by the exact quantities of aggregate used.

7.11.3.3 Discussion

It is therefore necessary to decide what precise modus operandi is to be used before commencement of the work.

It should be noted that the process described here applies essentially to new construction.

a) Once the single layer of aggregate lying shoulder-to-shoulder has been applied, the heavy 10-12 ton steel-wheeled roller may commence rolling, starting at the edge of the surfacing and moving a half wheel at a time towards the centre and back again. The quality of the final finish of the road depends on the efficiency of this operation, which should continue until a tight flat surface has been obtained. A certain amount of crushing/splitting of the coarse aggregate will occur, but the final finish should be "tight", uniform and "flat". On new construction a limited amount of "punching" in of the aggregate into the base will occur, resulting overall in a "tight", flat surface.

b) It should be noted that under no circumstances should this layer be opened to traffic before the second application of aggregate has been applied. If this road is opened to traffic for any reason, bleeding and fattening up of the surface will result.

c) If construction traffic and/or the public use the road, re-rolling would be advisable before the penetration coat of binder is applied.

d) Although this is not common, both applications of aggregate may be precoated. The precoating assists in immediate adhesion of the coarse aggregate to the binder and allows effective brooming to take place with minimum delay, without disturbing/turning the aggregate in contact with the binder.

e) If emulsion is used as a tack coat, the emulsion should be allowed to break and adhere effectively to the aggregate before brooming commences. Brooming before the emulsion has broken will result in the turning of the aggregate, which, in turn, will result in the aggregate sticking to the rollers and broom bristles.

f) It is most important to obtain the correct application of aggregate at initial application so as to reduce brooming and the need for back-chipping as far as possible.

g) If emulsion is used for the penetration sprays, the precoating of the aggregate of the second application of the aggregate must not be done with a tar-based precoating fluid but with diluted emulsion or a commercially available bitumen precoating product

h) The quantity of binder calculated for the tack coat should be reduced to the minimum quantity of binder required to hold the first application of aggregate in place and prevent its movement when the surface is broomed. The balance of the binder should be added to the penetration sprays.

i) The application of the second spray should be delayed until all the excess volatiles have evaporated. Under no circumstances should cutback binders be used for the tack coat as subsequent sprays lock in the volatiles which flush up during the hot season. Heavy to medium traffic using the road under these conditions will cause excessive bleeding of the surface.

j) Finishing of the final layer is similar to that for single seals. This is described in the section on the construction of single seals (Section 7.6).

7.11.4 Specific recommendations for Cape Seals

After application of the first layer of aggregate the following procedures are recommended:

a) Rolling with the heavy pneumatic-tyred rollers should continue from the time the binder and aggregate are applied for a minimum of 8 passes per roller width. As a guide, 2½ hrs rolling with one heavy pneumatic-tyred roller is required for every km of single lane 3,7 m wide surfaced roadway, i.e. approx. 8 - 10 passes over each "width of roller" of surfaced width of the roadway.

b) All loose stone should be broomed off the surface before the fog spray is applied.

c) The fog spray is usually a penetration grade bitumen or a diluted emulsion. If a cationic bitumen emulsion is used as the fog spray, the aggregate should not be precoated with a tar-based precoating fluid. Precoating is important in so far as it assists in the application and preparation of the first application of aggregate.

Note:

Sufficient time should also be allowed between application of the tack coat and the fog spray, especially if emulsion is used in the tack coat.

d) Before the slurry is applied and the surface has been exposed to the elements and construction traffic, there probably will be some disturbance of the aggregate. It is therefore recommended that the surface be given one complete pass with a steel-wheeled roller early in the morning before the surface has warmed up.

e) If the surface has lain for any length of time, it should be inspected for contamination by dust, mud, vegetable matter or water. Loose material can be removed effectively with compressed air.

f) Depending on the texture required for the final surface, either a single or double application of slurry may be required. This may be applied either by hand or spreader box, but the mixing should be done in an approved mixer.

g) Care should be taken to determine the bulking of the fine aggregate used.

h) If the slurry is placed with hand labour, 13 mm diameter sisal rope (50 m lengths) should be placed on either edge of the section to be treated with slurry, i.e. at the edge of the surface and on the centre line. Work should be confined to these limits. The slurry should not be over-applied but levelled off neatly to the tops of the aggregate and finished off by dragging a moist burlap over the slurry before the emulsion breaks. If the slurry is applied with a spreader box, it is advisable to work up to approximately 100 mm from the edge and to use squeegees to spread the slurry to the edge.

Note:

A better result is obtained by hand spreading. However, the slurry must be “moved” too far as segregation could occur.

i) The surface should be well rolled with a heavy pneumatic-tyred roller, preferably 24 hours after application, in order to obtain a dense, well-knit surface. Depending on the texture required, a second application of slurry may be required.

Note:

The final texture will also be dependent on the closeness (shoulder-to-shoulder) of the underlying aggregate.

7.11.5 Construction of modified binder seals

When the modified binder and the spray rates applicable to the traffic, foundation and surface conditions have been selected, the following pertinent points should be observed during the construction process.

a) All the preliminary checks applicable to normal bitumen seals, as regards setting out of the work, traffic control, checking of equipment and aggregate should be carried out meticulously.

b) Sufficient quantities of aggregate, corresponding to the envisaged amount of binder to be sprayed, should be precoated 24 hours before it is required. (Some authorities specify 48 hours.)

c) If bitumen rubber is to be used, the rubber crumbs should be tested well in advance of the work to ensure that they comply with the specifications for grading, cleanliness, percentage of synthetic rubber and percentage of natural rubber.

Note:

Too high a percentage of natural rubber will result in blocked jets and stoppages on site.

d) Distributors spraying modified binders, especially bitumen rubber binders, should be tested on site for evenness of distribution of the spray bar and for delivery of the binder by the distributor pump. (Refer to APPENDIX J.)

e) It is advisable and recommended that when bitumen rubber is to be used, the rubber crumb be introduced on site, in order that the time for "digestion" can be controlled. The time for digestion i.e., the time between introduction of the rubber and spraying should not exceed 2 hours. The digestion temperature should be between 180 °C and 200 °C.

f) The temperature at which the selected binder is to be sprayed should be obtained from the supplier and adhered to on the work. For bitumen rubber this could vary between 185 °C and 195 °C. If the spraying temperature is too low, "roping" or "tramlines" will result when the binder is applied. Temperature control is equally important for other modified binders.

g) When bitumen rubber is used, it is recommended that the entire contents of the tanker be sprayed out in one operation wherever possible, provided that all the checks for availability of aggregate, equipment, standby equipment and area of road surface available have been carried out meticulously.

h) The treatment of the centre-line joint requires attention:

- The "shoulder" end of the spray bar should be fitted with an end nozzle and fishplate.
- The "centre-line" end of the spray bar should be fitted with an end nozzle but no fishplate.
- After the aggregate has been applied, any aggregate which may have fallen beyond the centre-line within the sprayed "flare" of the end nozzle across the centre-line should be removed.
- On the return spray the end nozzle "flare" will overlap the previous spray with a small amount of

overspray on the aggregate previously applied.

- Any aggregate falling on this overspray should be broomed off immediately so as to prevent the formation of a ridge consisting of a double layer of aggregate along the centre-line of the road.

i) The use of rotary brooms and pneumatic-tyred rollers (heavy) working in tandem to remove over-application of aggregate/double layers of aggregate and to distribute aggregate to the uncovered areas, is essential. This process should continue until all the binder has been completely covered and the aggregate is lying shoulder-to-shoulder.

j) All loose aggregate should be removed from the surface before the road is opened to traffic.

k) Summer grade bitumen rubber should only be used between approximately the middle of September and the middle of May, when minimum daily temperatures are ± 7-10 °C. Winter grade bitumen rubber may be used between the middle of May and the middle of September, when the minimum daily temperature can fall to -4 °C.

l) Modified emulsions are more accommodating than bitumen rubber and may be sprayed in the dry winter months, provided that the road temperature is 10 °C and rising.

m) Hot modified binders should not be sprayed in the cold months, i.e. from May to the end of August unless a special formulation is prepared by the suppliers or construction methods or the seal type can be changed e.g. to keep traffic off the newly constructed seal and/or change to a double seal.

Note:

Information regarding the minimum and maximum temperatures is available from the South African Weather Service on request or from their Website (http://www.weathersa.co.za).

7.11.6 Sealing on a wet base

7.11.6.1 New base construction

When constructing a road under traffic, practitioners are often confronted to either wait for the new granular base to dry out to fifty percent of optimum moisture content, as normally specified, or to commence with the construction of the seal before such ideal conditions occur.

Although this situation normally only occurs on lower volume roads where insufficient funds do not allow for temporary bypasses or proper half-width construction, a decision has to be made whether deterioration and ravelling of the base or embedment of the seal aggregate and possible early isolated base failures would be more acceptable.

Based on studies in South Africa regarding the moisture content of base layers, stabilising on sixty to eighty percent of optimum moisture content, the general perception is that the lesser of the evils would be to seal the road before the base has dried out to fifty percent of optimum moisture content.

The possibility of rain, the cohesion of the base material, traffic volumes and performance of the prime layer should be taken into account in making such a decision.

7.11.6.2 Reseal

Sealing too soon after rain on existing porous and cracked surfaces has resulted, on several occasions, in rapid deterioration and failures of the granular base layer. Therefore, it is recommended to allow sufficient time for moisture to evaporate.

Note:

Some road authorities in southern Africa prefer to apply a diluted emulsion or a rejuvenator during the dry season prior to the construction of the reseal.

8 RECOMMENDED MATERIAL STANDARDS

8.1 AGGREGATES

All the aggregates used in seals, whether stone, crusher dust or natural sand, should, in general, conform to the recommendations given in the COLTO Specifications[4] and comply with the requirements of SABS Specification 1200 M: 1996[31] for grading, crushing strength, (Aggregate Crushing Value (ACV) and 10% FACT), Flakiness Index, polished stone value, fines and dust content, adhesion and sand equivalent values applicable to the aggregate for that particular purpose. SABS Specification 1200 M: 1996[31] has replaced SABS 1083: 1976[35].

The minimum specifications for aggregates and sands in surfacing seals are summarized in Table 8-1 to Table 8-6.

The functions and performance of aggregates are discussed in paragraph 2.7.1.

Table 8-1 - Grading of Grade 1, 2 and 3 aggregates for surfacing seals[4]

Sieve size (mm)	*Grade*	Percentage passing by mass						
		26,5 mm nominal size	*19,0 mm nominal size*	*13,2 mm nominal size*	*9,5 mm nominal size*	*6,7 mm nominal size*	*4,75 mm nominal size*	2,36 mm nominal size
37,50	Grades 1&2	100	-	-	-	-	-	-
26,50		85 - 100	100	-	-	-	-	-
19,00		0 - 30	85 - 100	100	-	-	-	-
13,20		0 - 5	0 - 30	85 - 100	100	-	-	-
9,50		-	0 - 5	0 - 30*	85 - 100	100	-	-
6,70		-	-	0 - 5**	0 - 30*	85 - 100	100	-
4,75		-	-	-	0 - 5**	0 - 30*	85 - 100	*100*
3,35		-	-	-	-	-	0 - 30	-
2,36		-	-	-	-	0 - 5**	0 - 5	*0 - 100*
	Grade 3	*Grading shall comply with the requirements for grades 1 and 2 with the following exceptions: * 0 – 50 ** 0 – 10*						
Fines content: Material passing a 0,425 mm sieve (max)	Grade 1	0,5	0,5	0,5	0,5	0,5	1,0	*15,0*
	Grade 2	1,5	1,5	1,5	1,5	2,0	2,5	*15,0*
	Grade 3	N/A	N/A	2,0	2,0	3,0	3,5	*15,0*
Dust content: Material passing a 0,075 mm sieve (max)	Grade 1	N/A	N/A	N/A	N/A	N/A	N/A	*2,0*
	Grade 2	0,5	0,5	0,5	0,5	1,0	1,0	*2,0*
	Grade 3	*N/A*	*N/A*	*1,5*	*1,5*	*1,5*	*1,5*	*2,0*

Note:

It might not always be possible to get aggregate with grading fully in specification. Relaxation of standards could be considered for low volume roads.

Table 8-2 - Properties of aggregates for surfacing seals[4]

Property	Grade of Aggregate	
	Grade 1	Grade 2 & 3
Flakiness Index [%] (max) 19,0 mm nominal size 13,2 mm nominal size 9,5 mm nominal size 6,7 mm nominal size	 25 25 30 30	 30 30 35 35
10 % FACT [kN] (min) Wet to Dry Ratio [%]	210 75	210 75
Aggregate Crushing Value (ACV) [%] (max)	21	21
Polished Stone Value (PSV) (min)	50	50

Table 8-3 - Properties of sand for sand seals[4]

Sieve Size (mm)	Percentage passing by mass
6,7	100
0,300	0 - 15
0,15	0 - 2
Sand Equivalent [%]: 35 minimum	

Table 8-4 - Properties of sand for grit seals[28]

Sieve size (mm)	Cumulative percentage passing
4,75 2,36 1,18 0,600 0,300 0,150 0,075	100 0 - 100 0 - 50 0 - 20 0 - 10 0 - 5 0 - 2
Sand Equivalent [%] (min)	35

The following weathering tests may be conducted on aggregate for seals:

Sulphate soundness tests;

Freezing and thawing test;

Wetting-drying test;

Los Angeles abrasion test;

Weathering (Ethylene glycol)

None of these tests are specified in the SABS specifications[31,35] or by the Committee of Land Transport Officials (COLTO)[4]. It should be noted that not all laboratories possess the facilities to conduct these tests.

8.1.1 Relaxation of Specifications

On account of the decreasing availability of high quality aggregates, of the increasing demands made for these and the increased costs of hauling and crushing, consideration could be given to the use of aggregates which do not meet all the requirements of SABS 1200 M[31] in seals or reseals on suburban and township roads and possibly on lightly trafficked rural roads.

It has been found (Wright *et al*[36]) that, by the use of marginal materials of this type, savings of up to 30 per cent in the cost of aggregate alone could be realized, resulting in an overall saving of as much as 7 per cent of the total cost of the seal.

In view of the fact that the design of surfacing seals is based to a large extent on aggregate size, grading and ALD, no departure from the standard specifications for these parameters is recommended for aggregates used in seals on lightly trafficked roads.

8.1.1.1 Crushing Strength

On lightly trafficked roads or when resealing is carried out on moderately trafficked roads on top of old surfacings which are soft relative to a crushed stone base, the crushing strength requirements for the aggregate may be relaxed, in view of the satisfactory performance of such aggregates in seals on relatively lightly trafficked roads. In order to prevent crushing of the aggregate during construction of the seals (single or double) the use of steel-wheeled rollers should be avoided on these soft aggregates.

Whereas aggregates with a maximum ACV of 21 or a minimum 10% FACT of 210 kN are recommended, it has been found that satisfactory results have been achieved on low-to-medium trafficked roads with ACVs as high as 30 (equivalent to a 10% FACT value of approximately 100 kN). For very lightly trafficked roads, aggregates with ACVs of 40 have been found to be acceptable.

On high-speed rural roads, the skid resistance of the surfacing is a major functional aspect. For this reason limits are placed on the Polished Stone Value (PSV) of aggregates, since polishing of the stone reduces the skid resistance and, at speed, may make the surface hazardous, particularly in wet conditions, or at locations where braking is likely to take place, such as at approaches to intersections, traffic circles, or at tight bends where there is insufficient super-elevation etc.

However, it has been found[37] that skid resistance is rarely a problem on lightly trafficked roads carrying less than 500 vpd and, consequently, the PSV requirement may be dropped, except, possibly at intersections etc., as described in the preceding paragraph. The removal of this requirement, together with the relaxation of the strength requirement should make hitherto marginal aggregates acceptable in certain circumstances and, consequently, result in appreciable savings.

It is emphasized that this relaxation of some of the aggregate standards should not be construed as a lowering of quality or as a means of disposing of sub-standard materials by using these to construct sub-standard roads in communities and suburbs whose roads carry light traffic.

The recommendation to use marginal aggregates in such roads was originally made by the Southern African Bitumen Association (SABITA)[38] and is based on the results of a survey carried out in this and neighbouring countries in southern Africa, where high quality aggregates meeting all the requirements of the SABS Specifications[31] are not always available.

It sometimes occurs that, while the available aggregates may comply with the relevant specifications, their properties (such as ALD or Flakiness Index) may show great variation. This would impact on the design of the seal and may make it necessary to design and apply the seal in many short sections. In such cases, the use of aggregates which are slightly outside the specifications, but whose properties are consistent, may be considered.

It should also be noted that aggregates which comply with all the requirements of the specifications may not necessarily be suitable for use in surfacing seals.

If the aggregate comes from a source whose origins and geological properties are not well documented it is essential that they be thoroughly investigated, as there are many recorded instances of apparently suitable aggregates being totally unacceptable and performing very poorly (stripping, disintegration, extremely water sensitive etc.).

8.2 SLURRY AGGREGATE

The aggregate used in the manufacture of slurries generally consists of crusher sand or of a blend of crusher sand and natural sand. It should conform to the recommendations given in TRH 14[32].

The gradings of aggregate used in slurries are given in Table 8-5 and Table 8-6. Natural sand should not form more than 50 (COLTO specifies 25%) per cent by mass of the aggregate blend unless a cationic bitumen emulsion is used or an adhesion agent is added.

The aggregate used in rapid-setting slurries should have the same properties as those specified for conventional slurries. In addition they should be checked for compatibility with the emulsions to be used. The gradings of the aggregate to be used in rapid-setting slurries are given in Table 8-6.

Table 8-5 – Properties of aggregates for slurries[4]

Sieve Size (mm)	Percentage passing sieve by mass				
	Fine Slurry			Coarse Slurry	
	Fine grade	Medium grade	Coarse grade	Type 1	Type 2
13,20					100
9,50				100	85 - 100
6,70		100	100	85 - 100	70 -90
4,75	100	82 - 100	70 - 90	70 - 90	60 - 80
2,36	90 - 100	56 - 95	45 - 70	45 - 70	40 - 60
1,18	65 - 95	37 - 75	28 - 50	25 - 45	25 - 45
0,60	42 - 72	22 - 50	19 - 34	15 - 30	15 - 30
0,30	23 - 48	15 - 37	12 - 25	10 - 20	10 - 20
0,15	10 - 27	7 - 20	7 - 18	6 - 15	6 - 15
0,075	4 - 12	4 - 12	2 - 8	4 - 10	4 - 10
Sand Equivalent [%]: 35 (min)					

Table 8-6 - Aggregate gradings for rapid-setting slurries

Sieve size (mm)	Nominal Maximum Aggregate size (mm)			
	4,75	6,7	9,5	13,2
	OVERLAYS		RUT FILLING	
	Cumulative percentage passing			
13,2	100	100	100	100
9,5	100	100	100	80-100
6,7	100	100	66-100	60-84
4,75	100	70-100	57-75	50-70
3,35	80-100	50-75	48-85	44-62
2,36	64-80	46-60	42-56	38-57
1,18	40-55	32-47	28-43	28-43
0,600	27-38	20-34	18-30	18-33
0,300	14-24	10-22	10-20	10-20
0,150	9-18	7-16	7-14	7-14
0,075	5-15	5-10	5-10	5-10
Sand Equivalent	35 min			
Modified emulsion	200 ℓ/m^3	190 ℓ/m^3	160 ℓ/m^3	150 ℓ/m^3

8.3 ACTIVE FILLERS

8.3.1 Cement

The cement used in slurries should be Ordinary Portland Cement and should comply with current SABS specifications for cement[39].

8.3.2 Lime

The lime used in slurries should be slaked lime and should comply with current SABS specifications for lime[40]. A maximum of 1 - 1,5 per cent of lime (by mass of dry aggregate) may be added.

8.4 BITUMINOUS BINDERS

8.4.1 Unmodified binders

Unmodified bituminous binders used in the construction of surfacing seals should conform to the specifications of the latest edition of the SABS specifications, which are listed in Table 8-7.

The functions of a binder and the types available are discussed in Chapter 5.

Table 8-7 - Specifications added for unmodified bituminous binders for seals

Bituminous binder	SABS specification
150/200 pen bitumen	307[45]
80/100 pen bitumen	307[45]
MC 3000 cut-back bitumen	308[41]
MC 800 cut-back bitumen	308[41]
Anionic bitumen road emulsion (spray grade and stable grade)	309[46]
Cationic bitumen road emulsion (spray grade and stable grade)	548[47]

Cutback bitumens are specified in terms of the properties of the final product only. No reference is made in the SABS specifications[41] to the properties of the cutters used in the manufacture of cutback bitumens.

If a decision is made on site to further cut back cutback bitumens or to cut back penetration grade bitumens (to improve aggregate adhesion, facilitate the spraying of bitumen at a low residual binder application rate, reduce the viscosity of the binder or for any other reason), the cutters used (diesel or paraffin) should comply with current SABS specifications[42,43,44].

Where paraffin is used as a cutter, care should be taken to ensure that the paraffin and bituminous binders used are compatible. It has been found that one or other type of paraffin is more compatible with bitumens produced by certain refineries than with those from others. While this has not been formally investigated, this finding is based on experience in the field, where otherwise inexplicable failures have been reported.

Should it be necessary to cut back binders in the field, the manufacturer of the base bitumen should be consulted to determine the most appropriate cutter to use.

The issue of cutting back of binders on site is discussed in more detail in APPENDIX I.

8.4.2 Modified binders

The Asphalt Academy has published a Technical Guideline for the use of Modified Binders in Road Construction (TG1, October 2001). The TG1 document describes the different binder classifications and applications thereof in great detail. The product requirements for binders used in surface seals as found in TG1 (October 2001) are reproduced in this document. *It is very important that the reader refers to the latest version of TG1 as the specifications may change from time to time.* The classification of modified binders for surface seal applications is given in Table 8-8.

Table 8-8 - Classification of Modified Binders for Surface Seals

Modified Binder Class (S)	Application
S-E1	Surface Seal – Hot applied
S-E2	Surface Seal – Hot applied
S-R1	Surface Seal – Bitumen-rubber
SC-E1	Surface Seal – cold applied (emulsion)
SC-E2	Surface Seal – cold applied (emulsion)

The letter codes used in Table 8-8 are defined as follows:

S - surface seal applications (hot applied)
SC - surface seal applications (cold applied)
E - polymer of elastomer type (e.g. SBR or SBS)
R - crumbed rubber

The numerical code included in the binder classification has no bearing on the modifier concentration included in the binder but identifies the binder according to specific binder properties/requirements.

It is recommended that the base bitumen used for blending conforms to SABS 307[45]. This is applicable to both the hot- and cold-applied binders.

The properties for hot applied polymer modified binder for surface seals are given in Table 8-9. Table 8-10 contains the properties for cold applied modified binders for surface seals. The properties of bitumen-rubber binders used in surface seals are contained in Table 8-11. The test methods with MB pre-script refer to the test methods contained in the TG1 (October 2001) document.

Table 8-9 - Properties of hot-applied modified binders for surface seals

Property	Unit	Min/Max	Test Method	Binder Class	
				S-E1	S-E2
Softening Point (R&B)	℃	Min	MB-17	50	57
Dynamic Viscosity @ 165 ℃	Pa.s	Max	MB-18	0,55	0,55
Ductility @ 15 ℃	cm	Min	MB-19	75	50
Force Ductility @ 15 ℃	N	(*4)	-	Report (*1)	Report
Complex Shear Modulus (G*/sinδ @ 10 rad/s) (*2)		-	AASHTO: TP5	Report	Report
Creep Stiffness: Bending Beam Rheometer	MPa	-	AASHTO: TP1	Report	Report
Elastic Recovery @ 15 ℃	%	Min	MB-4	50	70
Flash Point	℃	Min	ASTM: D93-97	230	230
Stability (R&B diff. @ 60 ℃)	℃	Max	MB-6	5	5
Adhesion @ 5 ℃	%	Min	MB-7	90	90
Torsional Recovery @ 15 ℃ (*3)	%	-	MB-5	Report	Report
Torsional Recovery @ 25 ℃	%	-	MB-5	Report	Report
Properties after ageing (RTFOT)			MB-3		
Difference in Softening Point	℃	-	MB-17	-2 to +8	- 2 to +8
Elastic Recovery @ 15 ℃	%	Min	MB-4	40	50
Mass Change	%	Max	MB-3	1,0	1,0
Dynamic Viscosity @ 165 ℃	Pa.s	-	MB-18	Report	Repo rt
Torsional Recovery @ 25 ℃	%	-	MB-5	Report	Report

***Notes:**

There is a possibility that the "Report only" test properties could in future form part of the specifications. It is recommended that, wherever possible, they are carried out at the commencement of the project in order to develop a local database for these properties.

According to SHRP methods.

Based on Austroads method: This is a relatively cheap, quick and simple test which shows great promise as a quality control tool on site.

No values are given but the test may be utilised to rank various binders according to the improved properties required.

Table 8-10 - Properties of cold-applied modified binders for surface seals

Property	Unit	Min/ Max	Test Method	Binder Class			
				SC-E1		SC-E2	
Modified Binder Content	(% m/m)	-	MB-22	65-68	70-73	65-68	70-73
Viscosity @ 50 °C (Saybolt Furol)	seconds	-	MB-21	51-200	51-400	51-200	51-400
Residue on sieving	g/100 ml	Max	MB-23	0,5		0,5	
Particle charge	-	-	MB-24	Positive		Positive	
Sedimentation after 60 rotations	-	-	SABS 548	Nil		Nil	
Properties of recovered binder residue			MB-20(*1)				
Softening point	°C	Min	MB-17	48		55	
Ductility @ 15 °C	cm	Min	MB-19	75		50	
Elastic recovery @ 15 °C	%	Min	MB-4	50		55	
Torsional recovery @ 15 °C (*3)			MB-5	Report(*2)		Report	
Force Ductility	N	(*4)	-	Report		Report	

***Notes:**

Recovery of binder residue may follow either the rotary vacuum evaporation method or the simple evaporation method. As it is more practical to carry out the recovery in site conditions, it is recommended that the simple evaporation method is used. In addition, this method retains the fluxing oil and gives a better indication of the amount of binder that has been added. The residue obtained from the rotary evaporation method is believed to be substantially free of fluxing oil after recovery, possibly giving a better representation of the binder properties in-service after a period of "curing".

There is a possibility that the "Report only" test properties could in future form part of the specifications. It is recommended that, wherever possible, they are carried out at the commencement of the project in order to develop a local database for these properties.

Based on Austroads method. This is a relatively cheap, quick and simple test which shows great promise as a quality control tool on site.

No values are given but the test may be utilised to rank various binders according to the improved properties required.

Table 8-11 - Properties of bitumen-rubber for surface seals

Property	Unit	Test Method	Binder Class	
			S-R1	
			Min	Max
Compression Recovery: 5 minutes	%	MB-11	70	-
Compression Recovery: 4 hours	%	MB-11	70	-
Compression Recovery: 4 days	%	MB-11	25	45
Softening Point (R&B)	°C	MB-17	55	62
Resilience	%	MB-10	13	35
Flow	mm	MB-12	15	70
Dynamic Viscosity (Haake @ 190 °C)	dPa.s	MB-13	20	40

8.5 PRECOATING MATERIALS

For the precoating of stone the following materials are recommended:

a) Bitumen prime (MC 30) cut back with aromatic paraffin.
b) Diluted bitumen emulsion (cationic or anionic) (water must be compatible).
c) Diesel fuel, blend of diesel fuel and aromatic paraffin.
d) Other bitumen-based precoating fluids.

8.6 TEST METHODS

All materials used in surfacing seals should comply with the relevant specifications mentioned above.

In order to ensure compliance with the specifications, all tests on these materials should be carried out according to the following standard test methods:

Aggregates

Sieve Analysis	TMH1[17], Method B4/SABS Method 829[23]
Aggregate crushing value	TMH1[17], Method B1/SABS Method 841[52]
10% FACT	TMH1[17], Method B2/SABS Method 842[53]
Flakiness Index	TMH1[17], Method B3/SABS Method 847[54]
Polished Stone Value	SABS Method 848[18]
Fines content	TMH1[17], Method B4/SABS Method 829[23]
Dust content	TMH1[17], Method B4/SABS Method 829[23]
Sulphate soundness tests	AASHTO T104[21];
Freezing and thawing test;	AASHTO T103[21]
Los Angeles abrasion test,	AASHTO T96-45[21]
Deval abrasion test.	AASHTO T4-35[21]
Ethylene glycol test	HIGGS, 1976[20]

Sand

Sieve Analysis	TMH1[17], Method B4/SABS Method 829[23]
Sand equivalent	TMH1[17], Method B19/SABS Method 838[55]

Cement

Lime Saturation Factor	SABS Method 745[56]
Al_2: O_3 ratio	SABS Method 745[56]
SO_3 content	SABS Method 741[57]
Loss on ignition	SABS Method 743[58]
Insoluble residue content	SABS Method 744[59]
Coarse particles content	SABS Method 746[60]
Specific surface	SABS Method 748[61]
Density	SABS Method 747[62]
Compressive strength	SABS Method 749[63]
Transverse strength	SABS Method 750[64]
Setting time	SABS Method 752[65]
Soundness	SABS Method 753[66]

Penetration grade bitumens

Penetration	ASTM D5[27]/IP 49[67]
Softening Point	ASTM D36[48]
Viscosity (before and after Rolling Thin Film Oven Test)	ASTM D4402[27]
Ductility (before and after Rolling Thin Film Oven Test)	DIN 52013[49]
Change in mass after Rolling Thin Film Oven Test	ASTM D2872[27]
Spot Test	AASHTO T102[21]

Cutback bitumens

Kinematic viscosity	ASTM D2170[27]
Distillation	ASTM D402[27]/IP 27[67]
Penetration of residue	ASTM D5[27]/ IP 49[67]

Cutback bitumen emulsions

Viscosity	ASTM D244[27]
Binder content	ASTM D244[27]
Fluxing agent content	ASTM D244[27]
Particle charge	SABS 309[46]/SABS 548[47]
Residue on sieving	TMH1[17], Method E18
Binder deposit on cathode	ASTM D244[27]
Sedimentation	SABS 309[46]/SABS 548[47]

Anionic bitumen emulsions

Viscosity	ASTM D244[27]
Binder content	ASTM D244[27]
Residue on sieving	TMH1[17], Method E18
Sedimentation	SABS 309[46]/SABS 548[47]

Bitumen Rubber

Refer to Asphalt Academy, Technical Guideline: The use of Modified Binders in Road Construction (TG1, October 2001).

9 PROCESS CONTROL AND ACCEPTANCE CONTROL

9.1 HEADINGS

The process control of the work can be classified under the following headings:

- Materials
- Checking of plant
- Road checks
- Control checks and records
- Guidelines for process control and quality control. (Refer to TRH5[68]. The frequency of sampling and testing should be in accordance with the client's requirements.)

9.1.1 Materials

9.1.1.1 Laboratory Tests on the Aggregate

The aggregate to be used for the work should conform to the standards discussed in Chapter 8.

The aggregate should initially be sampled in accordance with TRH5[68] at the source of production and from the stockpiles. The following tests should be performed:

Sieve analyses
Determination of ALD
Determination of Sand Equivalent value
Measurement of Flakiness Index
Determination of Polished stone value
Hardness Test (A.C.V.), or 10% FACT
Adhesion Test (Riedel and Weber)
Test for deleterious substances

The geology of the parent rock should be established in order to enable its acidity or quartz content to be determined.

Sampling and testing should be carried out systematically as the material is delivered. The following check tests should be carried out:

Sieve analyses
Determination of ALD
Measurement of Flakiness Index (One test done on 5 random samples, i.e. 1 sample from each 10 m^3 load)

9.1.1.2 Laboratory tests on binders (refer to Chapter 8)

9.1.1.3 Penetration grade bitumen

As these tests are not normally done in the field, it is recommended that arrangements be made with the supplier for a complete set of tests to be performed on each batch prepared at the refinery and, if necessary, for determination of the constituent composition of the binder, indicating the following:

- Asphaltenes content
- Saturates content
- Aromatic content
- Resin content

Knowledge of the constituents of the binder will assist in the formulation of bitumen rubber binders as well as in cutting back of the binder in the field.

Notes:

Sampling of each truck load of bitumen is required. Each 1 litre sample should be clearly marked for future reference, indicating its application, chainages and position on the road, together with date and batch number.

9.1.1.4 Emulsions

As these tests are not normally done in the field, the supplier should be requested to conduct a complete series of tests on each batch of emulsion delivered in accordance with the relevant SABS Standard Specifications[46, 47], as follows:

Anionic Emulsion

- Viscosity at 50 ℃
- Residual binder content
- Residue on sieving
- Sedimentation after 60 rotations
- Coagulation value when mixed with standard dolerite chippings

Cationic emulsion

- Viscosity at 50 ℃
- Residual binder content
- Residue on sieving
- Sedimentation after 60 rotations
- Coagulation value when mixed with standard dolerite chippings
- Particle charge determination
- Determination of binder deposit on the cathode

The tests required on binders for seal work are summarized in Table 9-1.

Table 9-1 - Summary of recommended control tests on bitumens during construction

Tests	Bitumen emulsion Anionic - SABS 309[46] Cationic - SABS 548[47]	Penetration grade bitumen (SABS 307)[45]	Polymer-modified bitumen (SABITA Manual 3)[50)]	Bitumen rubber	Cutback bitumen (SABS 308)[41]
	Water content Saybolt Furol Viscosity	Penetration @ 25 ℃ R & B softening point	Penetration (after 24 hrs curing @ 25 ℃) R & B softening point Dynamic viscosity (Haake)	Ball pen. Resilience Compression recovery 5 min 1 hour 1 day 4 day Dynamic viscosity (Haake) Flow R & B softening point	Viscosity Distillation to: 190 ℃ 225 ℃ 260 ℃ 316 ℃ Residue at 360 ℃ Penetration on residue
Sampling frequency	2 x 1ℓ from each spray tanker. Notes : 1 x 1 ℓ to be kept on site as a duplicate sample	3 x 1 ℓ from each delivery or spray tanker. Notes : If the laboratory test results are out of specification, the SABS tests for compliance with SABS 307[45] are carried out, otherwise 2 x 1 ℓ samples are kept on site as replicate samples.	3 x 1 ℓ samples from each delivery or spray tanker. Notes : (i) Elastic recovery at 10 ℃ and ductility at 10 ℃ are tested off-site on the first sample and thereafter only if the site laboratory results show that the binder is out of specification. 1 x 1 ℓ sample is kept on site as a duplicate sample. (ii) The penetration of the base bitumen is usually specified.	2 x 1 ℓ samples at start of spray and 2 x 1 ℓ samples at end of spray. Notes : (i) 1 x 1 ℓ sample is kept on site as a duplicate. (ii) The penetration grade bitumen should conform to the requirements of SABS 307[45] and its latest amendments at time of tender.	3 x 1 ℓ sample from each delivery or spray tanker. Notes : (i) 1 x 1 ℓ tested on site; (ii) 1 x 1 ℓ tested off-site; (iii) 1 x 1 ℓ kept on site. Off-site tests are carried out on the first sample and when required by the Engineer.

Notes:

It is particularly important to determine residual bitumen content values when diluted bitumen emulsions are sprayed.

The residual bitumen content of each truck load of emulsion delivered should be determined.

The residual bitumen content of each truck load of diluted emulsion sprayed should be determined.

When emulsion is used for seal work it is advisable to establish its viscosity.

9.1.1.5 Modified binders

Current recommendations regarding the frequency of sampling and testing for modified binders is discussed in TG1 [(70)].

9.1.2 Checking of Plant

9.1.2.1 Distributor

- The supervisor should ensure that the distributor has a valid certificate for spraying and that the numbers of the pump, spray bar and dipstick are on the certificate.
- He should ensure that the machine is not leaking oil, diesel fuel or bitumen.
- The master screen in the system should be checked for cleanliness - especially when bitumen rubber is sprayed or after the distributor has sprayed bitumen rubber and is currently spraying normal binder.
- The supervisor should check that the nozzles are correctly set, that the nozzles at the extremities of the spray bar are "end nozzles" and that uniform nozzles are fitted in between the end nozzles.
- For checking lateral distribution of binder by distributor, the field test described in APPENDIX J should be carried out.
- He should check that all nozzles are clean by means of a trial spray well away from the road prism.
- He should ensure that the distributor has proper "fish plates", one at each end of the spray bar.
- He should ensure that the distributor does not start from zero speed at the beginning of the section to be sprayed but from 4 to 5 metres before the start.

9.1.2.2 Self-Propelled Chip Spreaders

The supervisor should:

- check that the "rollers" of distribution bins are not worn or bent. The roller drum support bearings must also be in good condition
- check that the conveyor belts of the chip spreader are in a good condition and not cut or worn, so as to ensure continuous application of aggregate without breakdowns occurring
- check that the gates of the bins are uniformly and correctly adjusted so as to give a uniform application before aggregate is applied on the road
- check that the sieve in front of the "roller" of the distribution box is in place and adjusted to ensure that clean aggregate initially falls on the binder and that, if any dust is present, this falls on top of the aggregate
- A dry run should be done to ensure that application of aggregate is uniformly applied to correct requirements
- After the trial run with the chip spreader has been done for all seal work, the supervisor and operator should agree on the application rates required. For (a) Cape Seals and (b) one and a half or double seals, where an "open" application may be required, the reduction in application can be more accurately established before the work commences.

9.1.2.3 Rollers

The supervisor should ensure that the contractor has at least two self-propelled pneumatic-tyred rollers fully ballasted on site in good working condition (20 tons unballasted), depending on the daily output planned by the contractor.

It is recommended and advisable that heavy pneumatic rollers be used for single seal reseal work. Light steel wheel rollers may be used where the existing surface is smooth before the application of the fogspray.

For double seal and Cape Seal work, steel-wheeled rollers are required in addition to the heavy pneumatic-tyred rollers.

There should be no leaks or spillage of any kind from the equipment, e.g. (oil, fuel, etc.) on the surface of road, either before or after the seal has been applied.

The tyre pressures of pneumatic-tyred rollers should be checked for correctness and uniformity of pressure and should be in good condition.

Tyre sizes and shapes should be uniform. Only tyres manufactured for the purpose should be allowed.

Tyre scrapers and spray nozzles for wetting the tyres must all be in good working order.

9.1.2.4 Trucks and loader

There should be sufficient trucks in good working condition and the loader should have sufficient capacity to enable each spray to be covered within 15 - 20 minutes of application. Trucks should be provided with correct couplings to couple to the chip spreaders.

9.1.2.5 Rotary brooms

The contractor should have at least two rotary brooms in good working condition with uniform broom segments.

Sufficient hand brooms and shovels should be available to remove any excess aggregate which may have been applied at joints or truck changes and for any other emergencies resulting from breakdown of equipment.

> *HINT: When heavily trafficked roads are being sealed and the width of carriageway exceeds 2 lanes, it is advisable to use a vacuum broom with self-propelled brooms (at least 2) to leave the surface free of loose chips when the road is opened to traffic at rush hour.*

9.1.2.6 Water bowsers

Sufficient water trucks should be available to lay the dust on any deviation adjacent to the surfacing project.

> *HINT: When an emulsion binder is used and dusty aggregate is all that is available, a light spray of water before the emulsion is applied will improve the quality of work.*

9.1.3 Road checks

The supervisor should:

- check that road signs and general traffic control arrangements have been made, e.g. he should make certain that the barricades are such that traffic cannot inadvertently be directed onto the surface being sprayed

- check that the prepared surface to be sprayed has been approved and is ready for spraying. No unwanted material should be carried over on the surface, i.e. mud, dust etc
- ensure that the area to be sprayed is properly demarcated (with twine held down with steel nails at 5m intervals on straight sections and at 3 m intervals on curves) to guide the distributor operator
- ensure that the deviation close to the area to be sprayed is watered to control dust
- ensure that the contractor has made adequate arrangements for equipment and materials to cover the sprayed area in the specified time
- check that there are no obstructions in the line of spray
- ensure that, after spraying the distributor does not park on the road without a "drip strip" being placed under the spray bar
- ensure that the specified reinforced paper is available and placed properly at the beginning and end of the section to be sprayed and that arrangements have been made to remove and dispose of the jointing material. Special “drip strips” of reinforced paper may be required where the distributor is parked on the road prior to spraying.

9.1.4 Control checks and records

a) Single and multiple seals and Cape Seals

The supervisor should:

- check that the bituminous binder is of the correct type and grade (e.g. tar, prime, bitumen or emulsion). He should obtain the batch certificate from the binder distributor operator, stating the grade of binder and batch number.
- record the temperature of the binder and ensure that the same type of binder is always sprayed at the same temperature
- record the road and air temperatures, as well as the maximum and minimum temperatures for 72 hours
- record the dipstick readings to determine the quantity of binder in the distributor. The distributor should be parked on level ground for this purpose.
- check alignment of distributor, i.e. width of spray bar + 100 mm should correspond with the distance of the guide chain from the edge of the surface to be sprayed
- check the height of the spray bar before spraying - (uniform height above surface for width of spray)
- record the length and width of road sprayed and the final dipstick reading. The distributor should be parked on a level surface. <u>Dipstick readings should be taken by the supervisor himself.</u>
- record the tachometer reading in case adjustments to the distributor’s speed of spray are required.

b) Slurry seals

The supervisor should:

- ensure that the road surface is cleaned and free of dust, mud or any other deleterious material
- ensure that the surface is kept <u>damp</u> before the slurry is applied
- ensure that the grading of the aggregate is checked on a regular basis and that it is the appropriate grading.
- The bulking factor of the aggregate should be established on a regular basis before the aggregate is introduced into the mixer and the quantities of emulsion to be added should be determined. These results should be recorded.
- The area covered for each batch should be recorded, together with the amount of emulsion used.

- The air and road temperatures and the time and date of application should be recorded.

9.1.5 Guidelines for process control and acceptance

The quality of seal work is highly dependent on the supervision, meticulous attention to detail and to close compliance with the specifications. The following guide lines are a summary of the various salient features of the items covered in the construction clauses and check lists for plant, materials and construction procedures.

- All plant should be checked before work commences.

- All materials should conform to the specifications and standards set for the project, even if this means that the aggregate has to be rescreened or washed prior to use.

- On single seals, after completion of the work, the aggregate should lie in shoulder-to-shoulder contact.

- On double seals, the aggregate should lie as specified for double seals: in shoulder-to-shoulder contact for the first application and as nearly shoulder-to-shoulder as possible for the second application, after the work has been completed.

- For one-and-half seals, the first application of aggregate can be opened up to receive the second application of aggregate.

- On completion of the work, all loose aggregate should be broomed off the road. This operation may have to be repeated on succeeding days.

- The application of double layers of aggregate should be avoided when aggregate is applied on the tack coats.
- Efficient rolling using heavy pneumatic-tyred rollers virtually equates to opening the road to traffic for lengthy periods under controlled conditions. Superior performance is achieved from any seal which has been properly rolled.

- Uniform application of binders can only be achieved if the preliminary tests on the distributor are carried out before spraying operations commence.

- The control of operations at the joints of each spray by using reinforced paper (at the start and the end of spray) is essential, as poor workmanship here may only be detected 2 to 3 years after the event.

- Careful attention should be given to the skill and workmanship of the distributor operator regarding the longitudinal joints between adjacent sprays.

- The rates of application of the binder should be within specification. To obtain consistent spray rates it is advisable to spray each load at the same temperature.

The degree of accuracy for the spraying of binders for acceptance should be within 5 per cent of the specified rate.

The acceptance control of the work is dependent on each and every step of the process, e.g.:

i. Approval of the aggregate

ii. Approval of the precoating

iii. Approval of the aggregate spread rates

iv. Approval of the binder application rates

v. Approval of the brooming and rolling

vi. Approval of the string lining of the road and the handling of the joints, both transverse and longitudinal.

10 MAINTENANCE PLANNING AND BUDGETING

10.1 MAINTENANCE PLANNING

The identification, planning, budgeting, design and execution of maintenance projects are all important activities in the process of managing road networks. However, each of these activities requires effort from the responsible agency and should be properly scheduled to ensure that the appropriate maintenance actions are taken timeously. A typical remark from experienced pavement engineers and technicians is "rather seal one year too early than one year too late". Experience, therefore, indicates that deferred maintenance is rarely an economical solution, as it often results in an expensive major rehabilitation at a cost approximately ten times greater than that of a reseal.

Using the typical graph of pavement deterioration shown in Figure 10-1, the time needed to schedule activities, budget, let tenders and to carry out maintenance actions, indicates that projects should be identified at a very early stage. Based on the high percentage of roads in South Africa sealed with surfacing seals as well as on their performance, a visual assessment method (TMH9)[6] has been developed to assist in the timely identification of reseal needs.

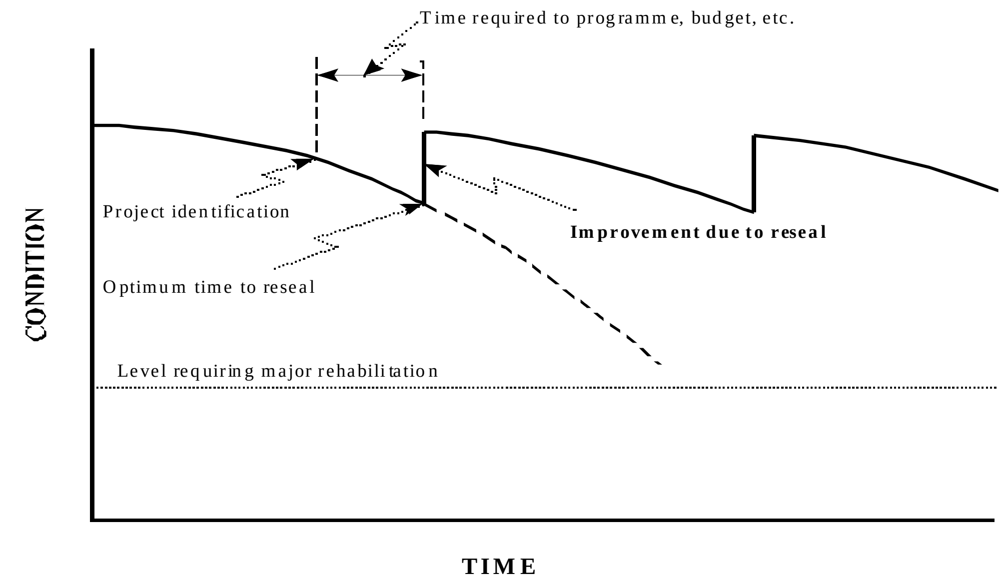


Figure 10-1 Importance of timely project identification

Pavement management systems have been implemented by numerous road authorities as a tool to assist in the identification, planning and budgeting of maintenance and rehabilitation activities.

Although sophisticated models are sometimes used to evaluate the implications of different maintenance strategies (including types of reseals), there is a high confidence in South Africa with regard to the knowledge built into locally developed PMS', recommending the timing of actions and appropriate measures (TRH22)[5] .

10.2 BUDGETING

Different approaches are used in the preparation of budgets for maintenance and rehabilitation needs, depending on the existence and level of sophistication of PMS' in operation. The following may be used as guidelines:

- The average increase in seal costs is in the order of 14 per cent per annum. (Refer to APPENDIX C for relative costs of surfacing seals.)

- The World Bank recommends that about 2,5 per cent of the road network asset value (pavement and surfacing layers) should be allowed for per annum as an overall target maintenance budget. Historical information from roads authorities in South Africa indicates that, on average, approximately 1 per cent of the pavement value is required per annum to carry out routine pavement maintenance and that a further 1 per cent of the value is required per annum to reseal the pavement at appropriate intervals.

- The average life of surfacing seals is believed to be in the order of 10 years (rural roads), which indicates that approximately 10 per cent of the road network should be resealed per year. (Refer to APPENDIX B, Life expectancy of seals.)

Reseal needs identified by means of pavement management systems in South Africa over more than 10 years, indicate that the figure of 2,5 per cent mentioned is realistic for budgeting purposes on network level.

The complete life cycle costs should be estimated during the initial design of a facility and decisions with regard to the pavement structure and initial surfacing should take into account the ability of the road authority to maintain the facility. Cheaper pavements and lower cost initial surfacings usually result in more frequent maintenance and higher recurrent costs to ensure good performance. The policy of the road authority with regard to these issues can, therefore, govern the future maintenance budget.

11 CONSTRUCTION OF SEAL WORK USING LABOUR-INTENSIVE METHODS

11.1 INTRODUCTION

Labour-intensive construction of seals can be done effectively with bitumen emulsion binders. Depending on the type of seal, anionic or cationic emulsion may be used. The quality of the work could be equivalent to that of a machine-laid seal surfacing, depending on the care taken when doing the work. To obtain the most successful results, it is essential that the personnel engaged in the work are adequately trained in the use of all the minor equipment required and are familiar with the details of the application of the various surfacing specifications.

11.2 SEALS WHICH CAN BE CONSTRUCTED EFFICIENTLY BY LABOUR-INTENSIVE METHODS

11.2.1 Slurry seals

Slurry seals can be split into:

For maintenance and pre-treatment	• Fine slurry • Medium slurry
For new surfacing	• Medium slurry • Coarse slurry

11.2.2 Cape Seals

Cape Seals, which consist of a single seal (19 mm or 13 mm) plus a slurry, are mainly used for new surfaces. The binder used may be either cationic emulsion for the tack coat or anionic emulsion for both the tack coat and penetration sprays, depending on the aggregate used. The grading of the slurry aggregate for a Cape Seal may be either “medium” or “coarse”, depending on the surface texture of the 13 mm or 19 mm seal.

11.2.3 Double seals

Double seals consist of two applications of aggregate (13,2 mm and 6,7 mm or 9,5 mm and crusher sand) and two applications of binder, i.e. a tack and penetration spray plus, in some cases, a fog spray. The binder for the tack coat and penetration spray may be either cationic or anionic emulsion. An emulsion with a bitumen content of 65 per cent is recommended in order to increase the viscosity of the emulsion.

11.2.4 Single seals

The use of single seals with an emulsion tack coat limits the size of aggregate which can effectively be used to:

- crusher dust or sand; or
- 9,5 mm or 6,7 mm aggregate.

These seals can be effectively used on new surfaces for low volume roads with well prepared smooth base layers.

Cationic bitumen emulsions are used for sand seals.

Cationic bitumen emulsion is used for 9,5 and 6,7 mm aggregate. When 9,5 mm aggregate is used a penetration fog spray is recommended.

11.2.5 Slurry bound Macadam seals

Local research since 1995 has led to the knowledge and ability to construct this high quality surfacing at relatively low cost.

Following the preparation of the base layer and priming thereof, single size aggregate (9.5 mm, 13.2 mm or 19.0 mm) is placed on the road surface and levelled to the required thickness (not less than 2 times the ALD of the aggregate) using thickness guides and straight edges. A pedestrian roller, without vibration, is used to orientate and level the aggregate, where after a slurry is vibrated into the layer. If necessary, a fine slurry is applied as a final layer.

The slurry bound Macadam has been constructed with success from 15 mm to 50 mm and is highly effective in accommodating heavy vehicle turning actions

11.3 ADVANTAGES AND DISADVANTAGES OF THE VARIOUS TYPE OF SEAL

11.3.1 Slurry seal

If properly constituted, slurry seal is a powerful medium for multi-purpose surfacing for maintenance, pre-treatment and new surfaces.

- It is user-friendly and can be mixed and laid with a minimum of light plant.
- The method of measuring each batch accurately and mixing in a small concrete mixer ensures a relatively uniform product which can be laid rapidly.
- There are very few possible "hold-ups" resulting from plant breakdowns. At worst, hand-mixing in wheelbarrows can be resorted to if necessary.

One disadvantage is its cost per square metre. This cost would appear to be high but, depending on the thickness laid, the cost may be controlled by limiting the thickness, thus reducing the cost per square metre.

11.3.2 Cape Seals

Cape Seals are normally used for new surfaces. Advantages of Cape Seals are -

- They are relatively easy to lay and are user-friendly.
- Application rates of the binder are not critical as regards under-application, as the slurry will compensate for any under-application.

- Structurally, they are sounder than double seals and perform well under fairly heavy traffic, such as on bus routes in townships.

One disadvantage is their relatively high cost - they are an expensive surfacing medium - but this is compensated for by their longer, maintenance-free life.

11.3.3 Double seals

Although, based on the cost of the materials, double seals would appear to be more economical than slurry seals or Cape Seals, they are more difficult to lay accurately with a uniform final surface appearance. However, with trained operating staff it is possible to obtain a neat and acceptable finish.

The main difficulties are related to control of the rate of application of the binder.

Rolling with a pedestrian roller (Bomag 65 or 90) is not as effective as rolling with a heavier self-propelled static steel-wheeled roller or a heavy pneumatic-tyred roller. Efficient rolling of a surface affects its ultimate performance.

The life of this type of seal depends very largely on binder application rate and rolling techniques.

11.3.4 Single seals

When applied to a well constructed smooth base, which have been primed, single seals can be cost effective if they are properly applied. However, as the rate of application of the binder is largely governed by the potential run-off of the binder, this limits the rate of application to 0,7 to 0,8 ℓ/m², necessitating a second application of binder in the form of a penetration spray.

When 9,5 mm or 6,7 mm aggregate is used it is recommended that a 65 per cent cationic bitumen emulsion binder be used, as the viscosity of this material is higher than that of a normal 60 per cent anionic bitumen emulsion.

One disadvantage of this type of seal is that single seals are relatively thin surfaces which are prone to mechanical damage and, if laid on unstabilised base layers, are prone to rapid development of potholes.

Their main advantage is the low cost of the surfacing. They are also user-friendly in that the effects of over-application of the binder, especially on low volume roads, are not serious. Under-application is a more serious problem.

Use of a motorised hand sprayer overcomes the problem of "tramlines" being sprayed. This can be a serious problem on thin surface treatments.

11.3.5 Slurry bound Macadam seals

Although proper training of the work team is required and particular attention should be given to the slurry design and full depth penetration, no problems have been experienced in obtaining work of acceptable quality.

Tendered prices for a 15 mm Slurry bound Macadam are similar to 19 mm Cape seals and thicker layers compare favourably with similar thickness hot mix asphalt.

Dependent on the thickness of the layer a work team of ten labourers could complete approximately 240m^2 to 400m^2 per day.

The main benefits of this seal type could be summarised as:

- No major plant required
- Ease of construction
- High strength - ability to accommodate heavy vehicle turning actions
- Ability to rectify small surface undulations
- Competitive price.

11.4 BASIC PLANT AND EQUIPMENT REQUIRED FOR LABOUR-INTENSIVE SURFACING

11.4.1 Equipment required for slurry seals

The equipment required for mixing and spreading slurry seals is listed below:

- Stand for 210 litre drum and steel ramps
- Small concrete mixer (250/175 litre)
- Small spreader box
- Templates/steel rails
- Shovels
- Steel and rubber squeegees
- Wheelbarrows
- Measuring containers
- String line
- Hessian.

11.4.2 Plant required for double and single seals

The plant required for the application of double and single seals is listed below:

- A motorised hand sprayer is recommended, as a more uniform rate of application of binder can be achieved. The sprayer should also have a gas burner for heating the emulsion.
- Pedestrian roller, a Bomag 65 or Bomag 90 or the equivalent
- Lifting equipment for 210 litre drums of binder
- Screens (see Figure 11-9)
- Measuring containers for spotting the aggregate (see Figure 11-3)
- Wide brooms
- String line.

11.4.3 Equipment required for Cape Seals

As a Cape Seal is a combination of a single seal and a slurry seal, the equipment required is as described in paragraphs 11.4.1and 11.4.2.

11.4.4 Equipment required for Slurry bound Macadam Seals

Apart from the equipment required for slurry seals as described in paragraph 11.4.1, straight edges are required to level the aggregate and a pedestrian roller required to assist with the penetration of the slurry..

11.5 CONSTRUCTION: SOME PRACTICAL HINTS AND PRECAUTIONS

11.5.1 Slurry seals

The process of design and selection of materials for slurry seals is exactly the same as that for slurry seals laid by machine.

Application of slurry by hand, however, requires certain precautions when the material is placed on new work. The thickness of the layer should be carefully controlled by means of templates in order to ensure uniform thickness of the desired layer. Where excessive thicknesses are required to rectify excessive unevenness in the levels in the finished base, this unevenness should be rectified before the final layer of slurry is applied. If steel templates are used for controlling the thickness of the surfacing, it is possible to control the depth of slurry by checking before application, even if this means chipping away some of the high spots. As the work progresses relatively slowly, this method is both practical and effective.

11.5.2 Single, Double & Cape Seals

11.5.2.1 Binder application

The main problem experienced in seal work with the application of binders concerns their application for the tack coat and penetration sprays at specified spray rates. To overcome these problems cognizance should be taken of the following:

- When a particular type of seal is specified and the rates of application of the binder are designed, it should be borne in mind that there is a limit to the quantity of emulsion which can be applied for the tack coat before run-off of the emulsion occurs because of the cross fall or longitudinal gradients.
- Any shortage in the amount of binder required in the tack coat can be accommodated by increasing the application rate of the penetration spray.
- Selection of a binder with higher viscosity can overcome some of the above problems.
- The use of a motorised hand sprayer will overcome many of the problems of uniformity of application if it is used by trained operators.
- When emulsions are used, the problem of over-spraying/excessive application will only occur if untrained staff are used, as over-application is visually discernable.
- It is advisable to check the rate of delivery (ℓ/min) of the sprayer and to determine the rate of application over a measured area before proceeding.
- It is possible to control the rate of application with a stop watch once the rate of delivery is known.

11.5.2.2 Application of aggregate

Hand labour may be used to apply aggregate efficiently and neatly if training of the field staff is done and if the following aspects are borne in mind:

- The aggregate to be applied should be neatly and accurately spotted along the shoulder of the road to be surfaced before spraying commences.
- The aggregate should not be shovelled onto the sprayed surface but should be "pitched" into the air so that the chips fall vertically onto the surface without rolling.
- The aggregate should lie shoulder to shoulder. Careful back-chipping and brooming of the aggregate, to ensure that it does not lie in double layers, can effectively be done with hand labour.
- Care should be taken, when the surface is rolled with a pedestrian roller, that only limited vibration is used.
- Screens should be used on both sides of the road to avoid contamination of kerbs, gutters or concrete drains. Where there are no kerbs, gutters or drains, the edges of the road should be set out so that neat straight edge lines of the surface are obtained. This may be done by using ±7 mm diameter rope as guide lines on the edges of the surface.

Table 11-1 - Application rates for binder and aggregate

ALD (mm)	Rate of application of 60 % emulsion (ℓ/m^2)	Rate of application of aggregate (m^3/m^2)
4	1,5	0,004
5	1,8	0,005
6	2,1	0,006
7	2,4	0,007
8	2,7	0,008
9	3,0	0,009
10	3,3	0,010

Table 11-2 - Adjustments to final binder spray rates

Traffic count (vpd) (Est for the road)	Adjustment to calculate total spray
500	No adjustment
250	add 0,25 ℓ/m^2
< 100	add 0,33 ℓ /m^2

Notes:

The aggregate should be applied before the emulsion breaks and turns black.

The surface of the aggregate should be lightly sprayed with water but not flooded before the emulsion is applied.

In a Cape Seal the quantity of binder sprayed should be reduced by 15 - 20 percent.

The above simplified method is included for the use of field staff whom do not have access to the expertise required for the sophisticated design methods described in Chapter 7.

11.5.3 Slurry bound Macadam seals

The principle of this surfacing is to obtain stone-to-stone contact with only the voids filled with a slurry. Using smaller aggregate requires a finer slurry grading to be able to penetrate.

Testing the consistency of the slurry mix on a regular basis is important as workers often tend to add too much water to the mix.

Checking for full-depth penetration is essential, especially at the road edges. During the initial stages of projects, it is often necessary to chip out the surfacing at the edges and to replace both aggregate and slurry.

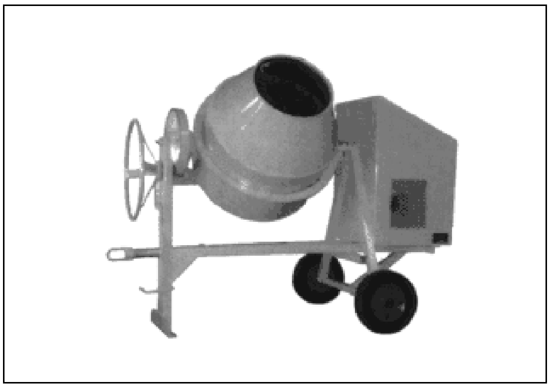


Figure 11-1 Concrete Mixer (250/175ℓ)

For uniform mixing and increasing the speed of the work, a small concrete mixer is recommended. For minor work (maintenance repairs), the slurry can be mixed in wheelbarrows.

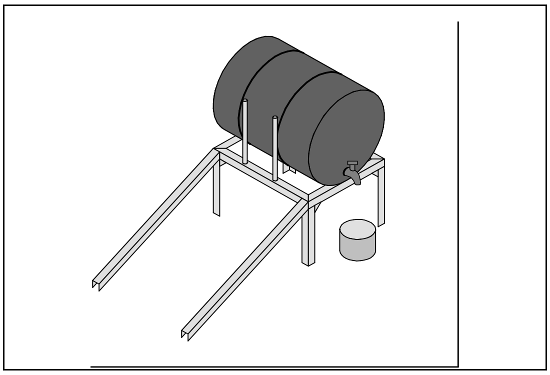


Figure 11-2 Stand for 210 litre drums of emulsion

An easily removable ball-valve/tap is used for discharging emulsion into measuring containers in order to ensure a clean and neat operation with minimum wastage. The operation is facilitated by rolling the drum up the ramp onto a steel frame which is high enough to accommodate the measuring cans/containers.

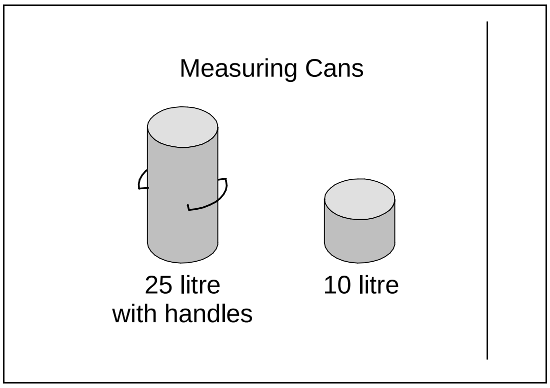


Figure 11-3 Measuring Containers

For accurate work, measuring containers are essential for both aggregate and emulsion. 25 litre cans with handles are user-friendly. 10 litre measuring cans are used for cement.

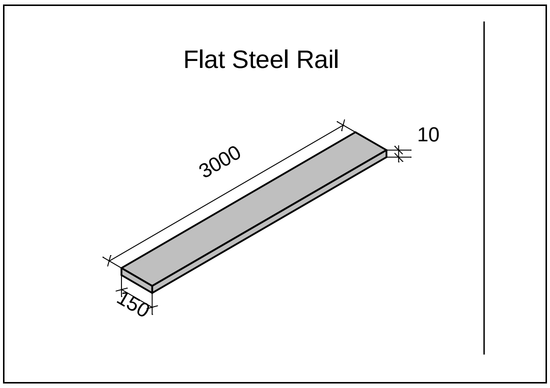


Figure 11-4 Flat Steel Rails

Flat steel rails ensure a uniform thickness of slurry seal on new work.

The slurry should be placed 10 mm thick when wet. This dries out to ± 6 mm.

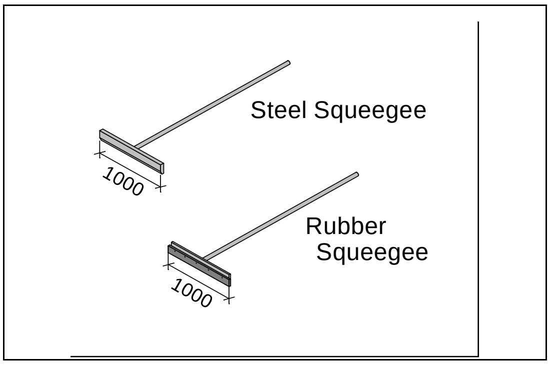


Figure 11-5 Squeegees

Squeegees, both steel and rubber, are required for spreading slurry.

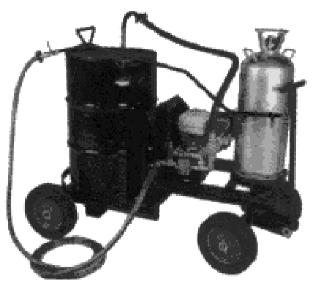


Figure 11-6 Motorised Hand Sprayer

The use of a motorised hand sprayer results in more uniform application of binder than a hand-operated sprayer. If cationic bitumen emulsion is used, the material should be heated to between 50°C and 60°C.

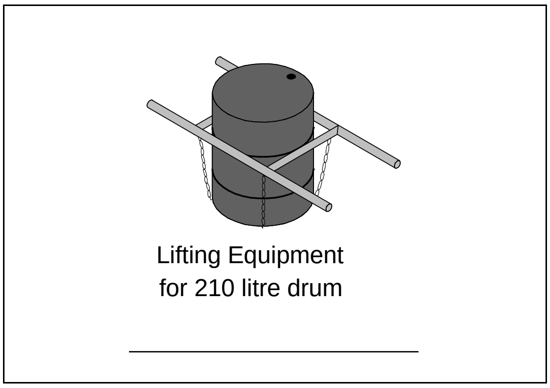


Figure 11-7 Lifting Equipment

The lifting equipment can be made up in any workshop. It is most useful and practical for picking up full drums of binder.

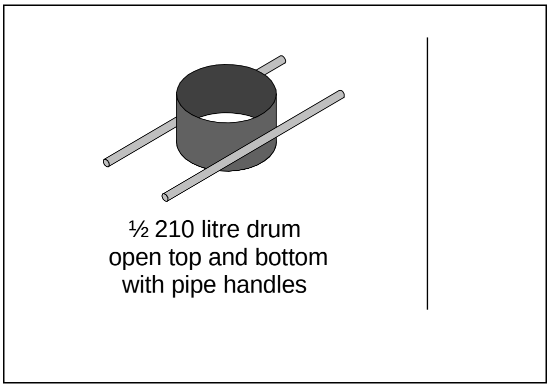


Figure 11-8 Measuring Containers

A half drum container is light and economical to manufacture. For spotting heaps of aggregate along the constructed base, the half drum works well.

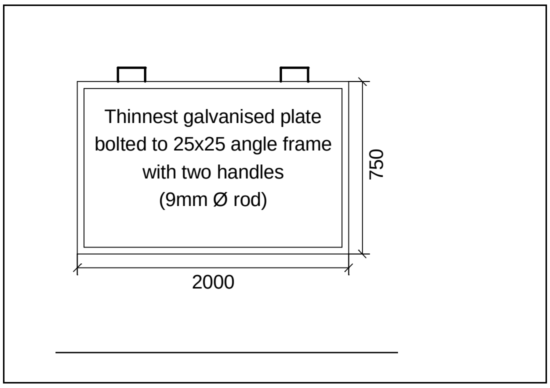


Figure 11-9 Protective Screens

In addition to the kerbs or side drains being covered with sand, protective screens can be used to ensure a clean neat line when the base is hand-sprayed.

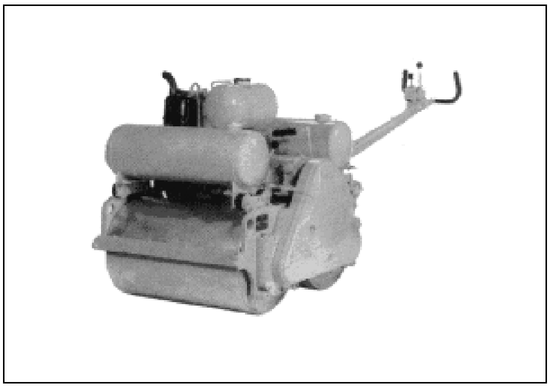


Figure 11-10 Pedestrian Rollers

The use of pedestrian rollers (Bomag rollers or their equivalent) is recommended.

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APPENDIX A

DEFINITIONS AND GLOSSARY OF TERMS

DEFINITIONS

Adhesion properties: The ability of the aggregate to form a strong and lasting bond with the binder.

Aggregate: Inert hard rock-type material which has been crushed and screened to produce the stone, sand or grit used in surface seals.

Aggregate crushing value: A measure of the ability of the aggregate to resist crushing under a compressive load. (See TMH1, Method B1[17].) (See also Hardness.)

Asphalt: A mixture of bituminous binder and aggregate in a prescribed ratio (this includes the term premix).

Average Least Dimension of aggregate (ALD): The overall average of the least dimension for a number of particles (at least 200) where the least dimension of an aggregate particle is the smallest perpendicular distance between two parallel plates through which the particle will just pass. (See TMH1, Method B18[17]).

Ball penetration test: A test for measuring the penetration resistance of a road surface using a steel ball with a diameter of 19 mm. The result (corrected for temperature and nature of existing surface) is used in the design of surface treatments.

Bitumen: A non-crystalline solid or viscous mixture of complex hydrocarbons which possesses characteristic agglomeration properties. Bitumen, obtained from crude petroleum by refining processes softens gradually when heated and is substantially soluble in trichloroethylene.

Bitumen emulsion: A liquid mixture in which a substantial amount of bitumen is suspended in a finely divided condition in an aqueous medium of one or more suitable emulsifying agents.

Bitumen rubber: Bitumen modified by the addition of approximately 20 per cent rubber crumbs to improve certain properties of the binder. Additionally, 2 to 5 per cent of liquid additive is often added to further improve its properties.

Bituminous binder: A product such as bitumen or derivatives thereof (e.g. cut-back bitumen, modified binder or bitumen emulsion) which acts as a binder for the aggregate in surfacing.

Bituminous surfacing: A surfacing seal or layer of premix asphalt which is directly subjected to traffic forces.

Bleeding: The condition which arises when excess binder is present in the seal, causing a layer of tacky binder to appear above the aggregate.

Blinding: The application of fine aggregate such as crusher sand (not dust) at a low application rate (0,0025 m^3/m^2) on top of fresh binder, to reduce the tackiness.

Brittleness: The condition which arises when the seal cracks, splinters or breaks under traffic impact or as a result of rapid deformation because of its rigidity.

Cape Seal: An application of bituminous binder followed by a layer of stone followed by one or two applications of slurry.

Choked seal: This is an open single seal, choked with a smaller aggregate, without the application of a binder penetration coat.

Cut-back bitumen: A penetration grade bitumen whose viscosity has been reduced by the addition of 5 to 20 per cent of a volatile solvent (kerosene or diesel).

Diluted emulsion: A mixture of a stable grade emulsion with water, generally in a 50/50 ratio, to obtain a lower binder content by volume. It is sprayed to enrich and/or soften the binder of an existing seal.

Double seal: An application of bituminous binder followed by a layer of stone followed by another layer of bituminous binder and a layer of smaller stone.

Dryness: The condition which arises when binder loses its elastic, plastic and adhesive properties.

Effective layer thickness: The volume of stone + voids covering the base of a tray or pan of a given area, divided by the area of the base of the tray or pan. This is used in the CSIR's rational design method instead of ALD. (see APPENDIX K.)

Embedment: The estimated total amount by which the sealing stone will be pressed into the underlying surface during the construction process as well as by traffic using the road after construction.

Equivalent light vehicles (elv): One car or light delivery vehicle per lane per day. Any vehicle larger than a car or light delivery vehicle is taken to be equal to 40 light vehicles.

Flakiness Index (FI): The mass of particles in the aggregate, expressed as a percentage of the total mass of that aggregate, which will pass through the slot or slots of specified width for the appropriate size fraction. The widths and lengths of the slots are respectively half and double those of the sieve openings through which each of the fractions passes. (See TMH1, Method B3T[17].)

Flushing: See Bleeding.

Fog spray: A light application of bitumen emulsion binder to the final layer of aggregate of a surfacing seal or to an existing bituminous surfacing as a maintenance treatment.

Geotextile seal: This consists of a single seal constructed on top of a geotextile material tacked with a bituminous binder to the existing surface.

Grit seal: A sand seal with a coarse-graded aggregate, such as that given in Table 8-1.

Hardness: The ability of the aggregate to resist crushing under a compressive load. (See TMH1, Method B1[17].) (See also Aggregate Crushing Value.)

Inverted double seal: This is a double seal in which the larger sized aggregate is applied on top of the smaller aggregate.

Liquid limit: The liquid limit of a soil is the moisture content of the soil at which the soil passes from a plastic to a liquid state.

Modified binder: Any standard bituminous binder which has been mixed with additives to produce a more durable binder with better mechanistic properties and/or lower temperature susceptibility than the original binder. Additives often used for this purpose are mineral fillers, rubber, plastic, fibres, metal bonds and polymers.

Penetration coat: The second binder layer of the seal which is sprayed after the first layer of stone of a double seal is spread and rolled.

Penetration grade bitumen (bitumen): A viscous material obtained from petroleum by refining processes.

Permeable surfacing: The condition which exists when an undesirable amount of water seeps through the surfacing to the base and subbase layers. The degree of permeability can vary.

PI: See Plasticity Index.

Plastic limit: The plastic limit of a soil is the lowest water content at which the soil remains plastic.

Polishing: The tendency of certain stone types to become smooth and rounded under the action of traffic. This should not be confused with attrition or bleeding.

Polymer-modified binder (PMB): Any standard bituminous binder to which a polymer has been added to produce a more durable binder with improved mechanical properties.

Porous seal: A seal which contains internal voids such that water can pass through with ease (e.g. honeycomb structure). The degree of porosity can vary.

Precoating: The precoating of the seal stone with a binder (tar- or bitumen-based) to improve the initial adhesion between the stone and the seal binder.

Premix: Premix refers to asphalt used for patching i.e. a mix of binder and aggregate which should meet specific requirements. (See also Asphalt.)

Prime coat: A layer of binder applied directly on top of the base course to promote and maintain adhesion between the surfacing and the base. This layer also prevents the absorption of surfacing binder by the base and assists in sealing the voids near the surface. It acts as a curing membrane on stabilised bases.

Reseal: A surfacing seal for maintenance purposes.

Residual binder: The residual binder or tar remaining after evaporation of any volatile constituents such as oils in cut-back bituminous binder or water in bituminous emulsion.

Road tar: A viscous material prepared entirely from crude tars produced as a by-product of the carbonisation of coal in coke ovens or from crude tars produced by the Sasol gasification process. Tar products are not allowed anymore for road construction or maintenance purposes.

SAMI: See Stress Absorbing Membrane Interlayer.

Sand seal: An application of bituminous binder followed by a layer of clean sand.

Service life: The life of a seal is the period from the construction of the seal to the time when the functionality of the seal ceases.

Sideways Force Coefficient (SFC): A wheel is dragged along a pavement by a test vehicle at a specific speed and an angle of inclination of 20° to the direction of travel. The SFC is the ratio of the friction force normal to the plane of the wheel of the test vehicle and the normal load on the wheel and depends on the angle of inclination of the wheel to the direction of travel and gives an indication of the skidding resistance of the road surface at the test speed.

Single seal: An application of bituminous binder followed by a layer of stone.

Skid resistance: The ability of a surfacing layer through friction to provide resistance to skidding of a vehicle tyre which is moving over the surface.

Slurry: A mixture of suitably graded fine aggregate, cement or hydrated lime, bitumen emulsion and water.

Slurry seal: A surfacing seal consisting of a layer of slurry.

Split seal: This consists of a double seal in which the top layer of aggregate is split into two applications. The first application of the top layer of aggregate is usually done without a penetration coat.

Spray rate: The rate of application of the bituminous binder expressed in litres per square metre (ℓ/m^2) at a given temperature.

Spread rate: The rate of application of the surfacing stone (chips) expressed in cubic metres per square metre (m^3/m^2) of stone applied at the loose bulk density in the truck or heap.

Stone: A single-sized aggregate used in single or double seals.

Stress Absorbing Membrane Interlayer: A single seal with a polymer-modified binder (usually bitumen-rubber) placed on the existing substrate immediately below an asphalt overlay. Its purpose is to prevent or retard stresses or cracks penetrating into the overlying asphalt layer.

Surfacing: Surfacings consist of two components, namely aggregate and binder. The purpose of a surfacing is to provide a uniform, skid-resistant impermeable coating to the underlying pavement structure.

Surfacing maintenance: Measures which maintain the integrity of the road surface in respect of skid resistance, disintegration and permeability without necessarily increasing the structural strength of the pavement.

Surfacing seal (surface treatment): A thin layer of aggregate and bituminous binder which, being the uppermost pavement layer, is directly subjected to the forces of vehicular traffic.

Surfacing stone: Crushed aggregate with a single-sized gradation.

Tack coat: First spray of bituminous binder applied during the sealing process. (This should not be confused with a coat of suitable binder applied to an existing surface as a preliminary treatment to promote adhesion between the existing surface and a subsequently applied asphalt layer.)

Tar: A viscous material produced entirely from crude tars. Tars, commonly known as road tars, are either produced as a by-product of the carbonisation of coal in high temperature coke ovens or by the low temperature Sasol gasification (Lurgi) process. Tars manufactured at high temperatures are commonly referred to as RTH road tars and those manufactured at low temperatures are known as RTL road tars. Tar products are not allowed anymore for road construction or maintenance purposes

Texture depth: A measure of the relative height difference between the troughs and the crests of the aggregate in the seal.

Texture treatment: The treatment of an existing seal in order to achieve a more uniform texture or to make a rough texture finer in preparation for resealing. Texture treatment usually takes the form of a thin sand seal or a slurry that is swept or brushed into the existing seal.

Traffic: The total number of expected equivalent light vehicles per lane per day at the time of construction of the surfacing seal.

Varying texture: A non-uniform texture across the width of the road surface, e.g. where the surface appears smooth in the wheel paths and has a different texture elsewhere.

Viscosity: A measure of the degree of internal friction or of the power to resist a change in the arrangement of the molecules in a viscous material.

Volatiles: Solvents used in cutting-back agents and those constituents of bituminous binders which are readily vaporisable at relatively low temperatures.

APPENDIX B

LIFE EXPECTANCY OF SEALS

	LIFE EXPECTANCY OF BITUMINOUS SEALS (Years)			
Seal type	Traffic ** (elv/lane)	New construction seals	Reseal on sound structure	Reseal on structure with fatigue/active cracks
6,7 mm and sand	<2000	6	6	4
	2000 -10000	3	3	2
	>10000			
9,5 mm and sand	<2000	8	8	5
	2000 -10000	6	6	3
	>10000	3	3	
13,2 mm and sand	<2000	12	12	7
	2000 -10000	9	9	4
	>10000	6	6	2
13,2 mm and 6,7 mm	<2000	14		
	2000 -10000	10		
	>10000	8		
Cape Seal 19 mm	<2000	14		
	2000 -10000	10		
	>10000	8		
Cape Seal 13 mm	<2000	12		
	2000 -10000	8		
	>10000	5		
Sand seal	<2000	4	7	3
	2000 -10000	2	3	2
	>10000			
Fine slurry	<2000	4	4	2
	2000 -10000	2	2	1
	>10000			
Coarse slurry	<2000	7	7	4
	2000 -10000	4	4	2
	>10000	2	2	
6,7 mm	<2000		6	4
	2000 -10000		4	2
	>10000			
9,5 mm	<2000		10	6
	2000-10000		6	3
	>10000			
13,2 mm	<2000		12	7
	2000 -10000		9	4
	>10000		6	2
13,2 mm polymer modified	<2000		14	8
	2000 -10000		10	6
	>10000		8	3
13,2 mm BR	<2000		16	10
	2000 -10000		13	7
	>10000		10	5

Note:

*** Equivalent Light Vehicles (elv) - 1 heavy vehicle = 40 light vehicles*

APPENDIX C

RELATIVE COST OF SURFACINGS

TABLE C-1

Cost ratio of different types of surfacing seals relative to that of a 13,2 mm single seal

Type of surfacing seal		Binder	Cost ratio
Single seals	13,2 mm (precoated)	Penetration grade bitumen Bitumen rubber Polymer-modified bitumen	1,00 1,49 1,25
	13,2 mm + fog spray	Emulsion 65%	1,11
	13,2 mm + fog + sand	Emulsion 65% Latex emulsion	1,52 1,61
	9,5 mm (pre-coated)	Penetration grade bitumen Polymer-modified bitumen	0,92 1,08
	9,5 mm + fog spray	Emulsion 65%	1,01
	9,5 mm + fog spray + sand	Emulsion 65% Latex emulsion	1,24 1,41
	6,7 mm (pre-coated)	Penetration grade bitumen	0,60
	6,7 mm + fog spray	Emulsion 65%	0,87
	6,7 mm + fog spray + sand	Emulsion 65%	1,09
	19,0 mm (pre-coated)	Penetration grade bitumen	1,06
Texture seals	Sand seal (single)	Penetration grade bitumen MC 3000 Emulsion 65%	0,63 0,69 0,73
	Fine slurry (3 mm)		0,87
	Coarse slurry (6 mm)		1,32
	Rapid setting coarse slurry (10 mm)		2,10
Double seals	13,2 mm + 6,7 mm	Penetration grade bitumen Polymer-modified bitumen	1,43 1,82
	19,0 mm + 9,5 mm	Penetration grade bitumen	1,60
	19,0 mm + 6,7 mm	Split application Polymer-modified	2,10
	19,0 mm + 9,5 mm	Bitumen Rubber	2,30
Cape Seals	13,0 mm	Emulsion 65%	1,65
	19,0 mm	Emulsion 65%	2,21

APPENDIX D

SELECTION OF TYPE OF RESEAL

Figures D-1 to D-5 can be used to enable the types of reseal appropriate to different situations to be selected.

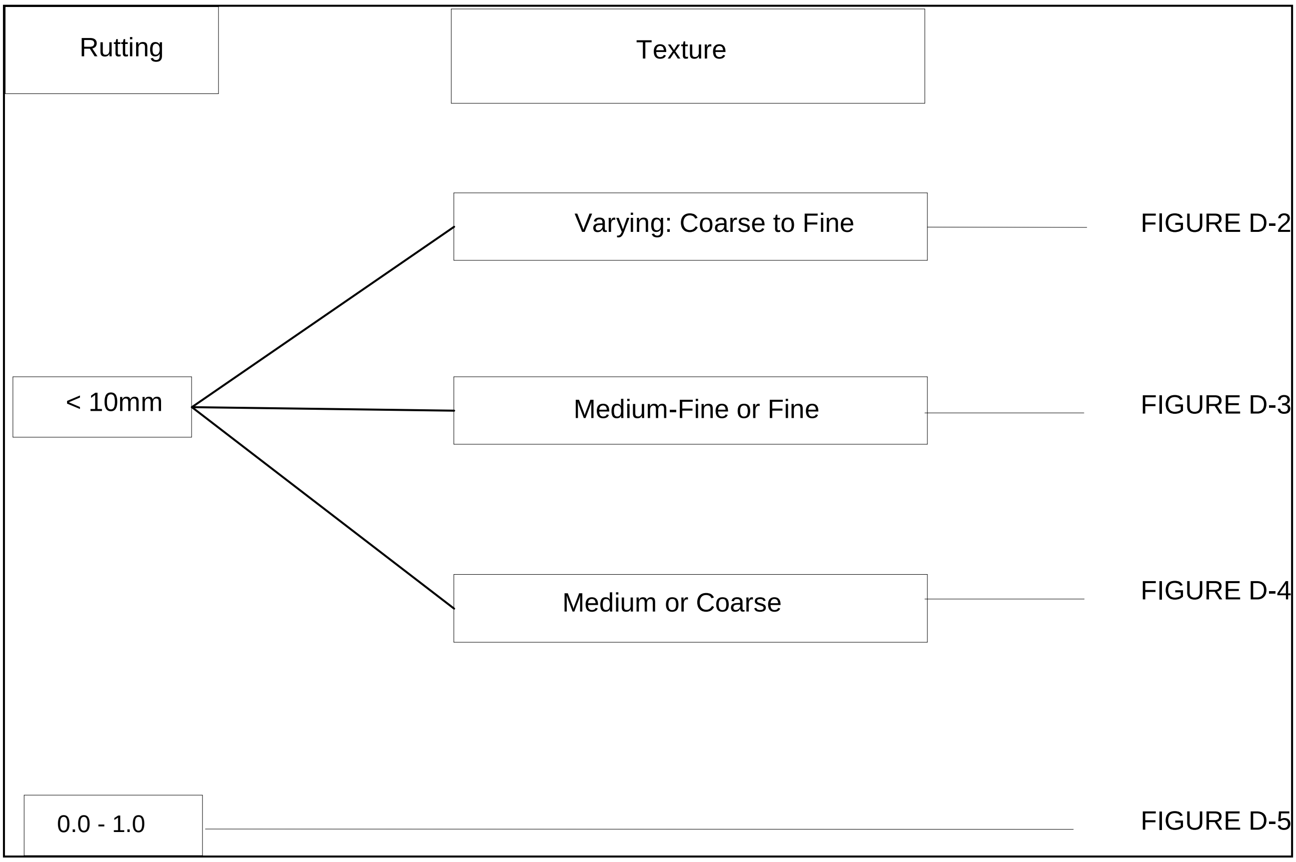


Figure D-1 Guideline for selecting appropriate surfacing types and treatments

ABBREVIATION	TREATMENT
Text	**Texture treatment**
Mod stone	**Single or double seal with modified binder**
Stone	**Single seal**
DE	**Diluted emulsion/ Rejuvenator**

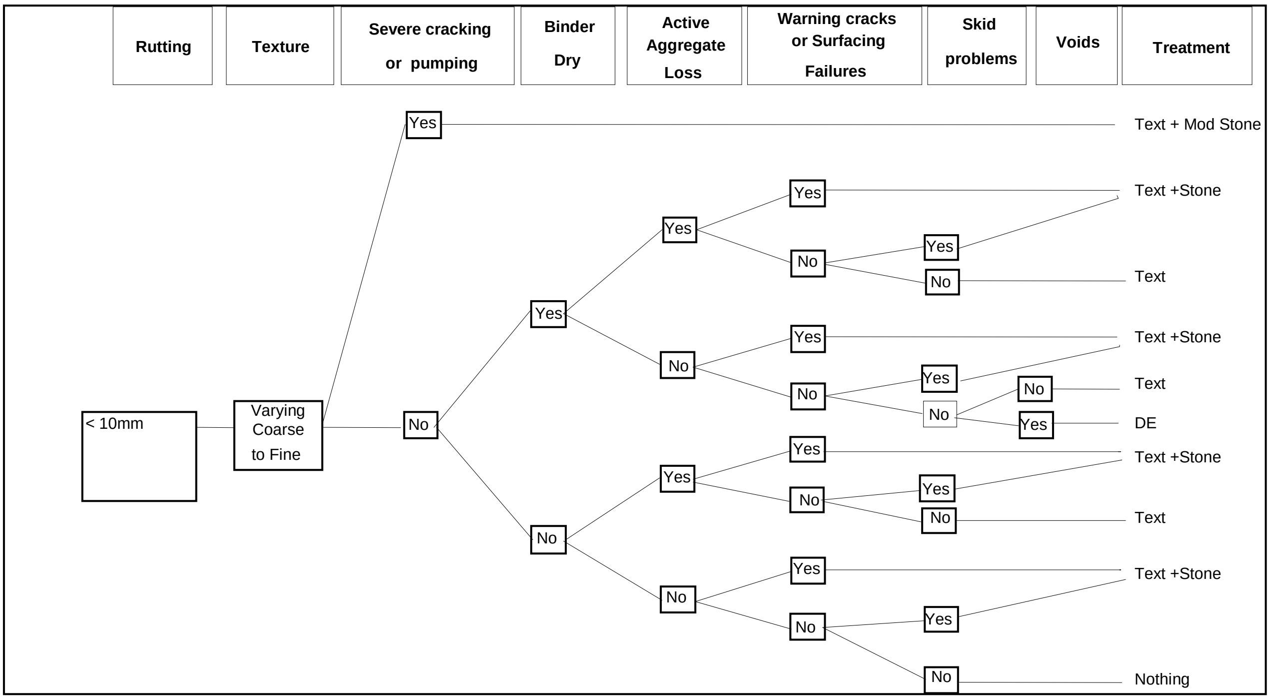


Figure D-2 Guideline for the selection of appropriate surfacing types and treatments

(Rut < 10 mm and varying texture)

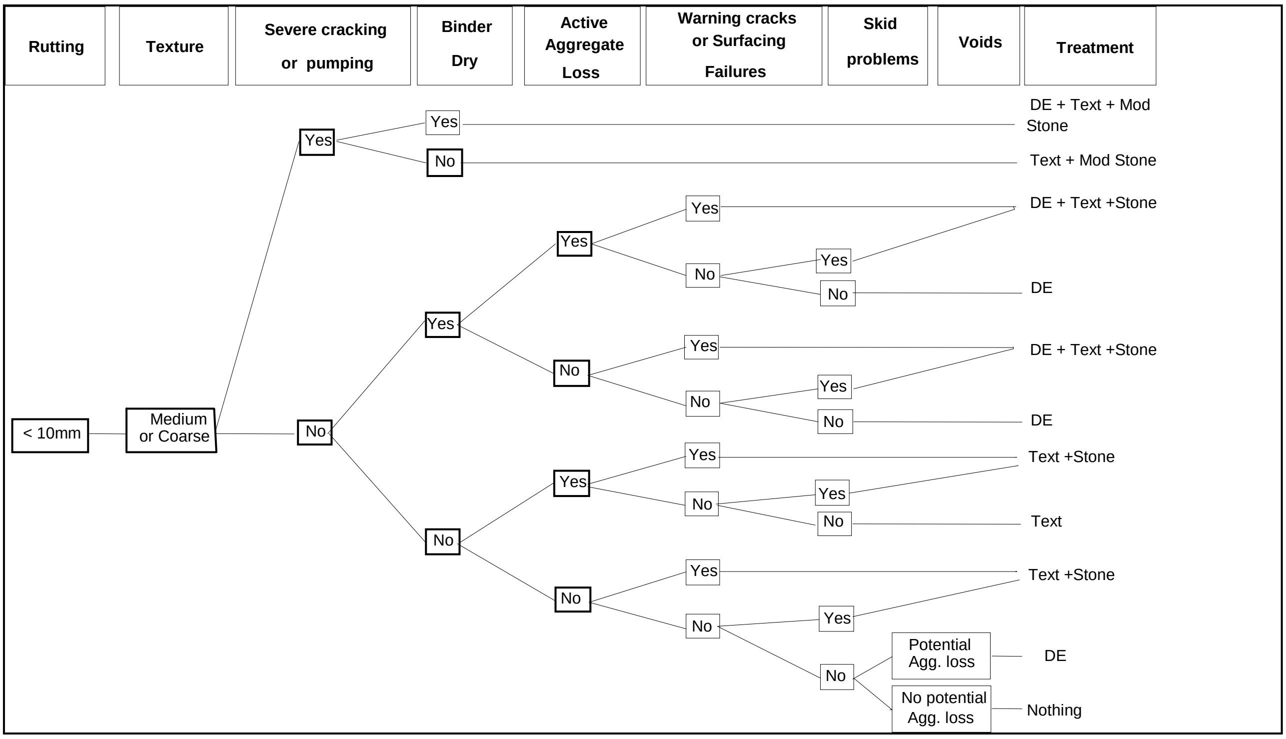


Figure D-3 Guideline for the selection of appropriate surfacing types and treatments

(Rut < 10 mm and medium to fine texture)

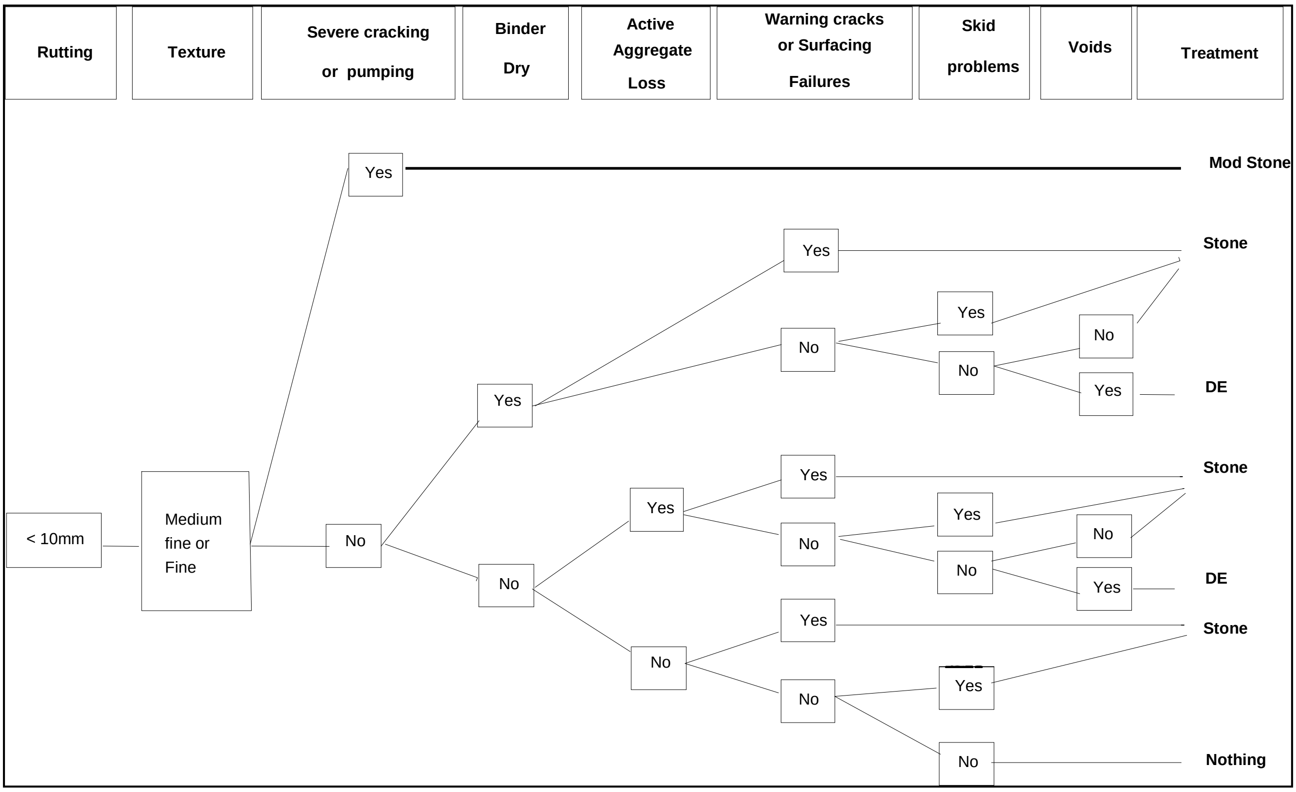


Figure D-4 Guideline for the selection of appropriate surfacing types and treatments

(Rut <10 mm and medium to coarse texture)

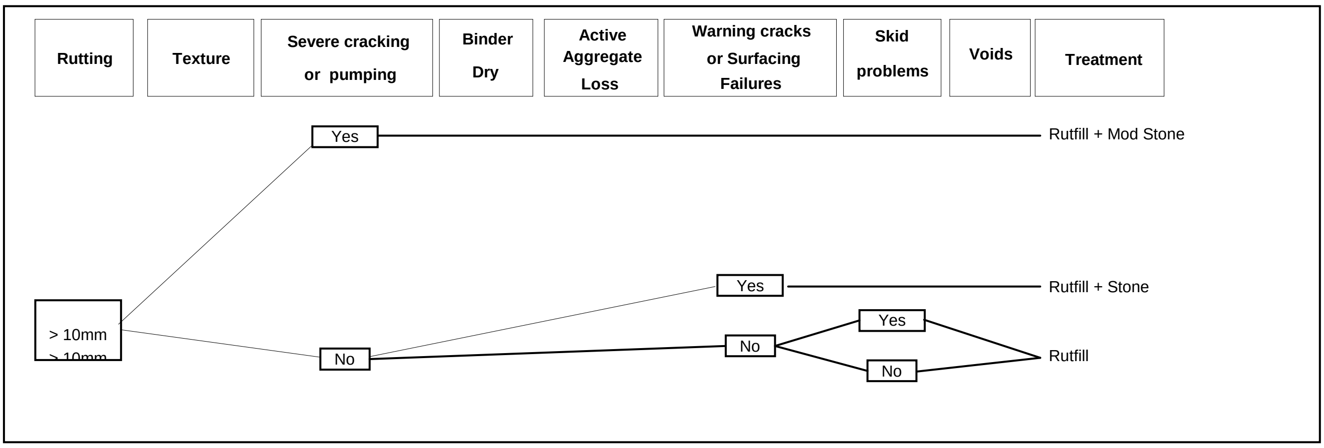


Figure D-5 Guideline for the selection of appropriate surfacing types and treatments

(Rut >10 mm)

APPENDIX E

DESIGN CHARTS FOR SURFACING SEALS

GUIDE TO THE USE OF THE DESIGN CHARTS

INFORMATION REQUIRED

- Equivalent Light Vehicles per lane per day (ELV);
- Corrected Ball Penetration value;
- Average Least Dimension (ALD) of the seal aggregate, and
- Required texture depth.

STEPS for determining net cold binder application rates (unmodified binders)

1 Select the appropriate ALD chart, or charts in the case of intermediate values, e.g. if the measured ALD is 7,9 mm, select the 7 mm and 8 mm ALD charts.

2 Enter the top graph from the left using the appropriate ELV value. Follow this line horizontally to its intersection with the relevant Corrected Ball Penetration curve.

3 From this point drop a vertical line into the lower graph to both the required texture depth curve and the minimum curve.

4 From the points of intersection of this line with these curves, draw horizontal lines to the left-hand vertical axis and read off the maximum and the minimum net cold binder application rates.

5 In the case of intermediate ALD values, determine the net cold binder application rates as described above from the ALD charts above and below the design ALD and do a straight line interpolation between the values obtained.

6 Refer to Chapter 7, paragraph 7.6.2 for adjustments and final selection of the binder application rate.

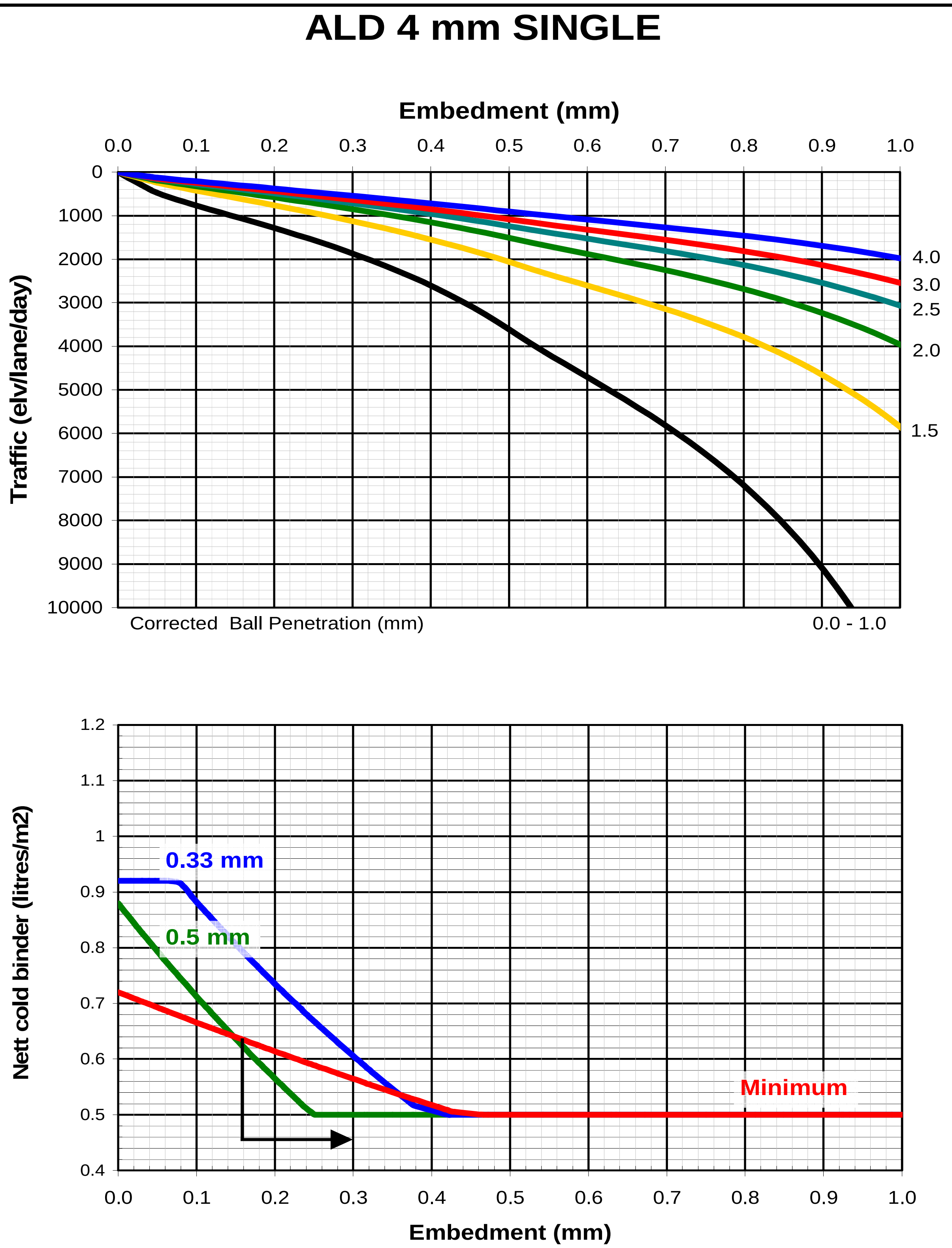
STEPS for determining net cold binder application rates for hot modified binders

1 Obtain the minimum and maximum net cold conventional binder application rates as for unmodified binders.

2 Apply the adjustments as discussed in paragraph 7.6.2. (No adjustment is made for climatic region)

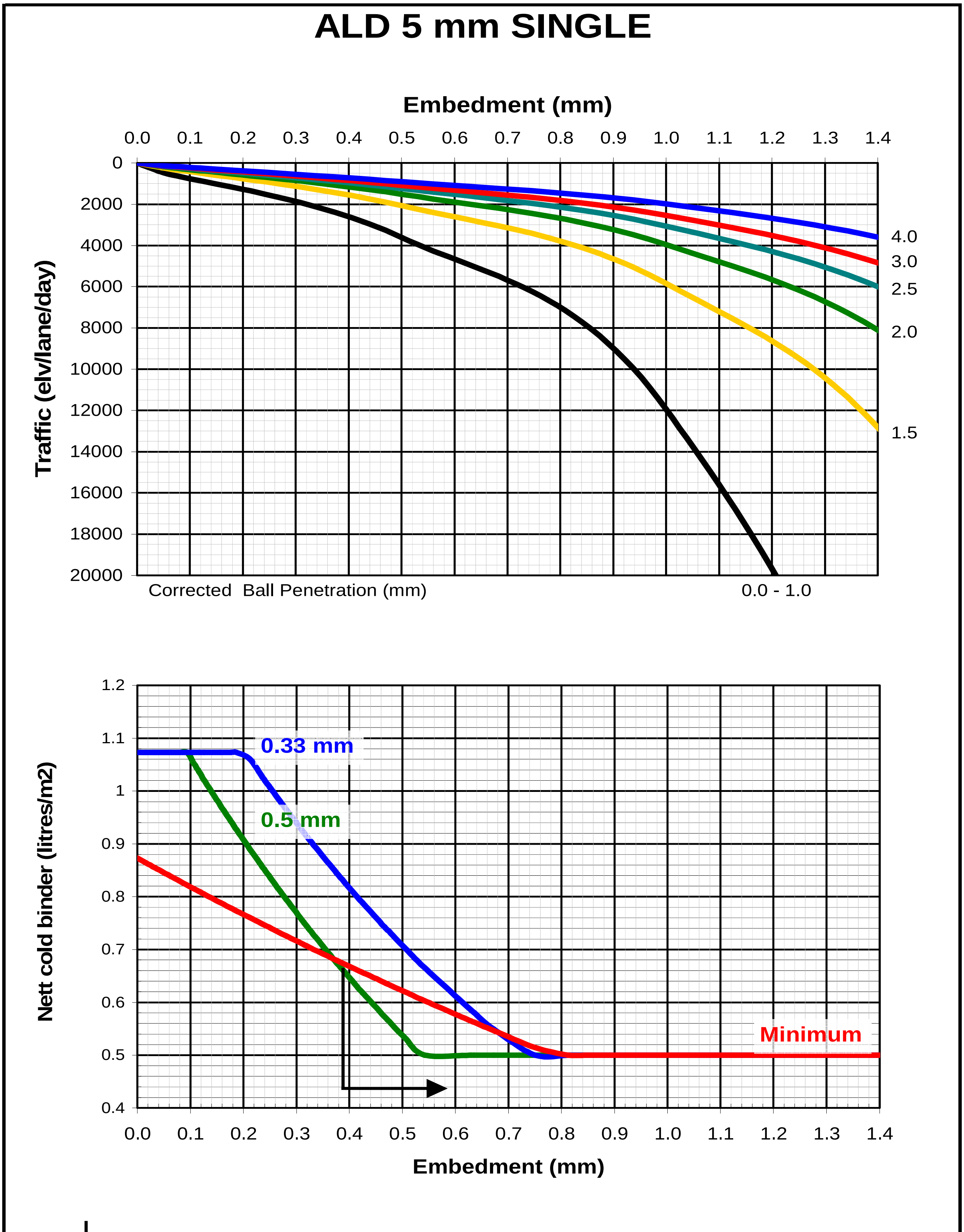
3 Select the type of modified binder and apply the conversion factors as provided in Table 7-6,Table 7-7 or Table 7-8

DESIGN CHART FOR SINGLE SEALS: 4mm ALD



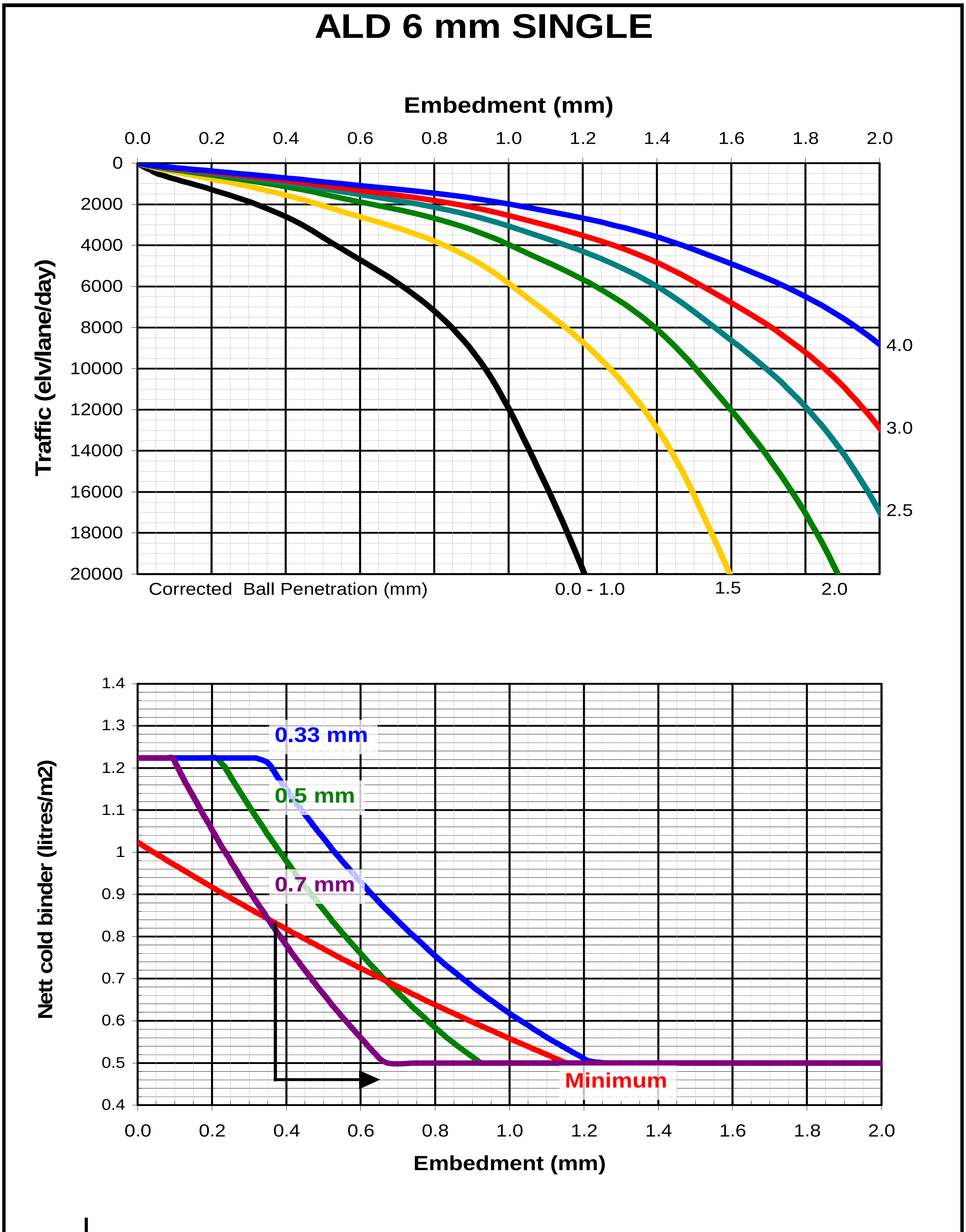
Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

DESIGN CHART FOR SINGLE SEALS: 5mm ALD



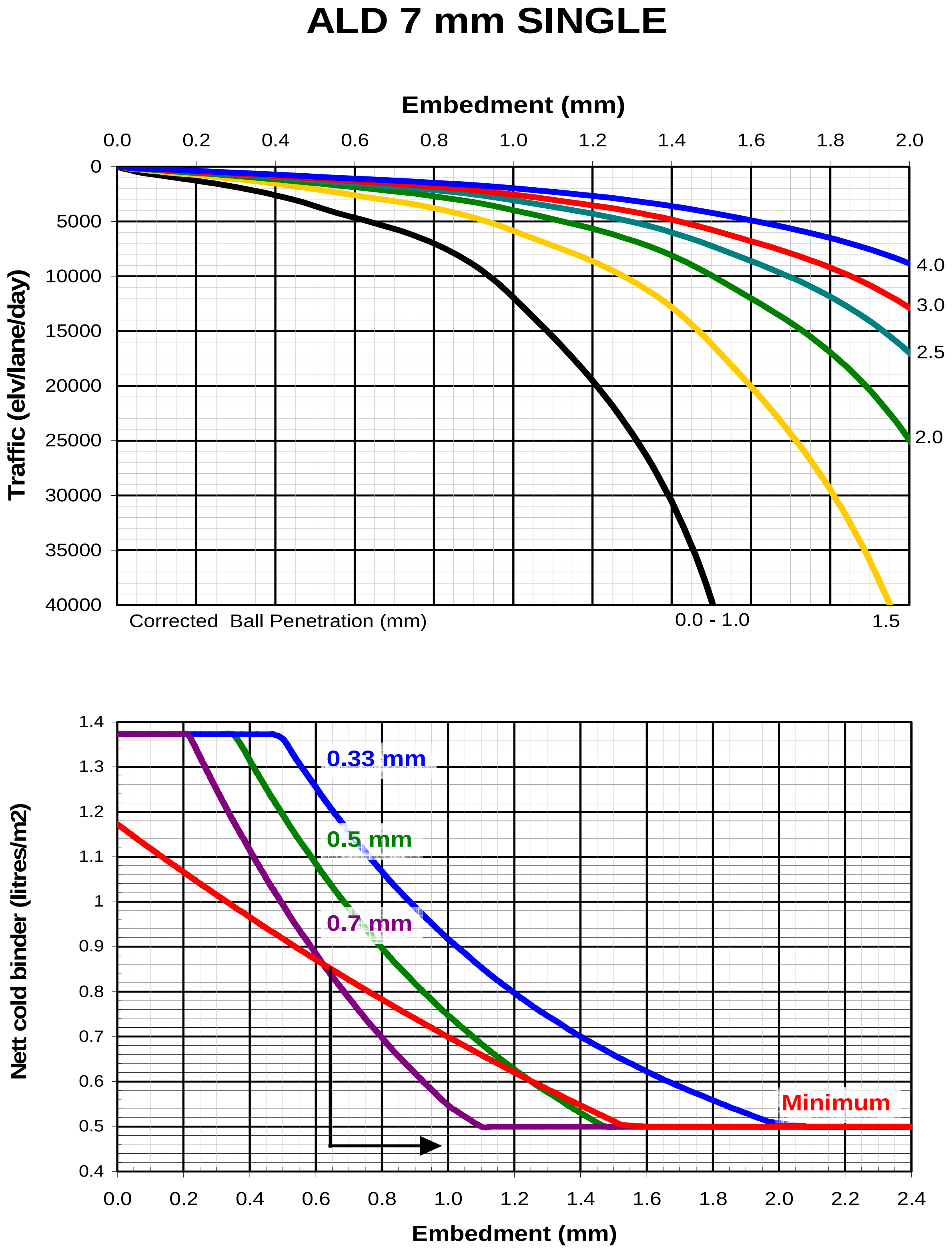
Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

DESIGN CHART FOR SINGLE SEALS: 6mm ALD



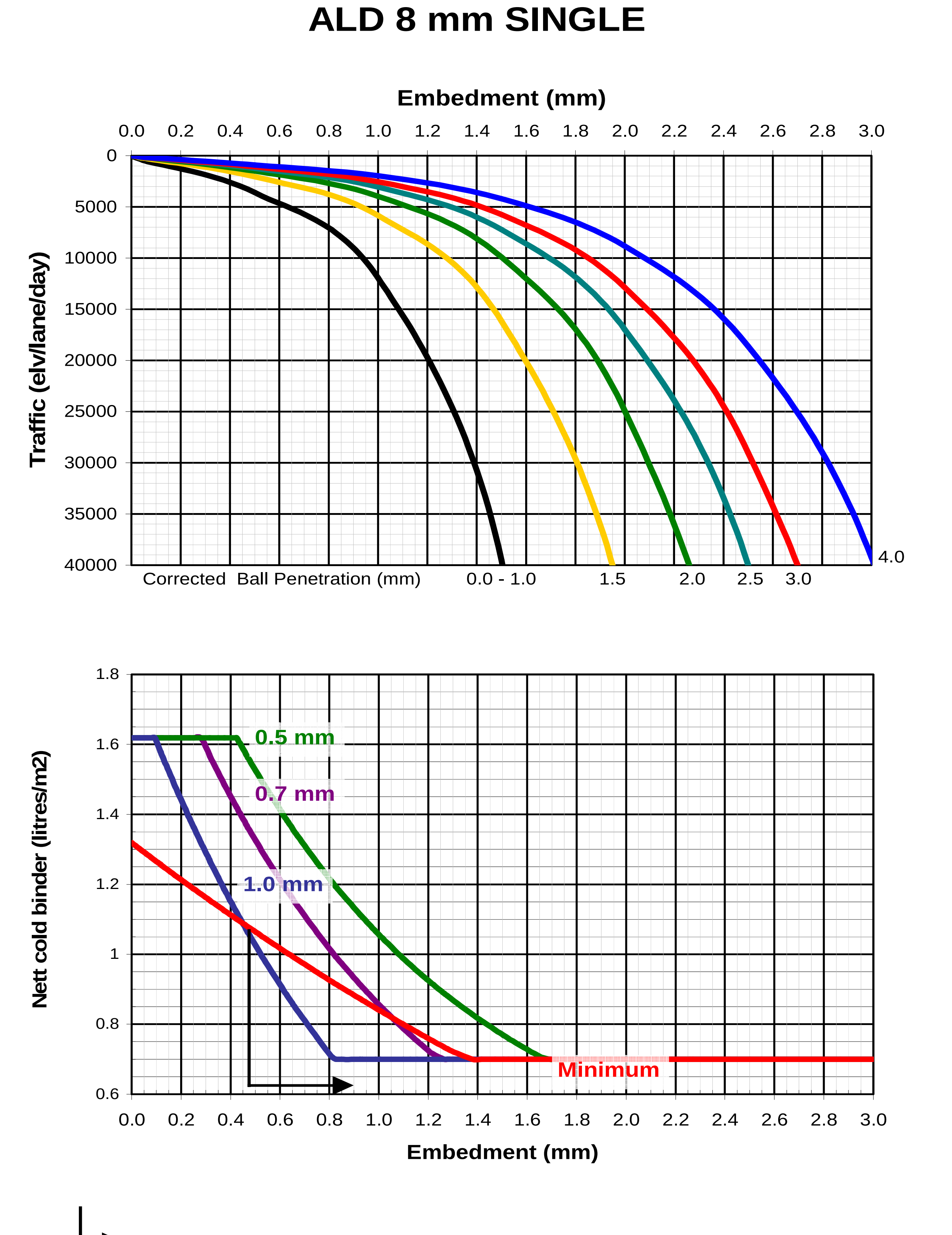
Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

DESIGN CHART FOR SINGLE SEALS: 7mm ALD



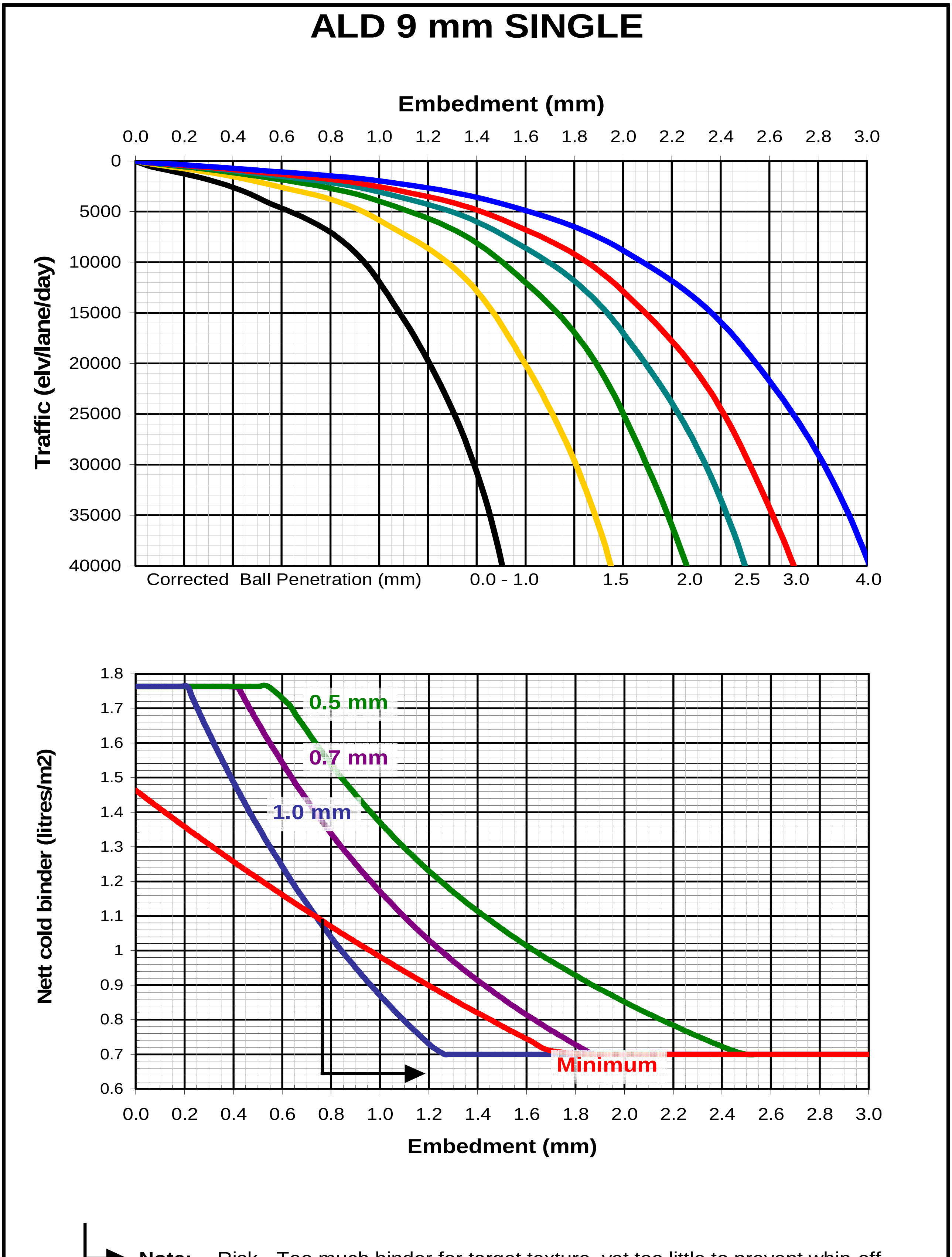
Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

DESIGN CHART FOR SINGLE SEALS: 8mm ALD



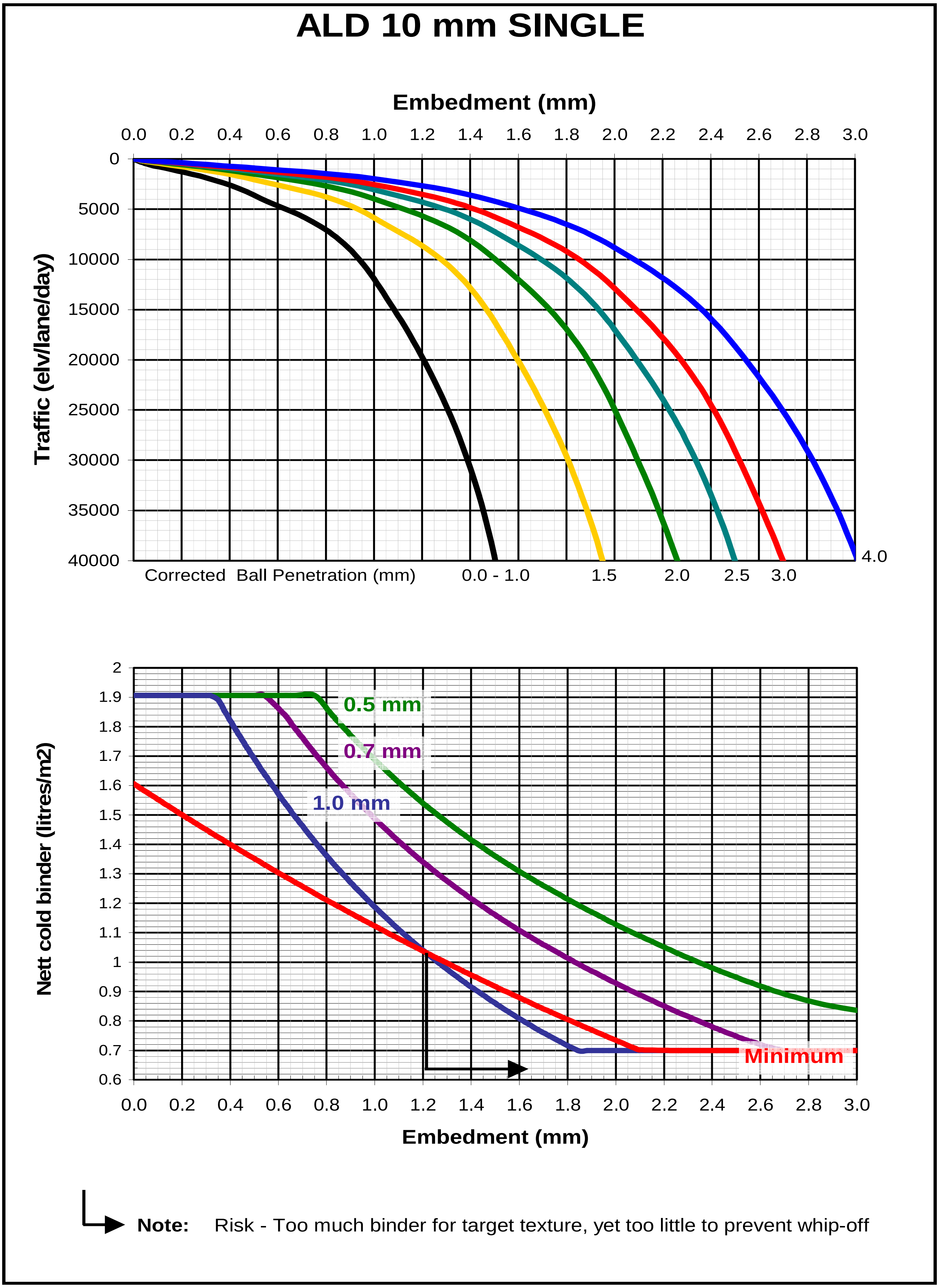
Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

DESIGN CHART FOR SINGLE SEALS: 9mm ALD

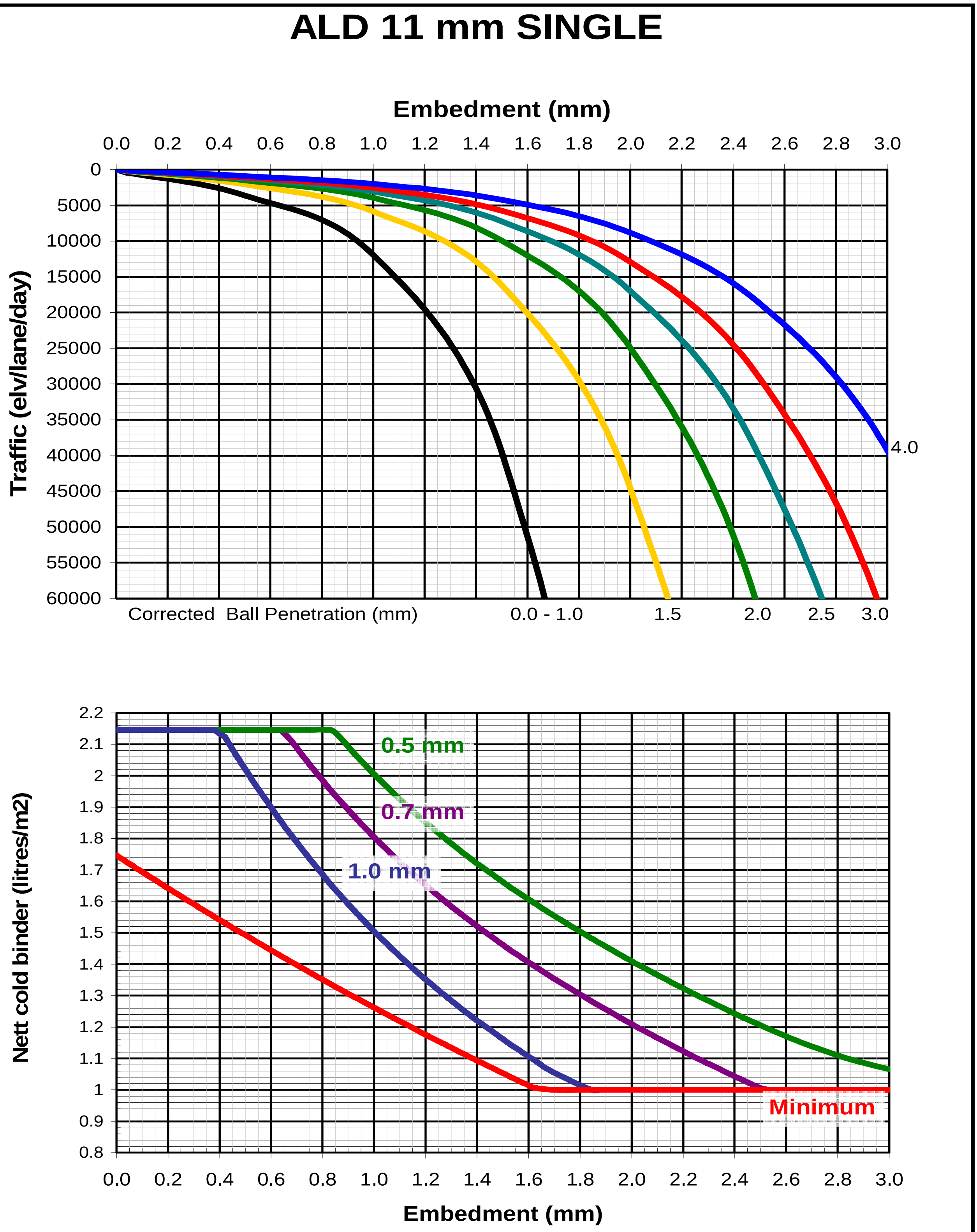


Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

DESIGN CHART FOR SINGLE SEALS: 10mm ALD

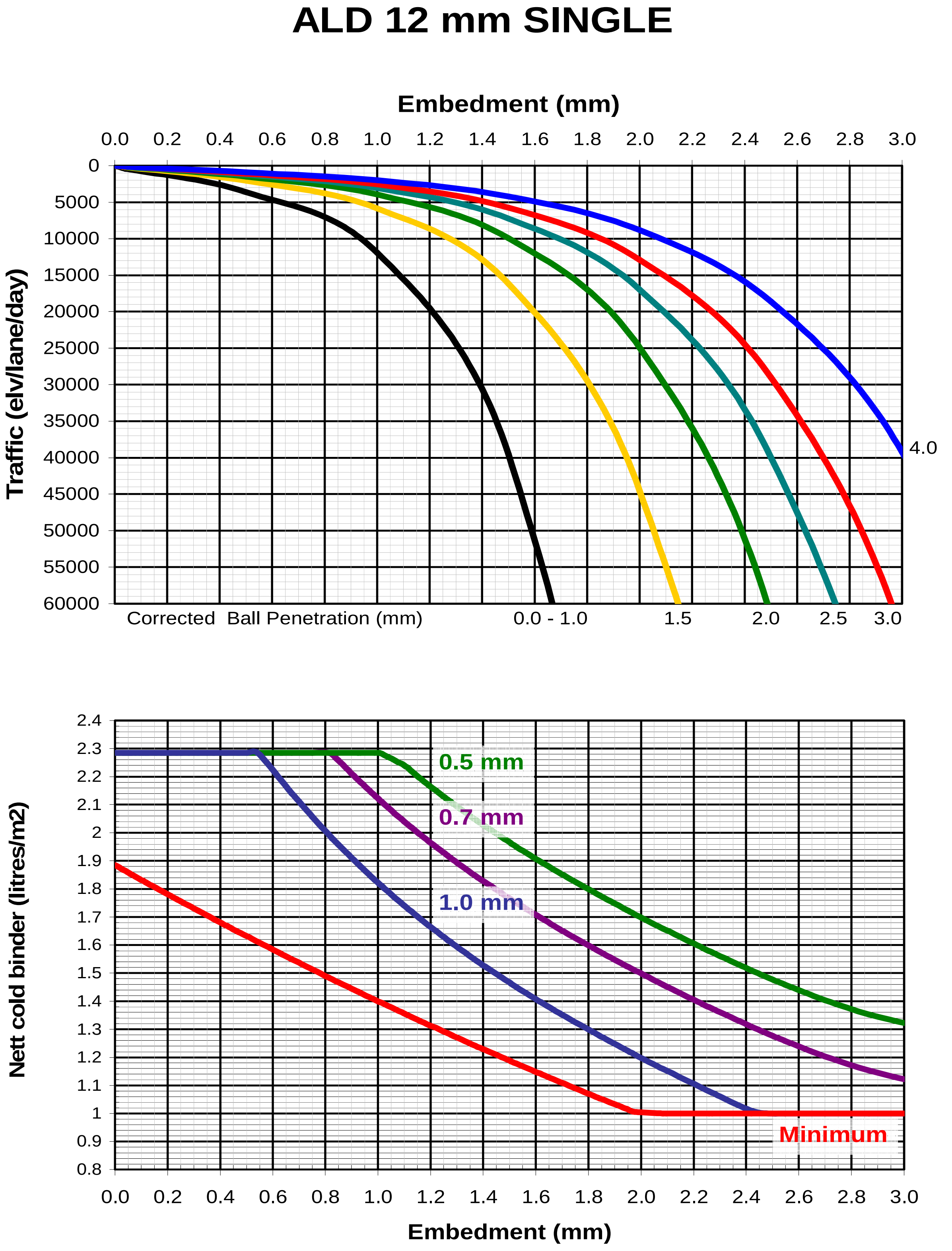


DESIGN CHART FOR SINGLE SEALS: 11mm ALD



Note: Practitioners recommend a minimum of 1 litre per square metre binder application

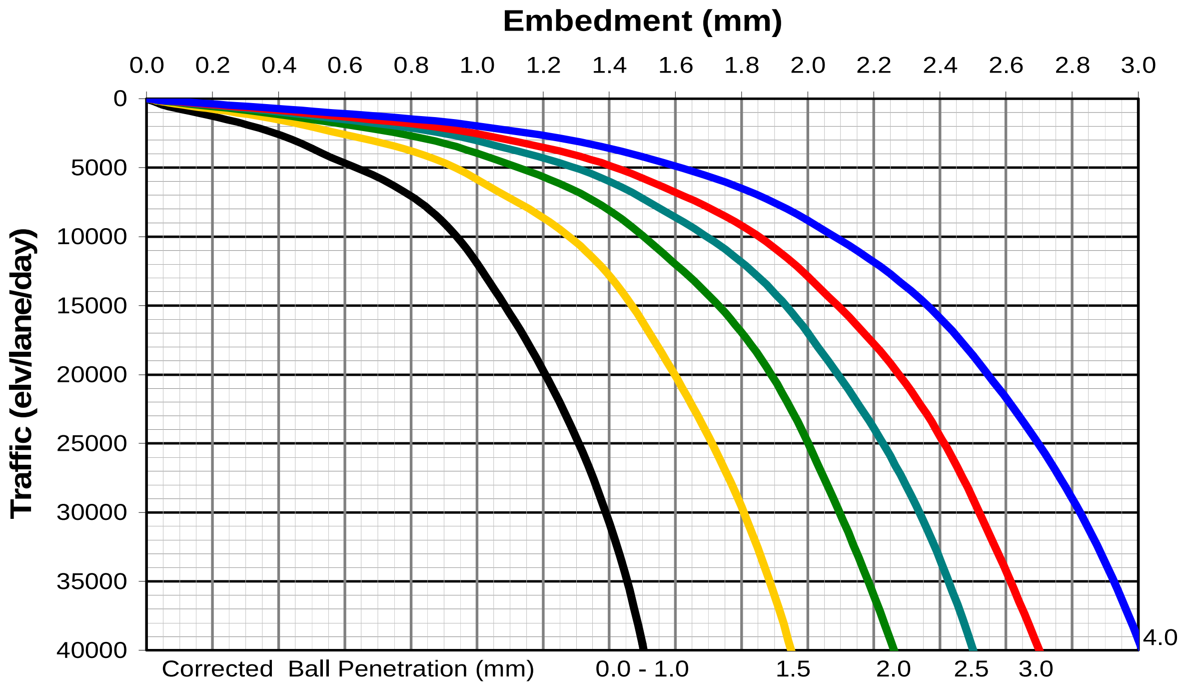
DESIGN CHART FOR SINGLE SEALS: 12mm ALD

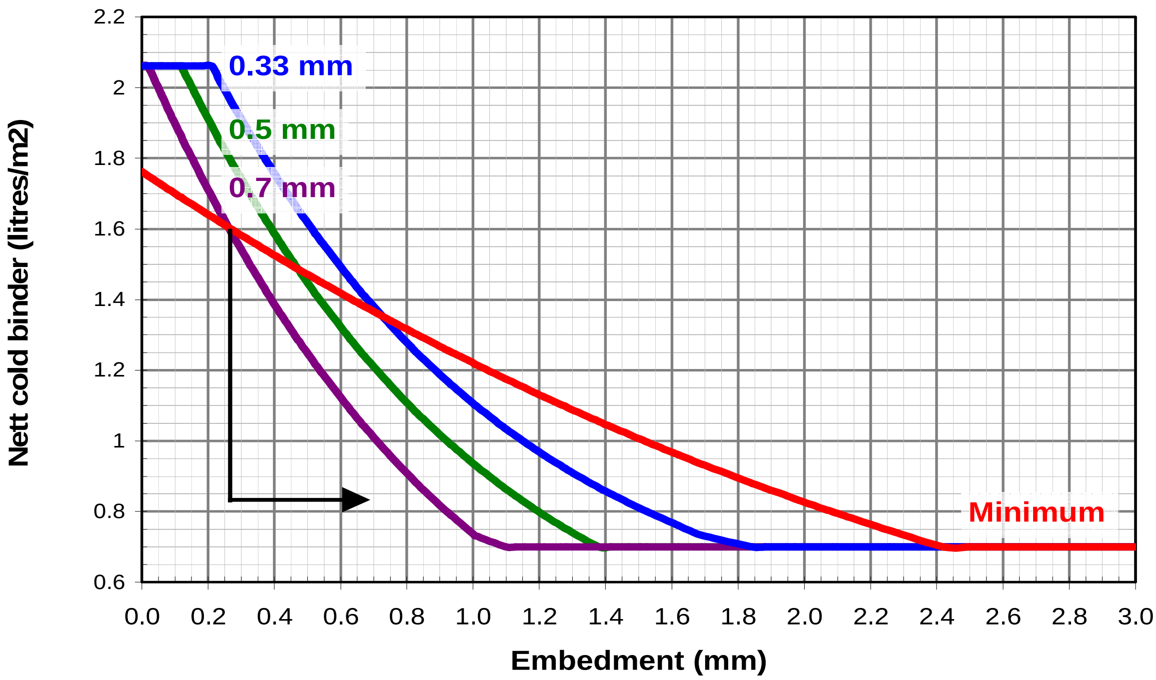


Note: Practitioners recommend a minimum of 1 litre per square metre binder application

DESIGN CHART FOR DOUBLE SEALS: Design ALD = 8mm

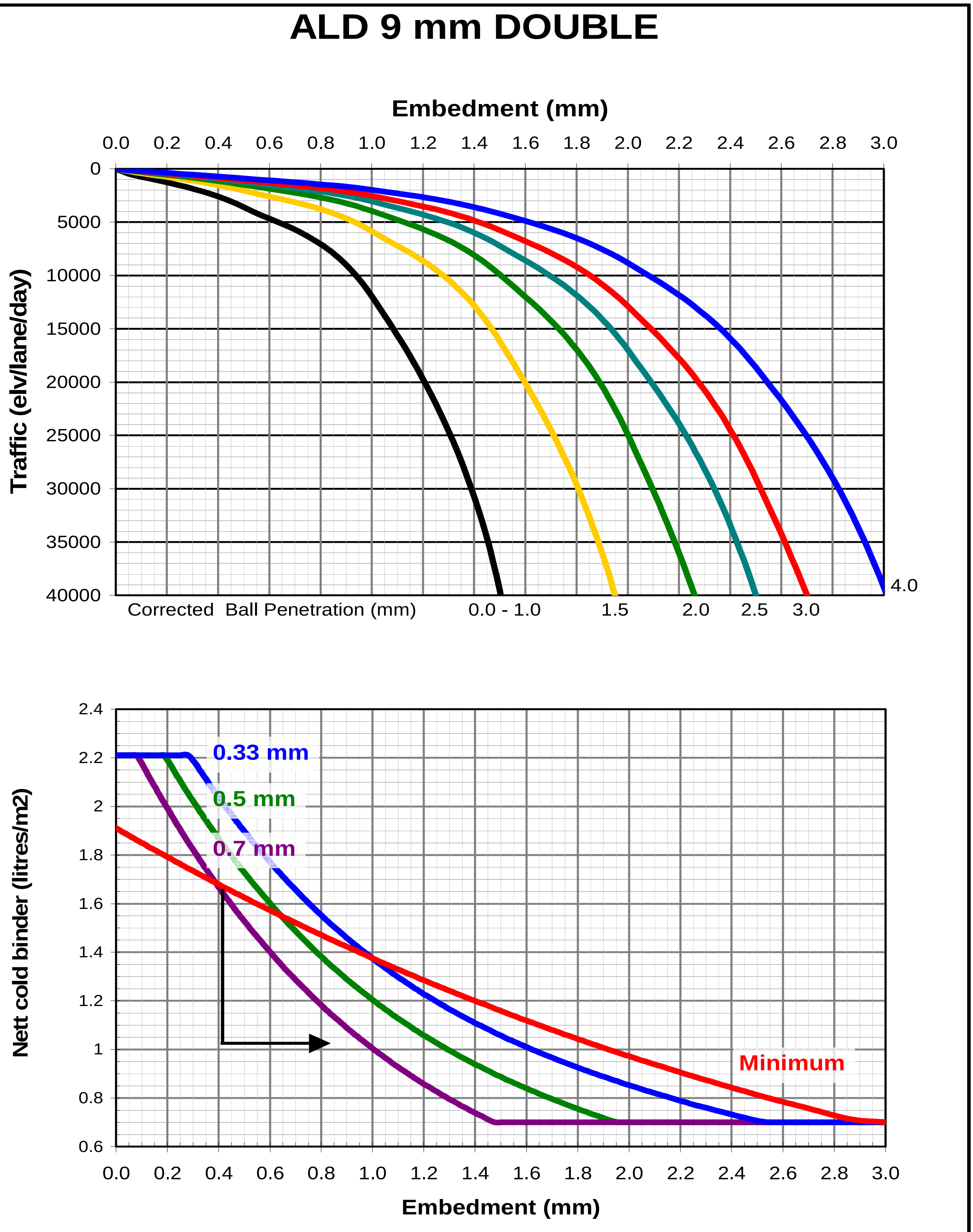
ALD 8 mm DOUBLE





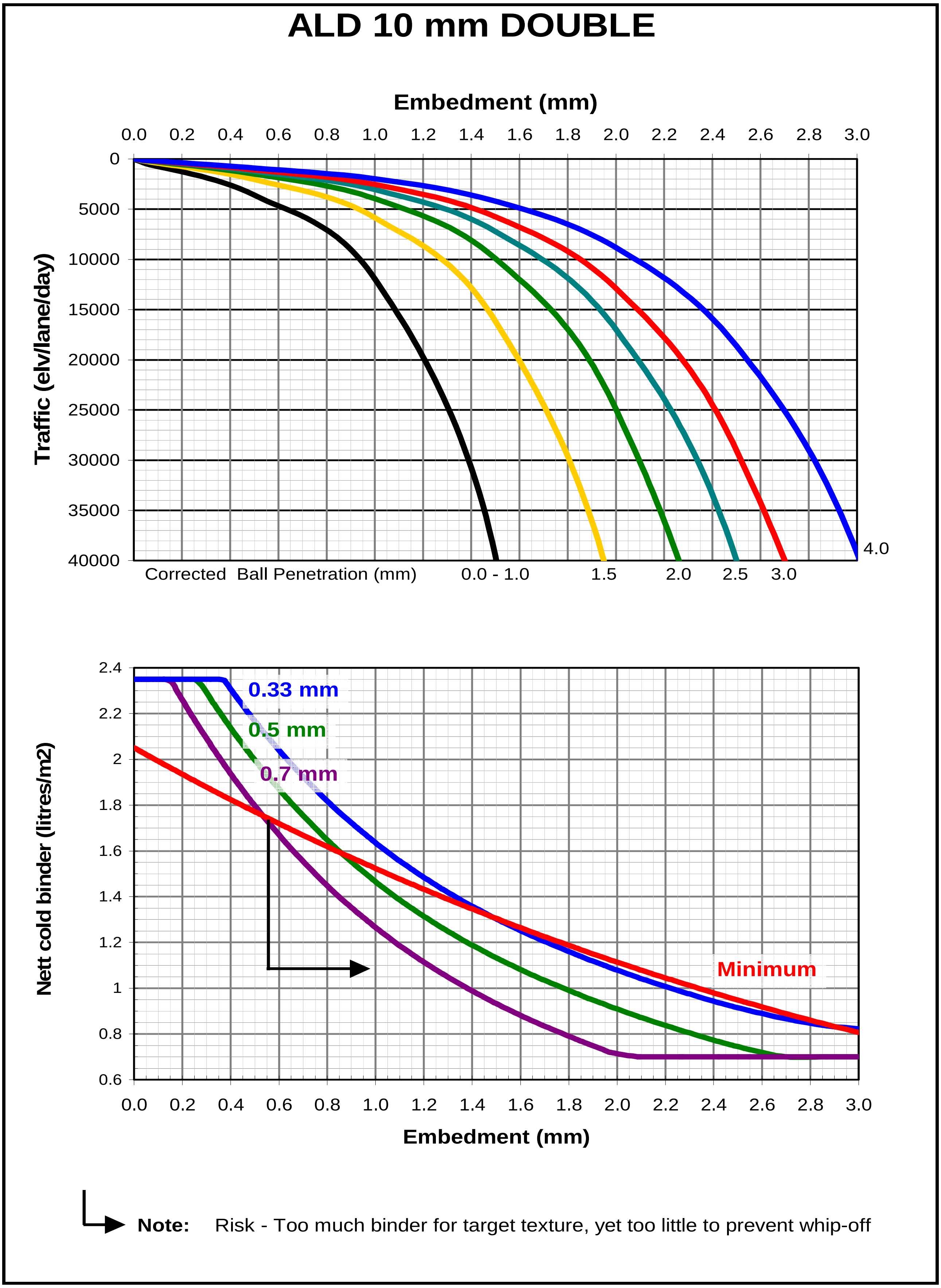
Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

DESIGN CHART FOR DOUBLE SEALS: Design ALD = 9mm

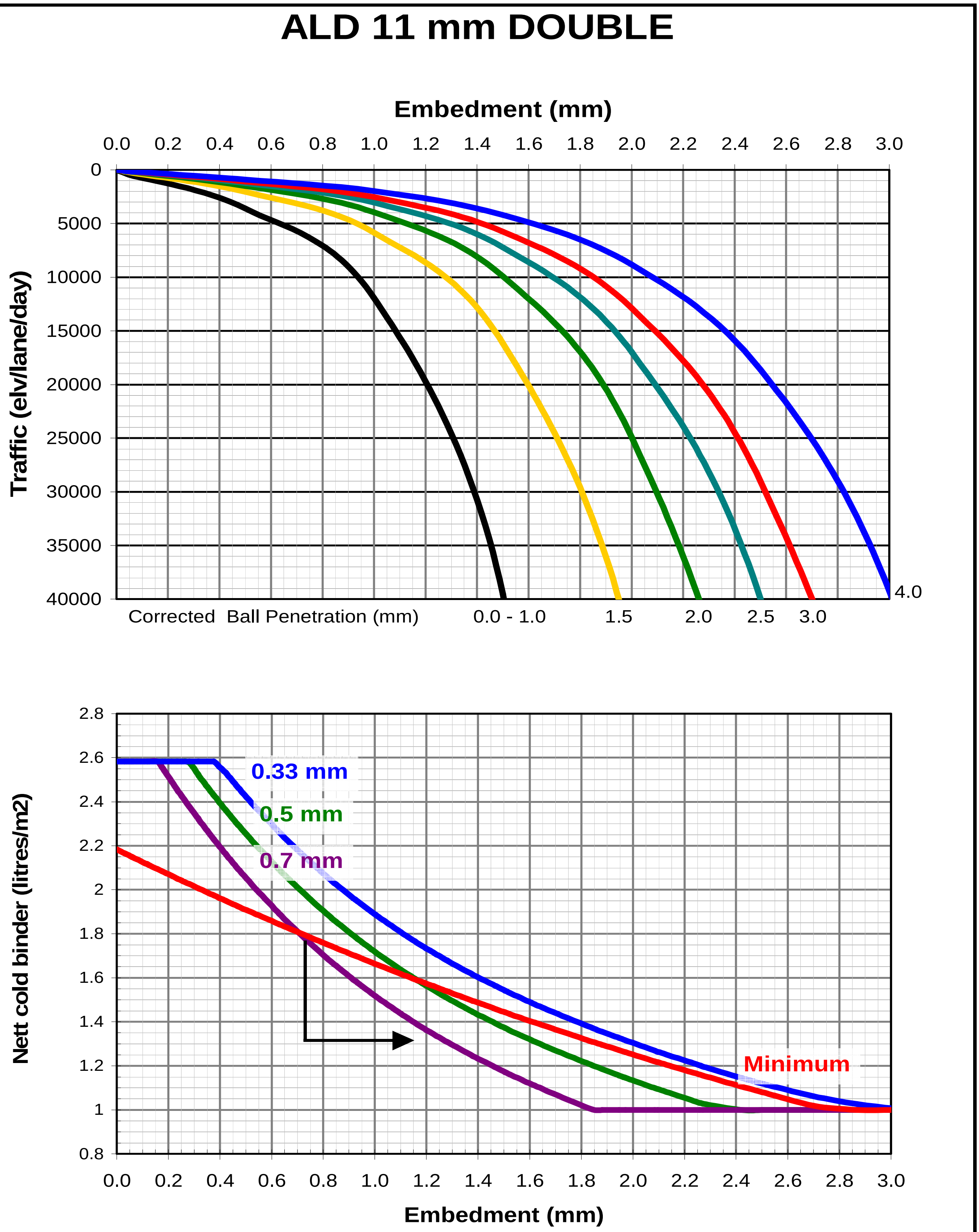


Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

DESIGN CHART FOR DOUBLE SEALS: Design ALD = 10mm

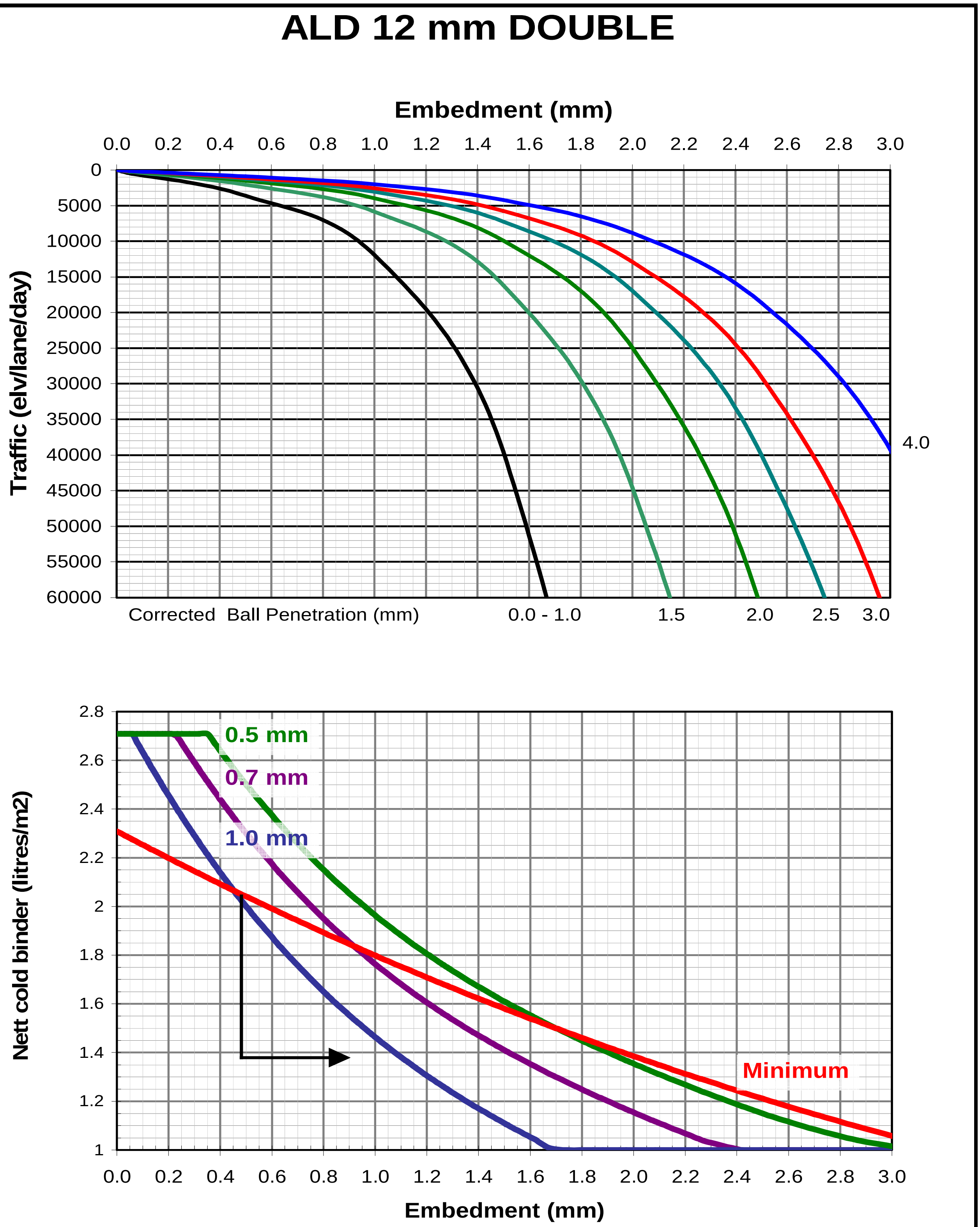


DESIGN CHART FOR DOUBLE SEALS: Design ALD = 11mm



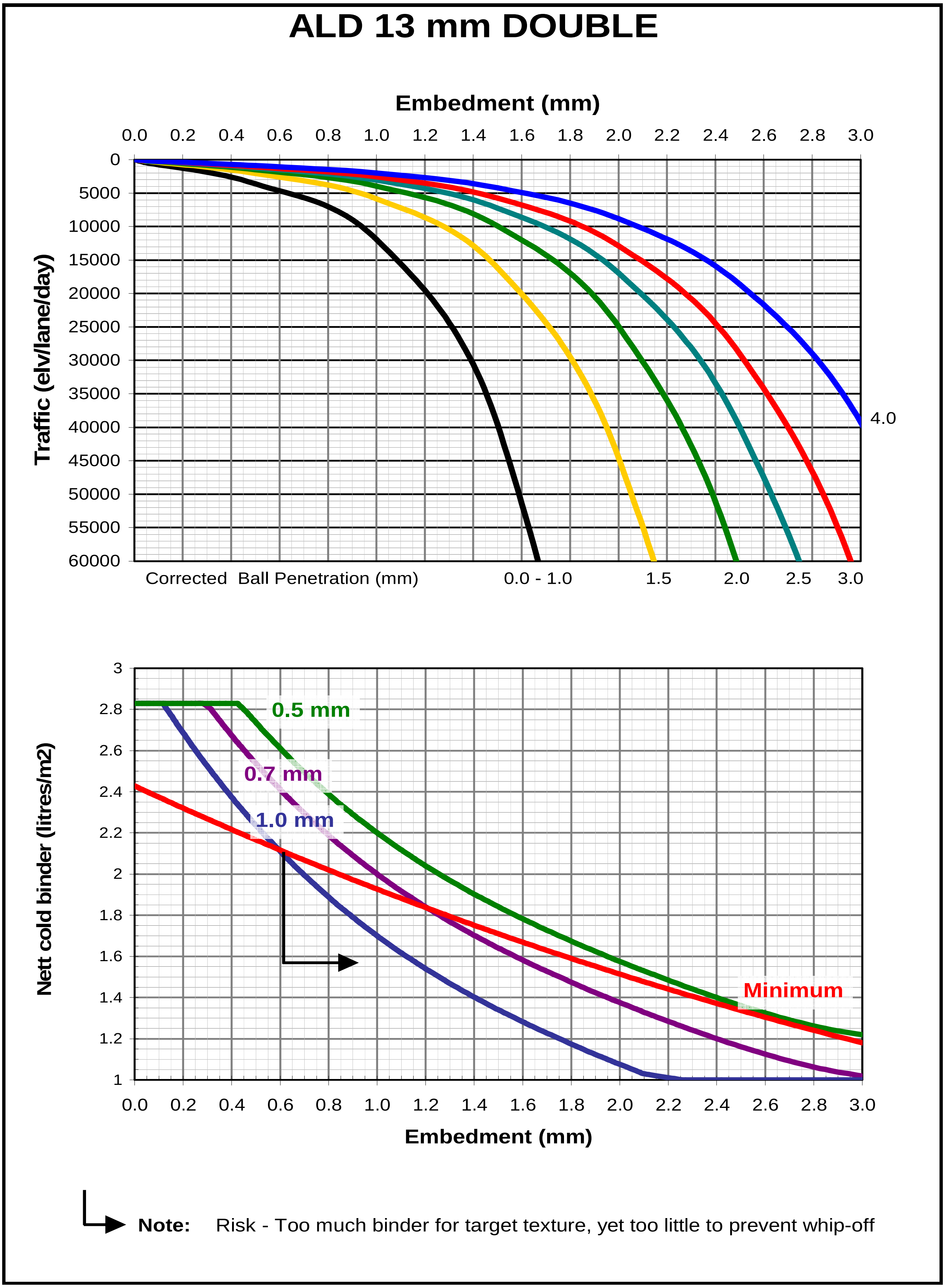
Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

DESIGN CHART FOR DOUBLE SEALS: Design ALD = 12mm

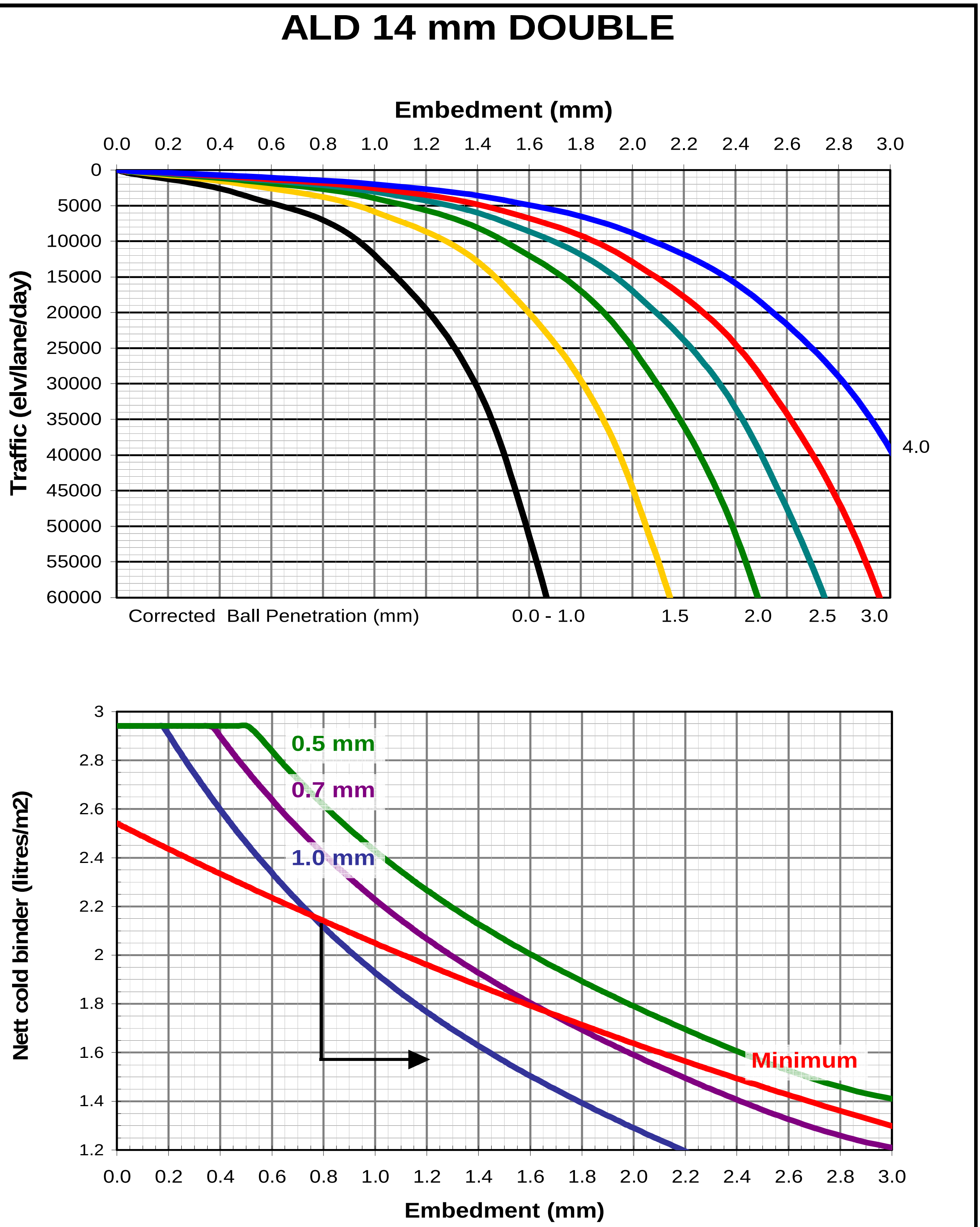


Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

DESIGN CHART FOR DOUBLE SEALS: Design ALD = 13mm

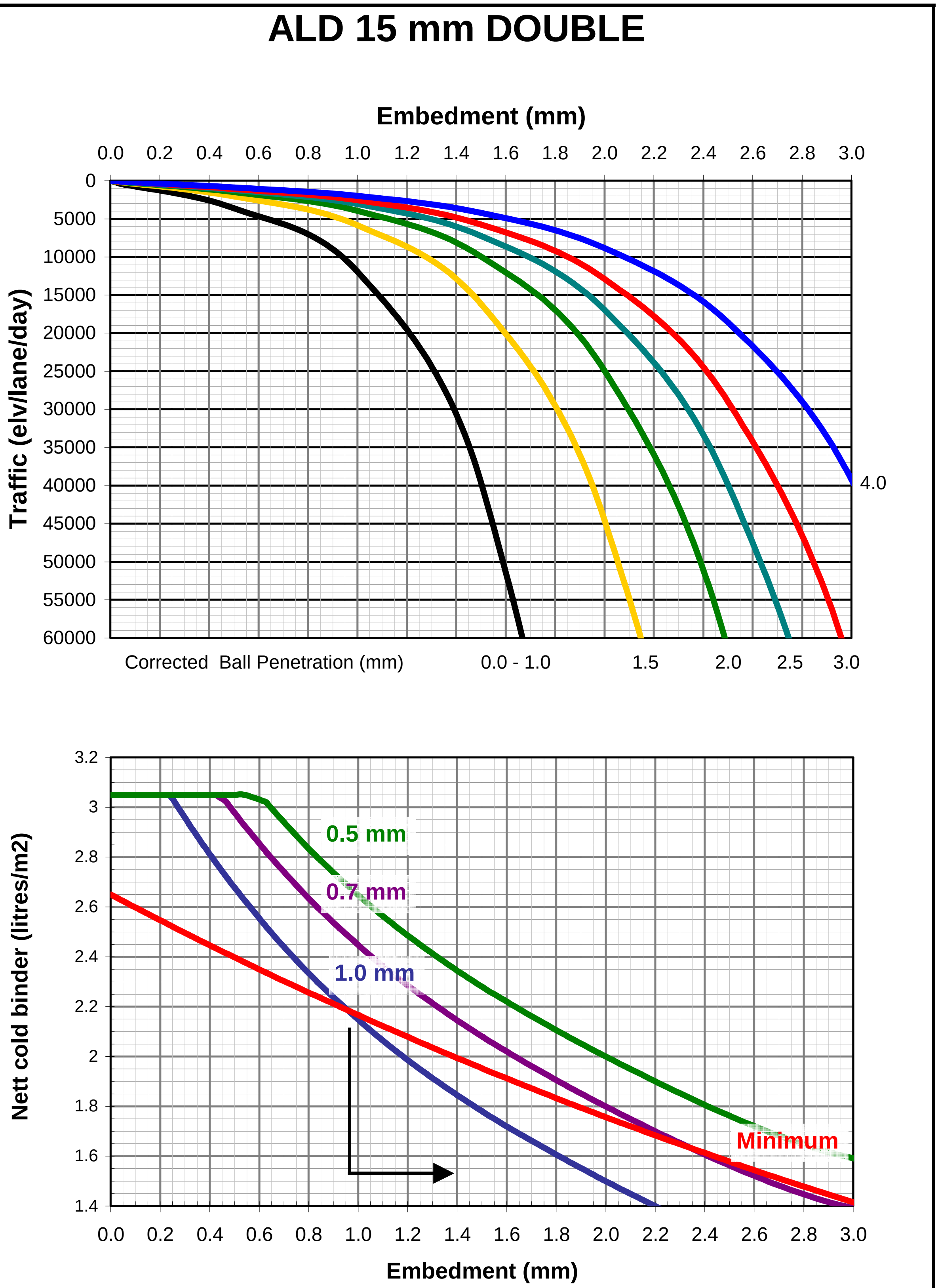


DESIGN CHART FOR DOUBLE SEALS: Design ALD = 14mm



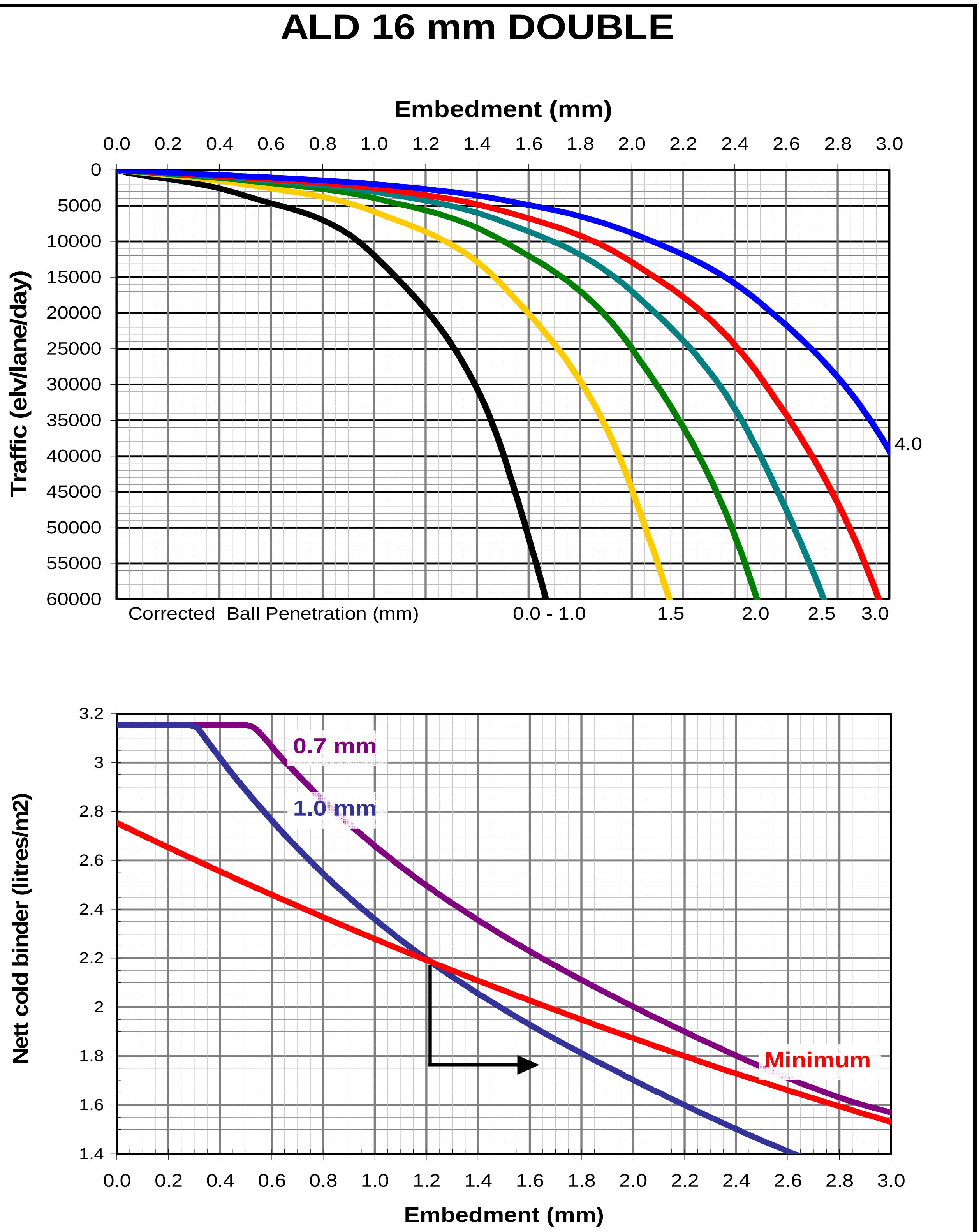
Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

DESIGN CHART FOR DOUBLE SEALS: Design ALD = 15mm



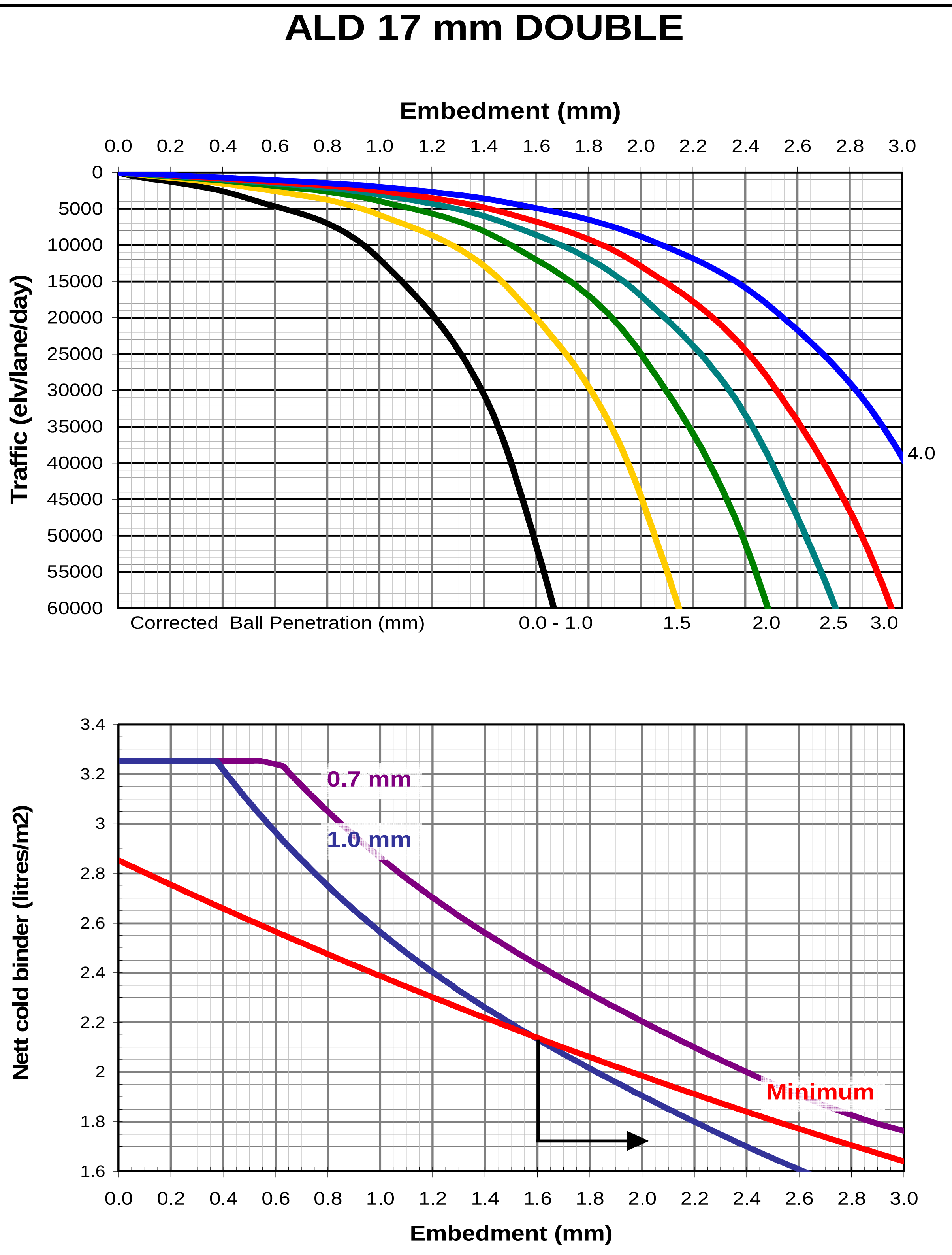
Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

DESIGN CHART FOR DOUBLE SEALS: Design ALD = 16mm



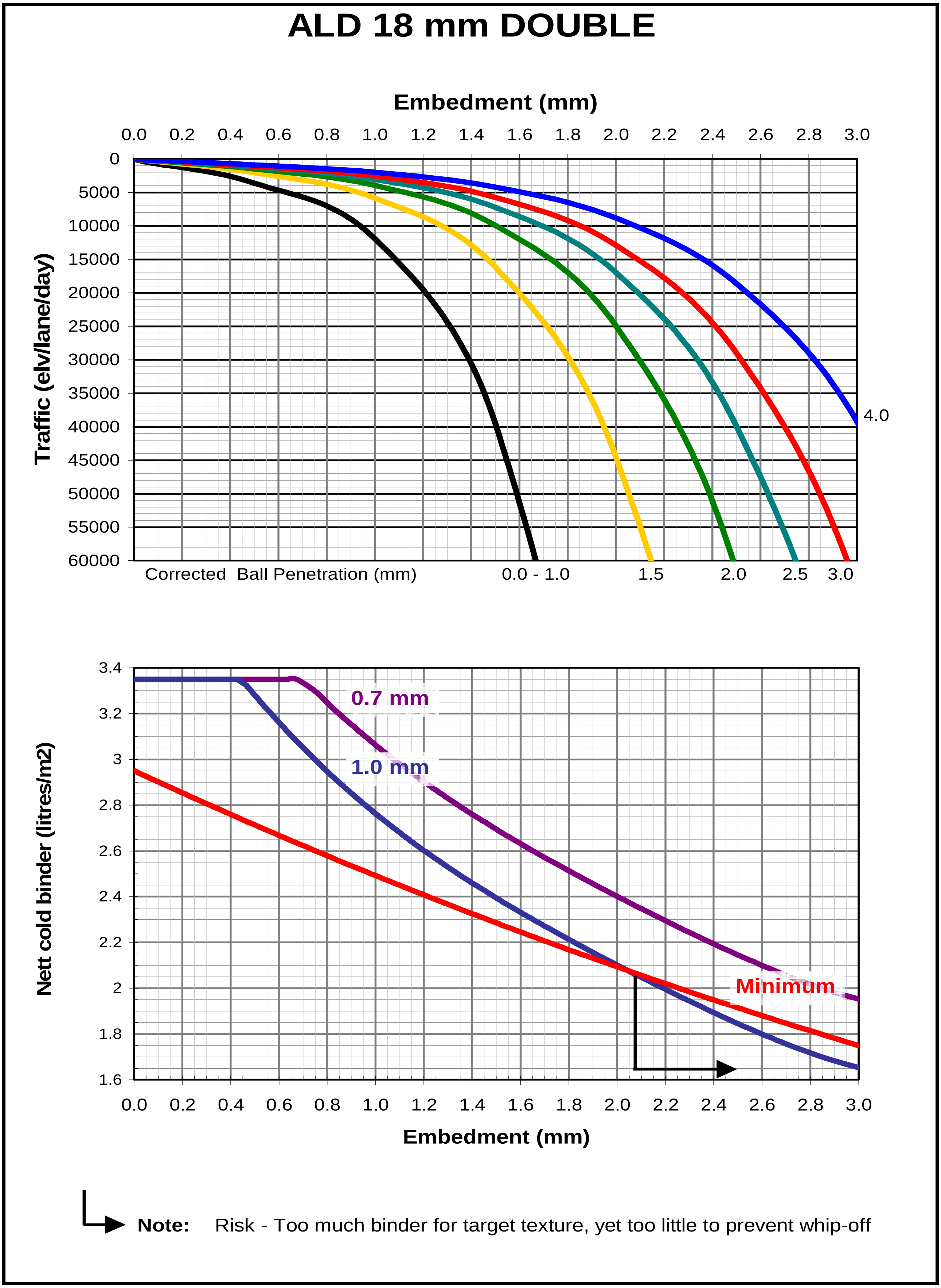
Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

DESIGN CHART FOR DOUBLE SEALS: Design ALD = 17mm

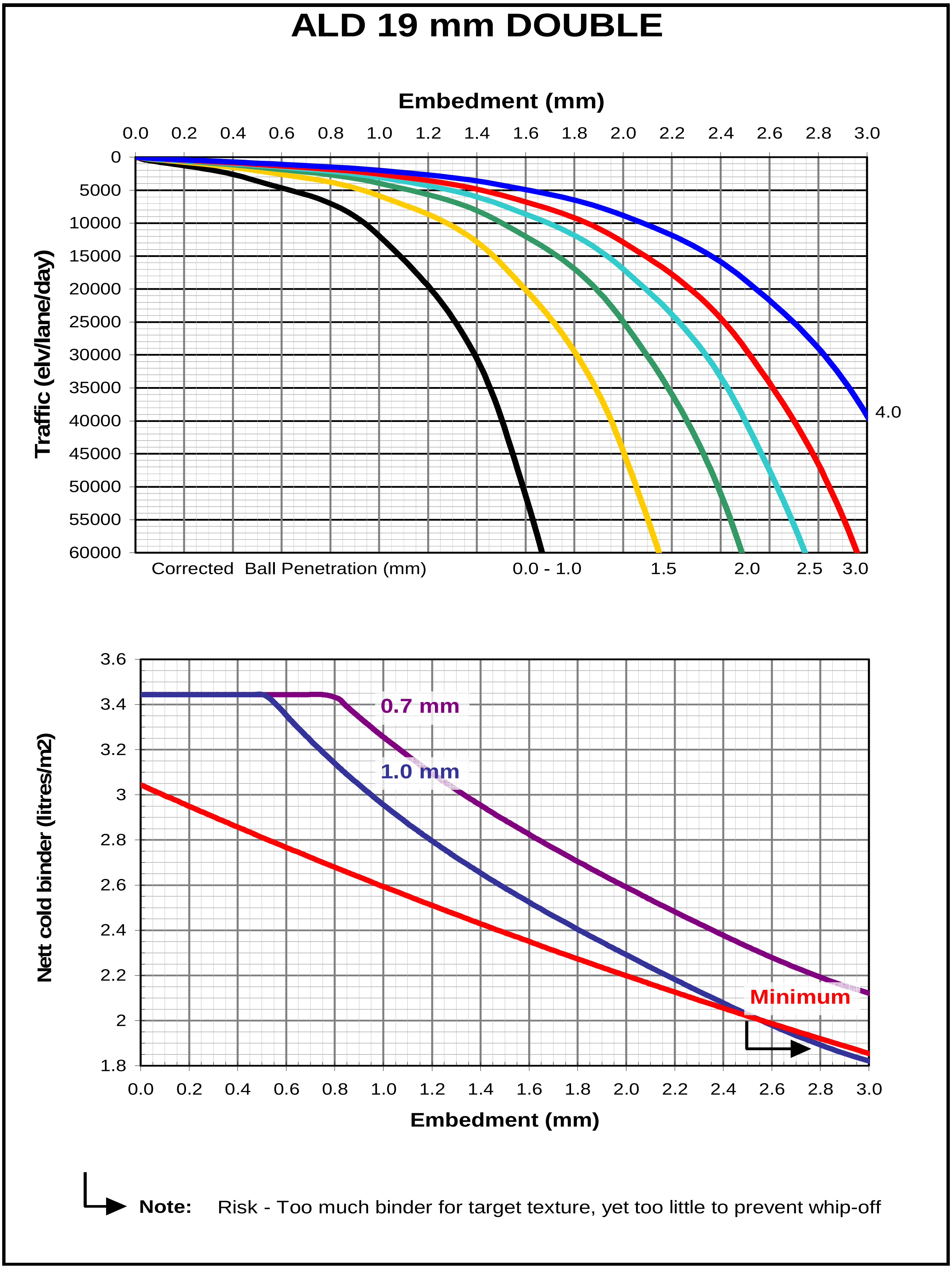


Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

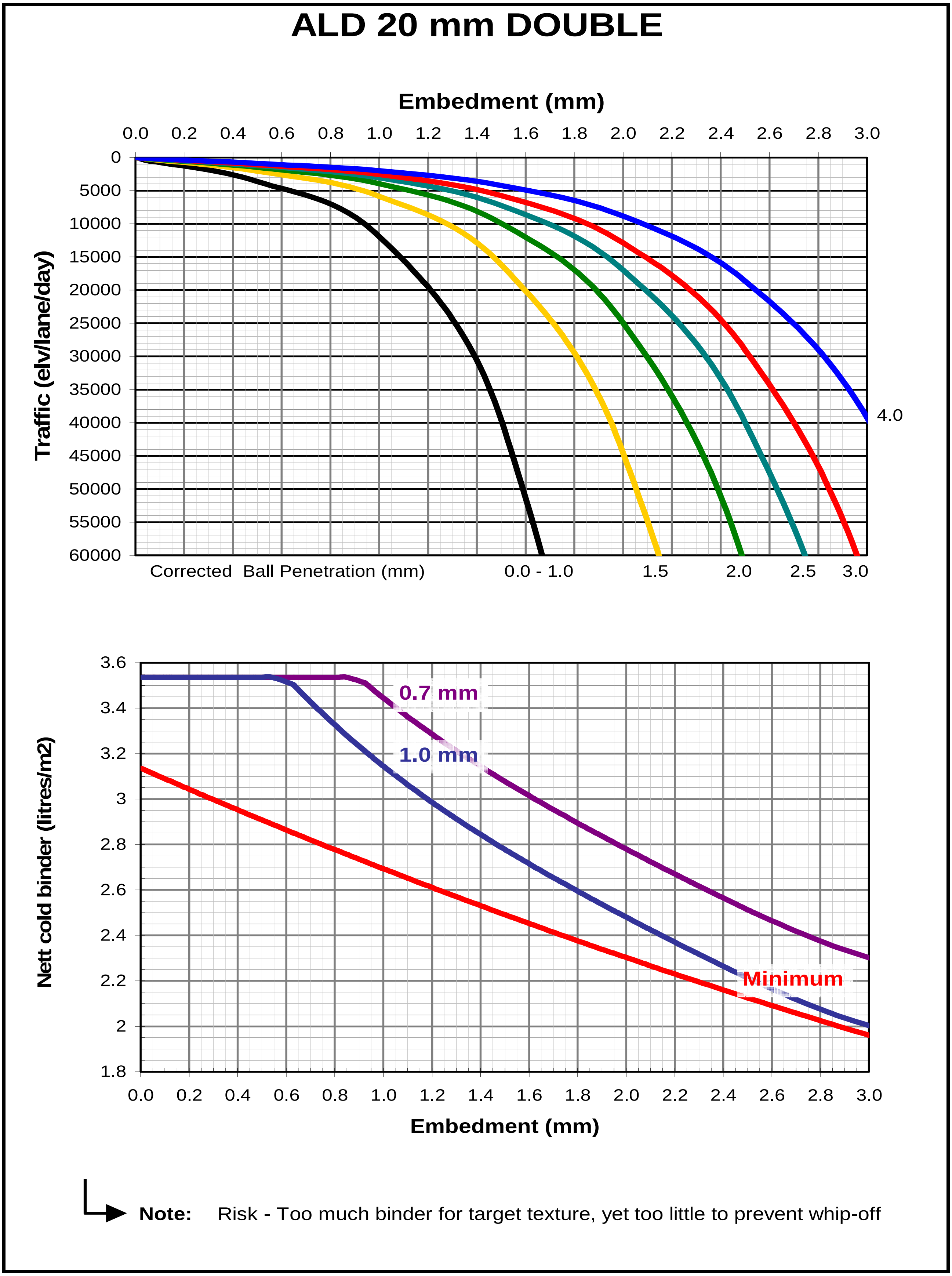
DESIGN CHART FOR DOUBLE SEALS: Design ALD = 18mm



DESIGN CHART FOR DOUBLE SEALS: Design ALD = 19mm

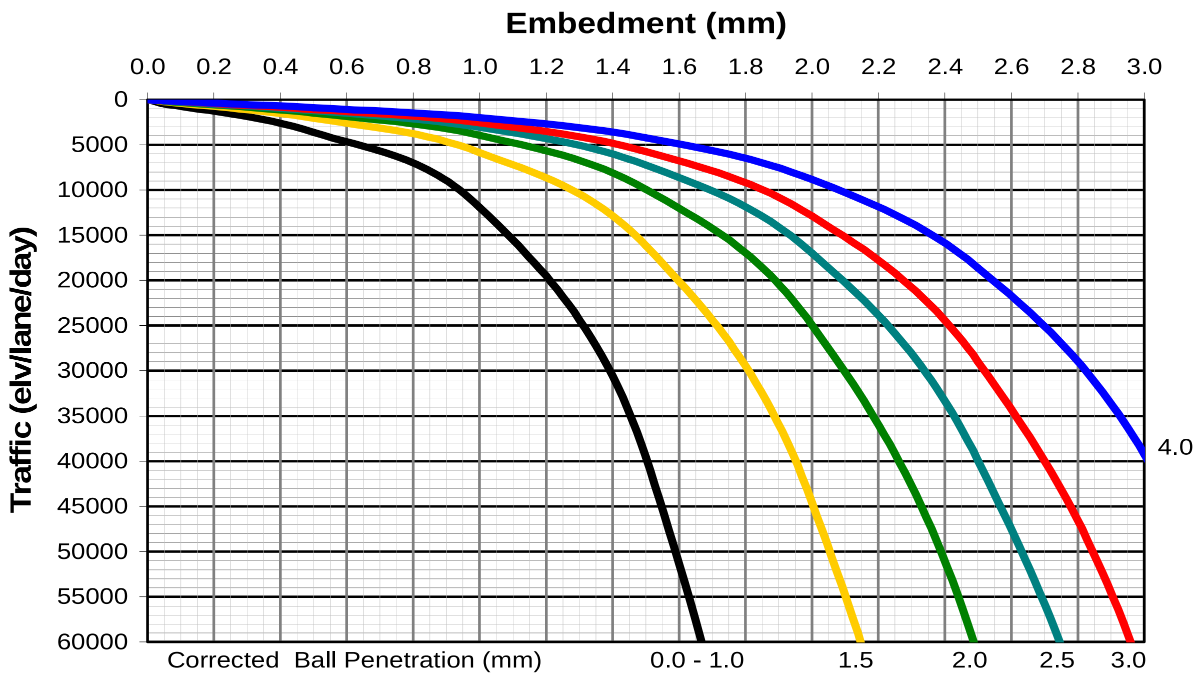


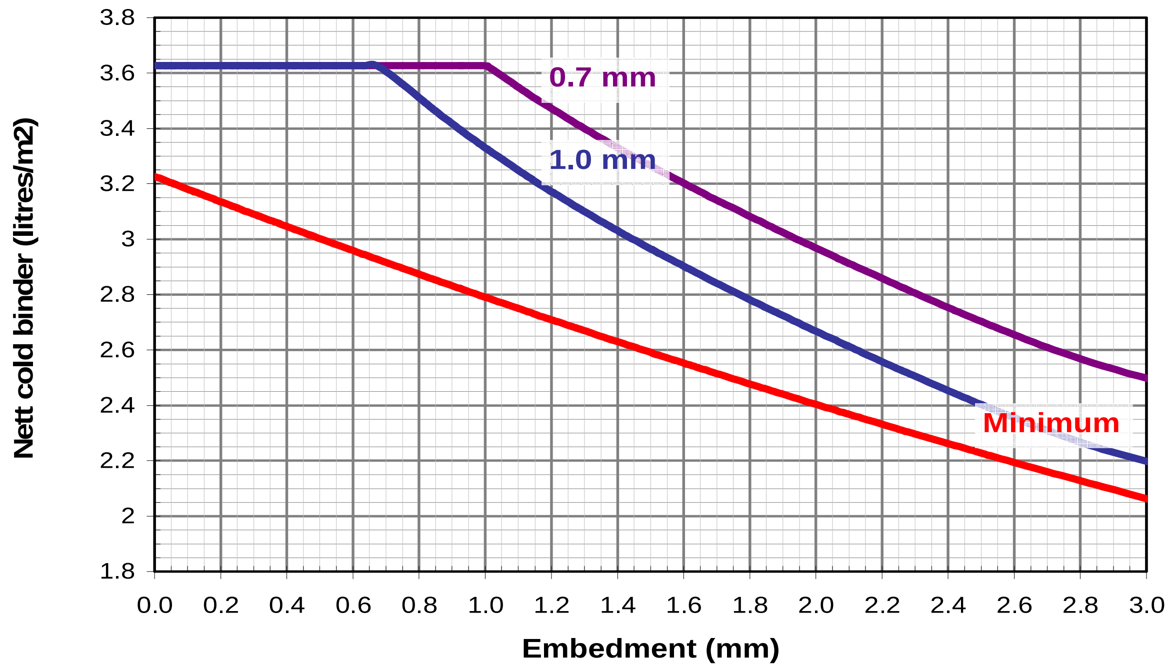
DESIGN CHART FOR DOUBLE SEALS: Design ALD = 20 mm



DESIGN CHART FOR DOUBLE SEALS: Design ALD = 21 mm

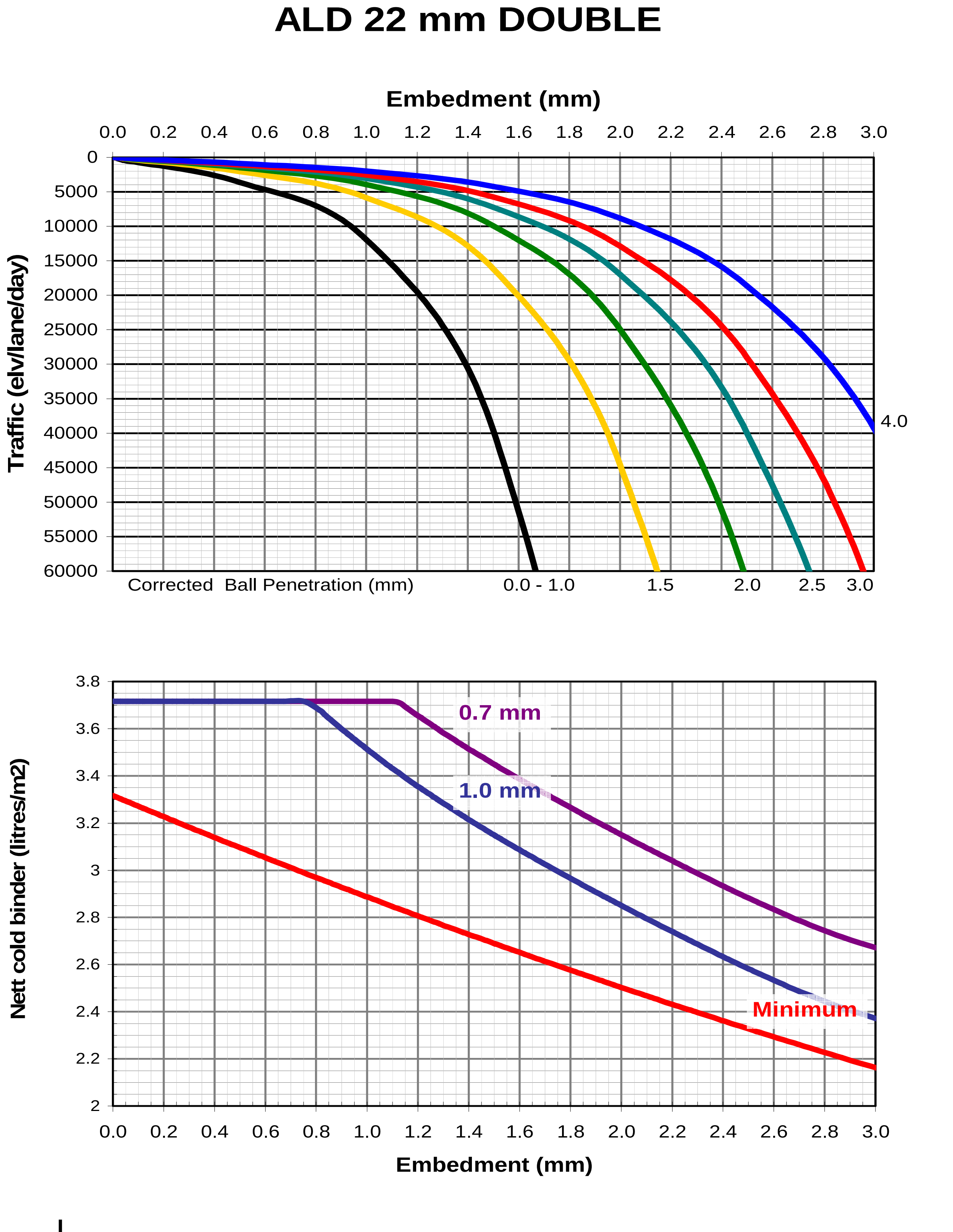
ALD 21 mm DOUBLE





Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

DESIGN CHART FOR DOUBLE SEALS: Design ALD = 22 mm



Note: Risk - Too much binder for target texture, yet too little to prevent whip-off

APPENDIX F

STONE SPREAD RATES

RECOMMENDED SPREAD RATES OF SEAL AGGREGATES

The ideal spread rates for aggregate may vary according to the purpose of the seal, shape and flakiness of the aggregate and personal preferences.

Final spread rates should be determined by spreading a known volume of aggregate by hand and confirmation of full-scale trials on site (Refer Figure F–1)

Figure F-1 Determining appropriate aggregate spread rate on site

Figure F-2 gives the approximate spread rates for single seals or first application of double seals, the second application on double seals as well as the approximate spread rate for Cape seals, based on the ALD and Flakiness Index

Notes:

Information provided only indicates approximate aggregate spread rates and can not be used as specifications

For purposes of ordering and stockpiling aggregate, provision should be made for wastage (approximately 5 per cent)

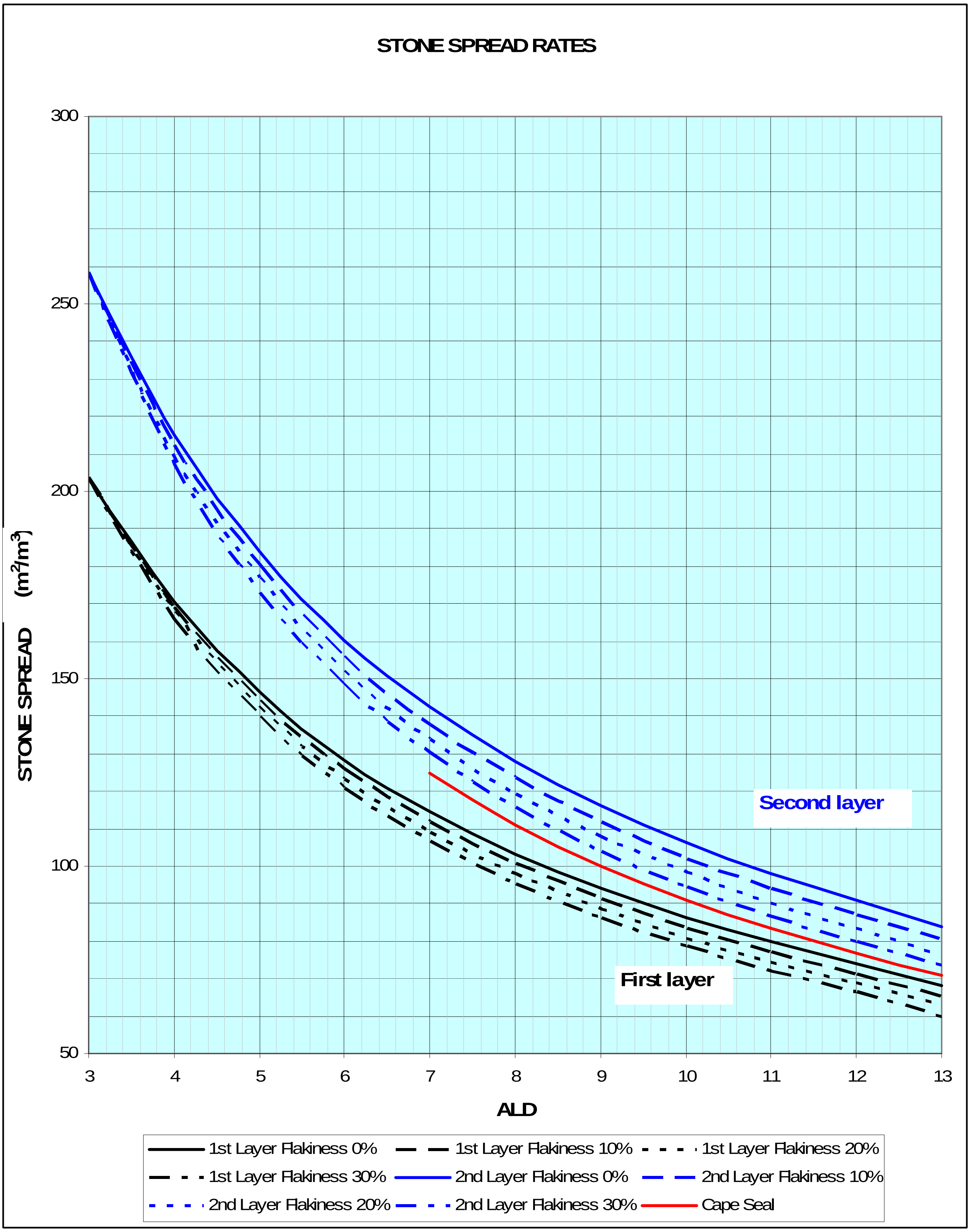


Figure F-2 Approximate spread rates for seal aggregate

Figure F-3 Dense shoulder-to-shoulder matrix

Figure F-4 Open shoulder-to-shoulder matrix

APPENDIX G

DETERMINATION OF THE CONSISTENCY OF A SLURRY MIXTURE

This method describes the determination of the consistency of a slurry mixture by means of the flow cone test.

1 DEFINITION

The consistency of a slurry mixture is defined as the amount of flow of the mixture over a flow plate, measured in millimetres.

The flow provides an indication of the effect of mix proportioning of the various constituents, as well as of the quantity of water in the mix, which determines its workability.

2 APPARATUS

2.1 *Flow plate:* a 5 mm thick round metal plate with a diameter of 250 mm having a smooth surface which is resistant to chemical substances. A circle of 90 ± 1 mm is engraved to a depth of between 0,5 and 0,8 mm in the centre of the plate. The width of the engraving is such that the cone (see 2.2) fits precisely into it. Concentric circles, at 10 mm diameter increments, are inscribed around the centre engraved circle outwards to the edge of the plate. The first circle after the centre circle is marked at 10 mm, followed by 20 mm, 30 mm etc.

The flow plate is mounted on a tripod, of which two of the legs are adjustable. A spirit level is mounted on the outer edge of the flow plate between the two adjustable legs.

2.2 A metal mould in the form of a frustum of a cone with the following internal dimensions: top diameter, 37,5 ± 1 mm bottom diameter, 90 ± 1 mm; height, 75 ± 1 mm. The cone should be manufactured from a chemical-resistant metal with a thickness of between 0,8 and 1,5 mm.

2.3 A balance with a capacity of at least 6,0 kg and accurate to 0,1 g.

2.4 A riffler with 13 mm openings, together with pans.

2.5 A thermostatically controlled oven capable of maintaining a temperature of 105 to 110 ℃.

2.6 A dispersing apparatus with a blade and container which should have a capacity of at least three times the volume of 3 kg of fine aggregate.

2.7 Mixing containers having a capacity of three times the volume of 500 g of fine aggregate.

2.8 Spatulas for mixing.

2.9 Measuring cylinders with capacities of 50 ml, 200 ml and 1 000 ml respectively.

2.10 A suitable organic solvent such as toluene.

3 SAMPLES

3.1 *Aggregates:* approximately 15 kg of each type of aggregate is required. Carry out sieve analyses of each aggregate according to Method B4 of TMH1[17].

3.2 *Mineral filler:* approximately 1 kg of each type of mineral filler is required. Cement or hydrated lime is normally used with anionic emulsions, while limestone dust, fly ash or silica fume is used with cationic emulsions.

3.3 *Emulsion:* the anionic or cationic emulsions should comply with the relevant SABS specifications[46, 47].

3.4 *Water:* only potable water free of deleterious substances or chemicals should be used.

4 METHOD

4.1 Weigh out 3 or more 500 g samples of fine aggregate. If more than one type of aggregate is to be used, the various aggregates should be weighed out in the correct proportions in order to obtain total samples of 500 g each.

The type and quantity of mineral filler to be added depends on the type of emulsion to be used as well as on the grading of the fine aggregate. This, however, is normally in the order of 1 to 2 parts per 100 (by mass) of the fine aggregate.

The proportioning of the slurry mixture is therefore as follows:

Fine aggregate	100 parts	=	500 g
Cement	1,5 parts	=	7,5 g
Emulsion	20 parts	=	100 g

The quantity of water required to obtain the desired consistency of the slurry is determined as follows:

4.2 Add the calculated quantity of mineral filler to each of the 500 g portions of fine aggregate and mix the blend until a homogenous colour is obtained. Add a small quantity of water to the first sample and mix it thoroughly. The calculated quantity of emulsion is now added to the mixture and mixed for 3 minutes. While continuing to mix, add additional quantities of water in small increments until a paste is formed i.e. until just before the mixture starts to flow. Record the total quantity of water added to the mixture.

Determine the flow of the slurry mixture as described in 4.3. Repeat the test on the second and third samples, but with higher water contents for each additional sample.

An alternative method for mixing in the water is as follows:

Add 9 parts water to the first sample and 12 and 15 parts to the second and the third samples respectively. After these have been thoroughly mixed, add the correct qualities of emulsion and continue mixing until a homogenous mixture is achieved. Carry out the flow test on each sample.

4.3 *Flow test:* Place the cone on the previously levelled flow plate, ensuring that it is firmly seated in the engraved circular groove. Hold the cone firmly in place and fill the cone with the slurry mixture. Lift the cone carefully, allowing the slurry to flow across the plate. The degree of flow, i.e. the distance that the fine aggregate has dispersed, is measured where the greatest flow has occurred, and is reported as follows e.g. 10 - 20 mm. The flow of the other samples is determined in a similar manner.

4.4 *Laboratory control test:* After the quantity of water required to produce a slurry mixture with a specific workability has been determined, a control sample is made up. With the same proportions as those determined above, make up a 3000 g sample of slurry utilising a mechanical mixer.

It is important that most of the water, together with the mineral filler, is first mixed in with the fine aggregate prior to the addition of the emulsion. Use the remainder of the water to rinse out the measuring cylinder used for measuring out the emulsion, prior to adding it to the mixture.

The flow is then determined on the flow plate as described above.

4.5 *Field control:* Blend approximately 20 kg of the slurry mixture in a large basin or clean wheelbarrow, and determine the flow in a similar manner to that described in 4.3. This control test should be carried out on each batch of slurry produced

5 NOTES

5.1 A flow of 20-30 mm indicates that segregation of the fine aggregate should not occur.

5.2 The flow of a slurry to be applied in a thick layer, in order to eliminate surface unevenness, should be less than that indicated in 5.1.

5.3 If two layers of slurry are to be applied, the flow of the slurry for the second layer should be greater than that for the first.

5.4 Additional water is not required if application of the slurry takes place during hot windy conditions.

DETERMINATION OF THE STIFFNESS OF A SLURRY MIX

Mix Proportion	Aggregate	:	100 parts
	Filler	:	1: 1¼: 1½ or 2 parts
	Emulsion	:	20 parts

AGGREGATE	DESCRIPTION	SOURCE	LAB NO.
* 6,7 mm aggregate			
* Crusher dust			
* Crusher Dust/Sand			

Mix proportions of aggregate

*6,7 mm aggregate : ________________ Parts)

*Crusher Dust : ________________ Parts) - 100 Parts

*Crusher Dust/Sand : ________________ Parts)

(A) Mix proportions of material (500 g of aggregate)

	1	2	3	4	5	6
6,7 mm g/Parts						
Crusher Dust g/Parts						
Crusher Dust/Sand g/Parts						
Filler g/Parts						
Emulsion g/Parts						
Water ml/Parts						
Flow (mm)						

(B) Control Test (3000 g aggregate)

*6,7 mm aggregate : ________________ parts = _______ g}

*Crusher Dust : ________________ parts = _______ g}

*Crusher Dust/Sand : ________________ parts = _______ g}

*6,7 mm aggregate : ________________ parts = _______ g}

*Crusher Dust : ________________ parts = _______ g}

*Crusher Dust/Sand : ________________ parts = _______ g}

Emulsion : ________________ parts = _______ g}

Water : ________________ parts = _______ g}

Flow : ________________ mm

Delete where not applicable

APPENDIX H

SEAL DESIGN – WORKED EXAMPLES

The main purpose of the worked examples is to give guidance in the use of the design charts given in APPENDIX E. Examples are given for the design of:

- single seals using conventional binders,
- double seals using conventional binders,
- single seals using a modified binder,
- double seal using a modified binder, and
- split application double seal using a combination of binders

EXAMPLE 1: SINGLE SEAL DESIGN

Situation

A section of road between Magaliesberg and Koster in the North West Province is to be resealed during October with a 13,2 mm single seal.

Details

Terrain:	Rolling with maximum gradients of 5 per cent with slow-moving heavy vehicles travelling at 35 km/h
Current traffic:	Heavy vehicles = 75 per day per lane Light vehicles = 500 per day per lane
Existing surfacing:	9,5mm single seal treated 3 years ago with a fine slurry texture treatment
Texture depth:	Texture depth is uniform on this section with an average of 0,3 mm
Embedment potential:	The average of corrected Ball Penetration values on this section is less than 1 mm
Aggregate:	The aggregate delivered on site conforms to COLTO specifications[4] with and ALD of 7,9 mm and a Flakiness Index of 15 per cent

Policies

Aggregate spread rate: A dense shoulder-to-shoulder matrix according to APPENDIX F is preferred.

In accordance with the maintenance strategy and policies of the department a lean seal is preferred.

Design

ELV/lane/day 500 + (75 x 40) = 3500

Corrected ball penetration < 1 mm

Refer to APPENDIX E

Net cold binder required for a 0,7 mm texture depth:

(single seals) for use of	For 8 mm ALD:	min: 1,07 ℓ /m²	max: 1,36 ℓ/m²
design charts and figures	For 7 mm ALD:	min: 0,92 ℓ /m²	max 1,02 ℓ/m²

For 7,9mm ALD do straight line interpolation

min: 0,92 + 0,9 (1,07 – 0,92) = 1,06 ℓ/m²

max: 1,02 + 0,9 (1,36 – 1,02) = 1,33 ℓ/m²

Adjustments (refer to 7.6.3.3)

a) Climate:
   Using Figure 1-3 – Weinert N-value is between 2 and 5, therefore no adjustment is required
b) Existing texture depth: 0,3 mm (and the corrected ball penetration is low)
   Using Figure 7-2 – add 0,19 ℓ/m²

c) Gradients: max = 5 per cent with some heavy vehicles travelling less than 40 km/h
Reduce net cold binder by 5 per cent on uphills

d) Aggregate spread: Dense matrix aggregate spread rate – no adjustment

In accordance with the strategy, only the minimum application rates are determined.

Net Cold Design application rate:

(flat and downhill)	= 1,06 + 0,19	= 1,25 ℓ/m²
(uphill – 5% gradients)	= 1,25 – (0,05 x 1,06)	= 1,20 ℓ/m²

Binder type: Using Table 5-1, a 80/100 Penetration Grade bitumen is selected

Hot application rate:

Convert the net cold application rate using Table 7-3

Hot binder application rate (flat and downhill) = 1,25 x 1,09 = 1,36 ℓ/m²

Hot binder application rate (uphill – 5% gradient) = 1,20 x 1,09 = 1,31 ℓ/m²

Notes:

The maximum application rates can be determined in a similar way

The contractor is allowed a 5% tolerance in application. Consideration could be given to increase the hot application rate with 5%.

Aggregate application rates:

Using Figure F-2 in APPENDIX F, the approximate aggregate spread rate = 100 m^2/m^3

EXAMPLE 2: DOUBLE SEAL DESIGN

Situation

A newly constructed section of road between Aliwal North and Bethulie is to be sealed with a 13,2 + 6,7 mm double seal.

Details

Terrain: Rolling with maximum gradients of 4 per cent and no slow-moving heavy vehicles

Current traffic: Heavy vehicles = 100 per day per lane
Light vehicles = 1000 per day per lane

Base: Crushed stone

Texture depth: The existing texture depth is uniform on this section with an average of 0,5 mm

Embedment potential: The average Corrected Ball Penetration value on this section is 2 mm

Note:

Refer to paragraph 3.3 for guidelines on Ball Penetration testing and result interpretation.

Aggregate: The aggregate delivered on site conforms to COLTO specifications[4]

ALD of 13,2 mm aggregate = 8,1 mm

ALD of 6,7 mm aggregate = 3,8 mm

Policies

Aggregate spread rate:	A dense shoulder-to-shoulder matrix according to APPENDIX F is preferred for the first aggregate layer

In accordance with the maintenance strategy and policies of the department, a lean seal is preferred.

Precoating of the second aggregate layer is recommended.

Design

ELV/lane/day	1000 + (100 x 40) = 5000
Design ALD (= ∑ALD)	8,1 + 3,8 = 11,9 mm

Refer to APPENDIX E

Net cold binder required for 0,5 mm texture:

(double seals) for use of	For 11 mm ALD		min: 1,60 ℓ/m²	max: 1,78 ℓ/m²
design charts and figures	For 12 mm ALD		min: 1,75 ℓ/m²	max: 1,85 ℓ/m²
	For 11,9 mm ALD			
		min:	1,60 + 0,9 (1,75 – 1,60) = 1,74 ℓ/m²	
		max:	1,78 + 0,9 (1,85 – 1,78) = 1,85 ℓ/m²	

Adjustments (refer to 7.6.5)

a) Climate: Weinert N-value > 5 – add up to 10 per cent binder
b) Texture: 0,5 mm – Using Figure 7-2 – add 0,21 ℓ/m²
c) Gradients max = 4 per cent with no slow-moving heavies – no adjustment
d) Dense matrix aggregate spread rate – no adjustment

Net Cold Design application rate (minimum) = 1,74 + (0,1 x 1,74) + 0,21 = 2,12 ℓ/m²

Binder type: Using Table 5-1, 80/100 Penetration Grade bitumen is selected

Total hot binder application rate = 2,12 x 1,09 = 2,35 ℓ/m²

Binder distribution between the tack coat and penetration coat:

The total binder application is sufficient to allow an 80/100 penetration grade bitumen to be used in both the tack coat and penetration coat. A distribution of 55 per cent (tack coat) / 45 per cent (penetration coat) of the total binder volume is recommended.

Tack coat application rate (hot)	=	0,55 x 2,35	=	1,29 ℓ/m²
Penetration cost application rate (hot)	=	0,45 x 2,35	=	1,06 ℓ/m²

Note:

The maximum application rates to obtain a 0,5 mm texture depth can be determined in a similar way.

Aggregate spread rates:

Using Figure F-2 in APPENDIX F		
Aggregate spread rate for first layer	=	100 m^2/m^3
Aggregate spread rate for second layer	=	200 m^2/m^3

EXAMPLE 3: SINGLE SEAL DESIGN USING A MODIFIED BINDER

Situation

A section of road between Brits and Rustenburg in the North West Province is to be sealed during February with a 13,2 mm single seal.

Details

Terrain:	Flat, with maximum gradients of 4 per cent and no slow-moving heavy vehicles
Current traffic:	Heavy vehicles = 425 per day per lane
	Light vehicles = 2800 per day per lane
Existing surfacing:	19,0 + 9,5 mm double seal treated with a find slurry texture treatment
Texture depth:	Texture depth is uniform on this section with an average of 0,3 mm
Embedment potential:	The average Corrected Ball Penetration value on this section is 2,0 mm
Aggregate:	The aggregate delivered on site conforms to COLTO specifications[4] with an ALD of 9,5 mm and a Flakiness Index of 15 per cent

Policies

Aggregate spread rate: A dense shoulder-to-shoulder matrix according to APPENDIX F is preferred (see Figure F-3).

Design

ELV/lane/day	2 800 + (425 x 40) = 19 800		
Design ALD	9,5 mm		
Refer to APPENDIX E	Net cold conventional binder required		
	minimum required texture depth = 0,7 mm:		
for design charts	For 9 mm ALD	min: 0,7 ℓ/m²	max: 0,7 ℓ/m²
	For 10 mm ALD	min: 0,76 ℓ/m²	max: 1,0 ℓ/m²
	For 9,5 mm ALD		
	min: 0,7 + 0,5 (0,76 – 0,7) = 0,73 ℓ/m²		
	max: 0,7 + 0,5 (1,0 – 0,7) = 0,85 ℓ/m²		

Adjustments (refer to 7.6.3.3)

a) Climate: No adjustments for modified binders
b) Existing texture depth: 0,3 mm – using Figure 7-2 – add 0,17 ℓ/m²
c) Gradients max = 4 per cent with no slow heavies – no adjustment
d) Dense matrix aggregate spread rate – no adjustment

Net Cold Design application rate before adjustment to Net Cold Modified Binder

min = 0,73 + 0,17 = 0,90 ℓ/m²
max = 0,85 + 0,17 = 1,02 ℓ/m²

Binder type: A bitumen rubber binder is selected (S-R1) – Adjustment factor = 1.9 (See par. 7.7.1.2)

Adjustment to net cold modified binder

min = 0,90 x 1,9 = 1,71 ℓ/m²

max = 1,02 x 1,9 = 1,94 ℓ/m²

Total hot application rate: The net cold modified binder is converted to hot application rate using Table 7-3

Hot binder application rate (min) = 1,71 x 1,07 = 1,83 ℓ/m²

Hot binder application rate (max) = 1,94 x 1,07 = 2.07 ℓ/m²

Note:

Conversion factors for modified binders can vary from one manufacturer's product to another.

Allow for 5% tolerance on non-homogeneous binder i.e. add 5% to minimum application

Therefore

Total hot binder application rate min: = 1,83 x 1,05 = 1,92 ℓ/m²

Total hot binder application rate max: = 2.07 ℓ/m²

Notes:

Experience indicates that the absolute minimum practical application rate for bitumen rubber is 1,8 ℓ/m² and that a minimum of 2,0 ℓ/m² is preferred

When the calculated binder application rate for the conditions at hand falls below the minimum practical rate, the aggregate size should be increased

Taking into account of the risk of under application and the maximum rate calculated, the design application rate is specified at 2,0 ℓ/m².

The recommended aggregate spread rate according to Figure F-2 in APPENDIX F = 87 m²/ m^3

EXAMPLE 4: DOUBLE SEAL DESIGN USING A MODIFIED BINDER

Situation

An existing road between Paarl and Stellenbosch is to be sealed with a 13,2 + 6,7 mm double seal.

Details

Terrain:	Rolling with maximum gradients of 4 per cent and no slow-moving heavy vehicles
Current traffic:	Heavy vehicles = 300 per day per lane
	Light vehicles = 5000 per day per lane
Existing seal	13,2 mm and sand
Texture depth:	The existing texture depth is uniform on this section with an average of 0,5 mm
Embedment potential:	The average Corrected Ball Penetration value on this section is 1,5 mm

Aggregate:	The aggregate delivered on site conforms to COLTO specifications[4]
	ALD of 13,2 mm aggregate = 8,0 mm
	ALD of 6,7 mm aggregate = 4,0 mm

Policies

Aggregate spread rate: A dense shoulder-to-shoulder matrix according to APPENDIX F is preferred for the first aggregate layer

In accordance with the seal strategy and policies of the department, a fogspray must be applied as the seal would be constructed close to winter.

Design

ELV/lane/day	5000 + (300 x 40) = 17000
Design ALD (= ∑ALD)	8,0 + 4,0 = 12,0 mm

Refer to APPENDIX E

Net cold binder required for 0,5 mm texture:

(double seals) for use of

design charts and figures For 12 mm ALD min: 1,57 ℓ/m² max: 1,62 ℓ/m²

Notes:

Experience with modified binder double seals suggests designs based on the minimum application rates. Therefore 1,57 ℓ/m² with final expected texture depth between 0,7 mm and 0,5 mm

Adjustments (refer to 7.6.5)

a)	Climate:	No adjustment
b)	Existing texture:	0,5 mm – Using Figure 7-2 – add 0,21 ℓ/m²
c)	Gradients	Maximum 4 per cent with no slow-moving heavies – no adjustment
d)	Dense aggregate matrix	No adjustment

Net Cold Design application rate (minimum) = 1,57 + 0,21 = 1,78 ℓ/m²

Binder distribution between the tack coat, penetration coat and fogspray:

Accept an application of 0,8 ℓ/m² fogspray of a 50/50 diluted Cat 65% spray grade emulsion (minimum). According to recommendations only 50% of the net binder of the fogspray should be taken into account for seal design purposes.
Therefore the remaining net binder = 1,78 – 0,5 x (0,5 x 0,8 x 0,65) = 1,65 ℓ/m²

Binder type: S-E2 binder is selected for the tack coat and penetration coat
The remaining cold S-E2 binder = 1,65 x 1,1 = 1,82 ℓ/m²
(see Table 7-7 for modified conversion factor)

Total hot modified binder application rate = 1,82 x 1,06 = 1,92 ℓ/m²

The total binder application is sufficient to allow the S-E2 binder to be used in both the tack coat and penetration coat. A distribution of 55 per cent (tack coat) / 45 per cent (penetration coat) of the total binder volume would result in the following.

Tack coat application rate (hot)	=	0,55 x 1,92	=	1,06 ℓ/m²
Penetration cost application rate (hot)	=	0,45 x 1,92	=	0,86 ℓ/m²

The minimum recommended spray rates for this seal type (refer Table 7-9) suggests 1,0 ℓ/m² for the tack coat and 0,8 ℓ/m² for the penetration coat. The suggested hot applications are, therefore, acceptable.

Specified application rates:

Tack coat S-E2	1,06 ℓ/m²
Penetration coat	0,86 ℓ/m²
Fogspray 50/50 diluted CAT 65% Spray grade emulsion	0,80 ℓ/m²

Aggregate spread rates:

Using Figure F-2 in APPENDIX F

Aggregate spread rate for first layer	=	100 m^2/m^3
Aggregate spread rate for second layer	=	210 m^2/m^3

Notes:
Modified binder seals often require approximately 10% higher stone spread rates.
If the first aggregate layer is rolled with a steel wheel roller, it is possible that the required spread rate for the 6,7 mm aggregate would have to be increased.

EXAMPLE 5: SPLIT APPLICATION DOUBLE SEAL DESIGN USING A MODIFIED BINDER

Situation

The National Route 2 Section 7 between Grootbrak and George must be resealed with a 19,0 and 6,7 mm split application double seal. This example only relates to steep grades on the slow lane

Details

Terrain: Steep gradients with high volume slow-moving heavy vehicles. Two sections with heavy vehicle speeds less than 40 km/h (as low as 25km/h) as shown below

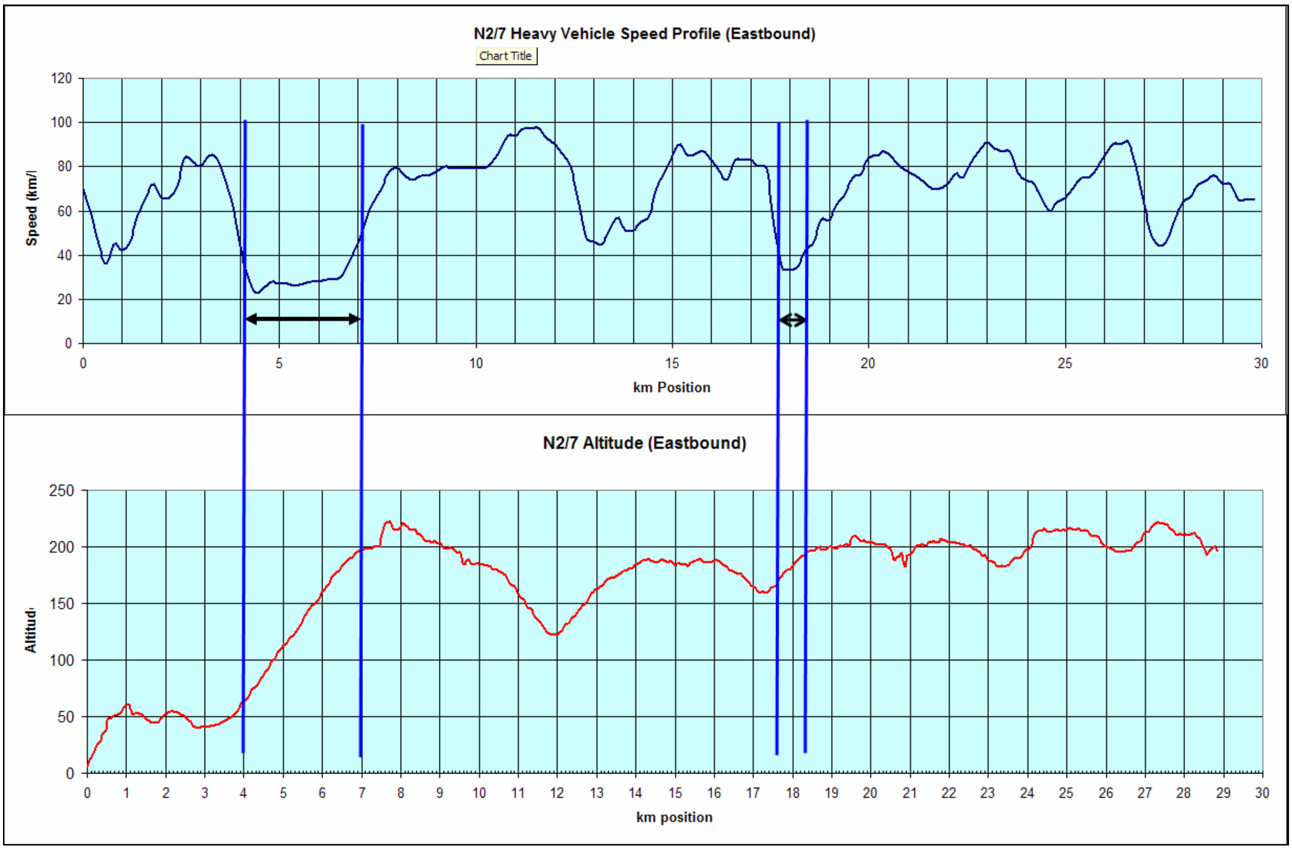


Figure H-1 Steep gradient comparison

Current traffic: ELV = 20000 per lane per day in the slow lane

Existing seal: 13,2 mm with recently applied texture slurry

Texture depth: The existing texture depth is uniform on this section with an average of 0,4 mm

Embedment potential: The average Corrected Ball Penetration value on this section is 2,0 mm

Aggregate: The aggregate delivered on site conforms to COLTO specifications[4]

ALD of 19,0 mm aggregate = 12,0 mm

ALD of 6,7 mm aggregate = 4,0 mm

Policies

Aggregate spread rate: A dense shoulder-to-shoulder matrix according to APPENDIX F is preferred for the first aggregate layer

In accordance with the seal strategy and policies of the department, a fogspray must be applied as the seal would be constructed close to winter.

Design

ELV/lane/day 20000

Design ALD (= ∑ALD) 12,0 + 4,0 = 16,0 mm

Refer to APPENDIX E

Net cold binder required for 0,7 mm texture:
(double seals) for use of
design charts and figures For 16 mm ALD min: 1,94 ℓ/m² max: 2,12 ℓ/m²

Adjustments (refer to 7.6.5)

a) Climate: No adjustment
b) Texture: 0,4 mm – No adjustment as a result of 2,0 mm corrected ball penetration
c) Gradients Reduce 10% due to slow moving heavy vehicles
d) Dense matrix aggregate spread rate – no adjustment

Net Cold Design application rate (minimum) = 1,94 – 0.19 = 1.75 ℓ/m²

Binder distribution between the tack coat, penetration coat and fogspray:

Accept an application of 1,0 ℓ/m² fogspray of a 60/40 diluted Cat 65% spray grade emulsion . According to recommendations only 50% of the net binder of the fogspray should be taken into account for seal design purposes.
Therefore the remaining net binder = 1,75 – 0,5 x (0,6 x 1,0 x 0,65) = 1,56 ℓ/m²

Binder type: S-E2 binder is selected for the tack coat and penetration coat

The remaining cold S-E2 binder = 1,56 x 1,2 = 1,87 ℓ/m²
(see Table 7-7 for modified conversion factor)

Total hot binder application rate = 1,87 x 1,06 = 1.98 ℓ/m²
Allow 5% tolerance = 1,98 * 1.05 = 2,08 or approximately 2,1 ℓ/m²

The total binder application is sufficient to allow the S-E2 binder to be used in both the tack coat and penetration coat.

The minimum recommended spray rates for this seal type (refer Table 7-9) suggests 1,1 ℓ/m² for the tack coat and 0,8 ℓ/m² for the penetration coat. The following suggested hot applications are, therefore, recommended.

Tack coat S-E2	1,1 ℓ/m²
Penetration coat S-E2	1,0 ℓ/m²
Fogspray 60/40 diluted CAT 65% Spray grade emulsion	1,0 ℓ/m²

Preliminary aggregate spread rates:
Using Figure F-2 in APPENDIX F and Table 7-10

Aggregate spread rate for first layer	=	70 m^2/m^3
Aggregate spread rate for second layer (dry)	=	300 m^2/m^3
Aggregate spread rate for final 6,7 mm layer	=	155 m^2/m^3

Final spread rates specified after trials on site (see Figure H-2)

Figure H-2 Spread rates

Aggregate spread rate for first layer	=	70 m^2/m^3
Aggregate spread rate for second layer (dry)	=	220 m^2/m^3
Aggregate spread rate for final 6,7 mm layer	=	160 m^2/m^3

APPENDIX I

CUTTING BACK OF BITUMINOUS BINDERS ON SITE

The effective viscosity of the bitumen at time of application may be changed to accommodate local conditions during construction.

Before the bitumen is cut back, the expected maximum and minimum temperatures for the ensuing 24 hours should be ascertained. During the summer months, i.e. November, December, January and February, the temperatures are usually most accommodating but work may be affected by sudden drops in temperature as a result of rain or hail. It is not advisable, therefore, to do any surfacing work if wet weather is anticipated (continuous rain). Thunderstorms are usually unpredictable and, as a safety precaution, allowance should be made for these by introducing 1 – 2 per cent *aromatic paraffin* into the bitumen.

Note:
Only petroleum-based cutters should be used with bitumen

Details of environmental condition, quantities of cutting-back agent and temperatures are given in Table I-1.

TABLE I-1 Cutting back of penetration grade bitumen

Minimum temperatures for 24 hours (projected °C)	Road temperature (°C)	Approximate air temperature (°C)	Percentage cutter (Aromatic paraffin) in 80/100 pen. bitumen	Spray temperature (°C)
0 – 3 [(a)]	16 – 24	10 – 16	9% – 7%	100 – 118 (max)
3 – 6	24 – 32	16 – 21	7% – 5%	115 – 135 (max)
6 – 9	32 – 40	21 – 26	4% – 3%	121 – 138 (max)
9 – 12	40 – 48	26 – 31	2% – 1%	132 – 149 (max)
> 12	> 48	> 31	0	150 – 175 (max)

Notes: *[(a)] Experience in the central parts of South Africa indicates that the addition of 9% cutter is still appropriate for conditions where minimum temperatures for 24 hours < 4 °C.*
During the rainy season it is recommended that 1 to 2 per cent cutter be added as a safety factor (not in addition to the above percentages).
These recommendations are applicable only to NATREF bitumens.
Chemical analyses of the binder and cutter are required before bitumens from other sources are cut back.
If the weather is predictably dry for the months November, December and January and the road temperature exceeds 31 °C, additives may be omitted.

Precautionary measures

When aromatic paraffin is added to bitumen, the temperature of the bitumen should not exceed 140 °C.
The aromatic paraffin should be siphoned out of 200 litre drums in measured quantities by means of a bitumen pump and added to the distributor. It should be circulated with the bitumen in the distributor for a minimum period of 45 minutes. During this process, all burners should be off and there should be no open flames.

Aromatic paraffin should not be poured through the manhole of the distributor, which should be kept closed. There should always be a minimum of two fire extinguishers in working condition at each distributor.

Unless good and responsible control cannot be exercised, the cutting back of bitumen is highly inadvisable.

APPENDIX J

TRANSVERSE DISTRIBUTION (Bakkie Test)

1 SCOPE

This methods sets out the procedure for the simple field determination of the transverse distribution of a binder distributor. Certain statistical criteria are applied to the results to determine conformance with requirements.

2 DEFINITION

The purpose of the test is to determine conformance of the transverse distribution of the spray bar, as measured by direct discharge from sets of 3 nozzles, using the project binder.

3 APPARATUS

3.1 Steel troughs

14 steel troughs fitted with handles and manufactured from 3 mm mild steel plate, conforming to the following or similar dimensions, are required for a 4,2 m wide spray bar:

Width	-	265 mm
Depth	-	405 mm
Height	-	300 mm

Each trough to be clearly numbered on it's side.

3.2 Balance

A balance capable of weighing up to 50 kg to an accuracy of 20 g.

3.3 Personal protective clothing

The appropriate safety gear must be worn when performing this test and should include a pair of asbestos gloves, face shield and approved overalls.

3.4 Cleaning fluid

Diesel or other suitable fluid.

4 PREPARATION OF THE BINDER DISTRIBUTOR

- Ensure that all the binder strainers on the sprayer have been cleaned.
- Preheat the binder in the distributor tank to within ± 5 ºC of the required spray temperature.
- Circulate the binder through the spray bar for at least 15 minutes.

- Position the spray bar over a full-length drip tray. A short preliminary spray is made to ensure that all the nozzles are functioning and that the machine is in normal working condition. Suck back the binder from the drip tray into the distributor tank on completion of test spray.
- If necessary, correct any malfunctioning of the spray bar.

5 METHOD

- Ensure that all troughs are clean and free of any water or other materials.
- Place the pre-weighed steel troughs described in 3.1 under the spray bar in such a manner that the discharge of each set of three nozzles are collected in one trough. Ensure that the troughs are placed in numerical order.
- Adjust the spray bar height to ensure that the nozzles are below the sides of the trough.
- Increase the bitumen pump speed to yield the desired triple spray overlap in accordance to the type of nozzles and type of binder being used. Typically this could vary between 12 and 20 litres per minute for conventional binders.
- Open the nozzles and spray sufficient binder to fill the troughs without risking spillage during handling.
- Weigh the troughs to determine the mass of binder sprayed.
- On completion of the weighing and before the binder cools suck back the binder into the distributor tank.
- Only clean the troughs with a suitable cleaning fluid once they have cooled down to room temperature.
- Store used cleaning fluid in a suitable container for re-use.

6 CALCULATION AND REPORT

- Determine the net mass of binder in each trough to the nearest 20 grams.
  Net mass binder $= (M_1, M_2, M_3 \ldots. M_n)$.
- Calculate the average mass of the binder collected in all the troughs.
  $M_{ave} = \sum (M_1 .. M_n) / n$
  where n = number of troughs
- Calculate the deviation from the average mass for every trough and express the value as a percentage.

  $\% \; Deviation = (M_{ave} - M_i)/M_{ave} \times 100$
- If the transverse distribution is out of specification, make the necessary adjustments to the spray bar and repeat the test.
- Report results on the example sheet .
- Update the ‘bakkie’ test record with the relevant information for the distributor.

7 ACCURACY

Due to the varying nature of the different types of binders, cognisance must be taken of the respective binder's viscosity at spray temperature when establishing achievable tolerances, namely:

Conventional binders	40 – 100 CPs
Polymer modified binders	120 –200 CPs
Bitumen rubber	2,000 – 3,000 CPs

Specifications
The mass of binder of any individual trough shall not deviate from the average mass by more than the following percentages:

Penetration bitumen, and cutback bitumen and bitumen emulsion	±5%
Homogeneous modified bitumen (Polymer modified)	±7%
Non- homogeneous binders (bitumen rubber)	±-10%

The spray bar shall be of such design to meet the above tolerances in order to achieve a uniform transverse and longitudinal distribution. This calibration procedure shall be carried out each time the distributor is first established on site or when a problem with transverse distribution is suspected.

Example Sheet

Transverse Distribution Test Report Sheet('bakkie' test)

DATE : ………………………………...

CLIENT/PROJECT : ……………………………..…..

DISTRIBUTOR COMPANY : …………………………………

DISTRIBUTOR REG. NO : ……………………………….

SPRAYBAR TYPE : ……………………………….

Trough no.	1	2	3	4	5	6	7
First weight, g							
Second weight, g							
Difference, g							
Deviation, % *							

Trough no.	8	9	10	11	12	13	14
First weight, g							
Second weight, g							
Difference, g							
Deviation, % *							

Trough no.	15	16	17	18	19	20	21
First weight, g							
Second weight, g							
Difference, g							
Deviation, % *							

Total mass binder in all trays, g : ………………….

Total number of trays, g : …………………..

Average mass of binder, g ** : …………………..

Formula * % Deviation $= (M_{ave} - M_i)/M_{ave} \times 100$

** $M_{ave} = \sum (M_1 .. M_n) / n$

Test performed by : ……………………………

APPENDIX K

RATIONAL SEAL DESIGN METHOD (CSIR)

1 INTRODUCTION

The rational method was developed from research done by the then National Institute for Transport and Road Research (now the Division of Roads and Transport Technology). No formal experiments have been built incorporating this method. However, the Division of National Roads of the Department of Transport (DOT) has incorporated the general approach in its design procedure for reseals and it is generally satisfied with the results obtained on reseals.

2 GENERAL DESIGN METHOD

In general the design tables may be used. The design tables incorporate the same design method as the refined design method except that they use the relationship between ALD and ELT and the average void content relationship (best fitting curve). The information required is the ADT per lane (may differ for different lanes of multi-lane roads; binder application will therefore also differ for different lanes), the corrected ball penetration value of the existing surface (see Draft TMH6[12] Method ST4) and the ALD of the aggregate to be used. The hardness (10 per cent FACT) of the aggregate is assumed to be 210 kN. A correction for surface texture of the existing surface should also be made (see Draft TMH6[12], Method ST1 and Table K-7).

2.1 Design tables for single and double seals (general approach)

Tables K-1 and K-2 give the nominal cold binder application rates used in the rational design method for single and double seals respectively. These are based on 42 per cent of the available void space being filled with binder in a single seal and 55 per cent of the available void space in the case of a double seal.

Table K-3 gives the nominal stone application rate used in the rational design method.

Notes:

Spread rates are still expressed in this Table as m^3/m^2, whereas the standard for the rest of the document has been accepted as m^2/m^3.

It is recommended that normally the minimum nominal cold binder application rate be used. The maximum nominal cold binder application rate gives an indication of how much the seal could absorb without any likely detrimental effects on the performance of the seal.

2.2 Examples (using tables)

(a) Single seals (Tables K-1 and K-3)

ALD	= 8,57 mm and FI = 25 %
Traffic (ADT/lane)	= 2 000 elv
Corrected ball penetration of existing surface	= 2 mm
Texture depth of existing surface	= 0,5 mm

Binder application rate (min.)	= 1,00 + (1,15 – 1,00)(0,57)
	= 1,00 + (0,15)(0,57)
	≅ 1,00 + 0,09
	≅ 1,09 ℓ/m^2
Binder application rate (max.)	= 1,32 + (1,46 – 1,32)(0,57)
	= 1,32 + (0,14)(0,57)
	≅ 1,32 + 0,08
	≅ 1,40 ℓ/m^2
Additional cold binder requirement due to the surface texture of the existing surface (for ADT/lane = 2 000 elv) (from Table K-7)	= 0,25 ℓ/m^2
Total binder requirement	= 1,09 + 0,25
	= 1,34 ℓ/m^2
Hot spray rate (150/200 pen bitumen)	= (1,34)(1,09)
	≅ 1,46 ℓ/m^2
Stone application rate (from Table K-3)	= (8,42 + 0,57(9,47 - 8,42)) x 10^{-3}
	= (8,42 + 0,57(1,05)) x 10^{-3}
	≅ 9,02 x 10^{-3} m^3/m^2

(b) Double seal (Tables K-2 and K-3)

ALD bottom = 8,57 mm and FI	= 25 %
ALD top = 4,55 mm and FI	= 20 %
Total traffic (ADT/lane)	= 3 000 elv
Ball penetration	= 3 mm
Texture depth	= 0,5 mm
Sum of ALDs = 8,57 + 4,55	= 13,12 mm
Binder application rate (min.)	= 1,95 + (2,07 – 1,95)(0,12)
	= 1,95 + (0,12)(0,12)
	≅ 1,96 ℓ/m^2
Binder application rate (max.)	= 2,26 + (2,49 – 2,26)(0,12)
	= 2,26 + (0,23)(0,12)
	≅ 2,29 ℓ/m^2

Additional cold binder requirement due to the surface texture of the existing surface (for ADT/lane = 3 000 elv) (from Table K-7)	= 0,22 ℓ/m^2
Total binder requirement	= 1,96 + 0,22 = 2,18 ℓ/m^2
Fog spray application rate	= (2,18)(0,25) = 0,545 ℓ/m^2
Tack coat application rate	= (2,18)(0,75/2) = 0,818 ℓ/m^2
Penetration coat application rate	= (2,18)(0,75/2) = 0,818 ℓ/m^2
(60 % bitumen emulsion)	= (0,545)(1,68) ≅ 0,92 ℓ/m^2
Hot spray rate (penetration coat) (150/200 pen bitumen)	= (0,818)(1,09) ≅ 0,89 ℓ/m^2
Stone application rate	The stone application rate in the bottom layer should be reduced by 5 % of the nominal stone application rate.
Bottom layer	$= 0,95\ (8,42 + (0,57)(9,47 – 8,42))\ x10^{-3}$ $= 0,95\ (8,42 + (0,57)(1,05))\ x\ 10^{-3}$ $\cong\ 8,57\ x\ 10^{-3}\ m^3/m^2$
Top layer	$= (4,31 + (0,55)(5,30 – 4,31))\ x\ 10^{-3}$ $= 4,31 + (0,55)(0,99)\ x\ 10^{-3}$ $\cong 4,85\ x\ 10^{-3}\ m^3/m^2$

3 REFINED DESIGN METHOD

When problems are experienced, particularly as far as the quality of the aggregate is concerned, the design can be refined by using more exact information.

3.1 Design of single seals

To design a single seal the following information is required:

(a) the Effective Layer Thickness (ELT[1]) and true void content[*] (as fraction of ELT volume) of the stone layer, V_1, as well as the hardness (10 per cent FACT) and bulk void content, V_b, of the stone to be used;

(b) the corrected ball penetration value of the existing surface (as determined with the ball penetration test) (Draft TMH6[12] Method ST4);

(c) the texture depth of the existing surface (as determined with the sand patch test) (Draft TMH6[12], Method ST1);

(d) the existing traffic expressed as equivalent light vehicles (elv) per lane per day, and

(e) the binder type to be used.

To determine the basic quantity of cold binder:

(a) determine the embedment due to traffic from the corrected ball penetration value and the traffic volume (see Table K-4) and express the embedment as a fraction of the ELT;

(b) determine the expected wear due to traffic from the hardness of the stone (10 per cent FACT) and the traffic volume (see Table K-5) and express the wear as a fraction of the ELT;

(c) determine the fractional void loss due to embedment and wear (separately) (see Table K-6);

(d) determine the fractional void loss due to the skid resistance requirement (0,64 mm average texture depth is required) 0,64 / (true void fraction x ELT);

(e) determine the total fractional void loss due to embedment, wear and the skid resistance requirement;

(f) determine the available void fraction by subtracting the total fractional void loss from one. This is the maximum void fraction that may be filled to ensure an expected seal life of at least 10 years under normal conditions;

(g) determine the embedment due to construction rolling (this is taken to be equal to 0,90 multiplied by the total embedment) and express this as a fraction of the ELT;

[1] The ELT and true void content, V_1, are determined by means of the modified tray test (see Appendix L). The ELT is not the same as the ALD used in the other methods. The ALD is determined in accordance with TMH1, method B18(a)[17].

(h) determine the fractional void loss due to rolling embedment (see Table K-6);

(i) determine the minimum void fraction that has to be filled with binder to prevent whip-off (stone loss). (The aggregate must be covered at least halfway to prevent stone loss.)

(j) compare the values of the minimum void fraction (i) and the available void fraction (f). If the available void fraction is larger than the minimum void fraction, calculate the maximum and minimum cold binder application rates by multiplying the available and minimum void fractions by the true void volume (true void content expressed as a fraction of the ELT volume x ELT in mm). If the available void fraction is smaller than the minimum void fraction that has to be filled with binder, the binder application rate is calculated by multiplying the minimum void fraction by the true void volume (= (true void content expressed as fraction of ELT volume) x ELT in mm). In the latter instance the seal will have a reduced life expectancy, and

(k) determine the aggregate spread rate with the following equation:

$$\text{Spread rate} = 1{,}06\ \text{ELT}\ (100 - V_1)/(100 - V_b) \times 10^{-3}\ \mathbf{m^3/m^2}$$

where V_1 = true void content of the layer of aggregate (%)
V_b = bulk void content of the aggregate (%).

Example

Data obtained from tests:	
Traffic (ADT/lane)	= 2 000 elv
Texture depth of present surface (as determined from the sand patch test)	= 0,50 mm
Corrected ball penetration value	= 2 mm
ELT of aggregate layer	= 7,81 mm
True void content of aggregate layer (V_1) (as determined from the modified tray test)	= 32,77 %
Bulk void content of aggregate V_b)	= 45 %
10 % FACT value = 250 kN aggregate (dry)	= 250 kN

Binder to be used is 150/200 pen bitumen.

(a) Embedment of aggregate (from Table K-4) = 0,629 mm

Embedment as a fraction of the ELT= 0,629/7,81 ≈ 0,081

(b)	Wear of aggregate (from Table K-5)	= 0,717 mm
	Wear as a fraction of the ELT	= 0,717/7,81
		≅ 0,092
(c)	Fractional void loss due to embedment (From Table K-6)	= 0,176
	Fractional void loss due to wear (from Table K-6)	= 0,196
(d)	Fractional void loss due to skid resistance requirement (0,7 mm texture required)	= 0,70 / (true void fraction x ELT) = 0,70/(0,3277 x 7,81) = 0,274
(e)	Total fractional void loss due to embedment, wear and skid resistance requirement	= 0,176 + 0,196 + 0,274 = 0,646
(f)	Available void fraction (if greater than 0,42 use 0,42)	= 1,00 – 0,646 = 0,354
(g)	Embedment due to rolling (0,50 x embedment due to traffic)	= 0,50 x 0,629 = 0,315 mm
	Rolling embedment as a fraction of the ELT	= 0,315/7,81 ≅ 0,040
(h)	Fractional void loss due to rolling (from Table K-6)	= 0,094
(i)	[2]Minimum void fraction to be filled with binder	= (0,420 – 0,094) = 0,326

(j) The available void fraction is larger than the minimum required void fraction; therefore the seal will have a normal life.

Nominal quantity of cold binder (max.)	= (nominal void fraction to be filled) x (true void fraction) x ELT = (0,354)(0,3277)(7,81) ≅ 0,91 ℓ/m^2
Nominal quantity of cold binder (min.)	= (0,326)(0,3277)(7,81)

[2] The aggregate should be covered at least halfway with binder to prevent whip-off.

$\cong$ 0,83 ℓ/m^2

(k) Extra quantity of cold binder (ℓ/m^2) due to surface texture of present surface (= 0,50 mm) (Table K-7) = 0,25 ℓ/m^2

(l) Total quantity of cold binder = 0,25 + 0,83 ℓ/m^2
= 1,08 ℓ/m^2

(m) Conversion factor for hot binder (150/100 pen)
(see
Table 6-5) = 1,09

(n) Total quantity of hot binder = (1,09) (1,08)
$\cong$ 1,18 ℓ/m^2

(o) Spread rate of stone = 1,06 ELT(100 – V_1)/(100 – V_b) x 10^{-3}
= (1,06)(7,81)(100 – 32,77)/
(100-45) x 10^{-3}
$\cong$ 10,12 x 10^{-3} m^3/m^2

3.2 Design of double seals

For the design of a double seal the same information is required as for the design of a single seal, except that the ELT and true void content, V_1, and the bulk void content, V_b, of both stone layers are required.

The ELT of the double seal (ELT_d) can be determined by using the following equation:

$$ELT_d = 0{,}86(\sum ELT) - 0{,}19$$

where $\sum ELT$ = $ELT_1 + ELT_2$
ELT_1 = ELT (bottom layer)
ELT_2 = ELT (top layer)

Calculate the factor F by means of the following equation:

$$\frac{(ELT_1(0{,}95\,V_{11} + 5) + ELT_2.V_{12})}{(\sum ELT)} \cdot \frac{(ELT_d)}{(\sum ELT)}$$

where V_{11} = true void content of the bottom layer as a percentage
and V_{12} = true void content of the top layer as a percentage

The true void content of the double seal can now be determined by using the following equation:

Percentage voids in double seal (V_d) = 1,006(F) – 0,87

The design of the double seal can now be done in exactly the same way as the design of a single seal, using the same tables.

The aggregate spread rate = (f) ELT $(100 - V_1) / (100 - V_b) \times 10^{-2} (m^3/m^2)$

where V_1 = void content in the aggregate layer (%)

V_b = bulk void content of the aggregate (%)

f = increase factor for variations in workmanship, etc.

= 1,00 for bottom layer of aggregate

= 1,06 for top layer of aggregate

This can best be illustrated by means of an example.

Example

Data obtained from tests:

Traffic (ADT/lane)	= 3 000 elv
Texture depth of present surface (as determined with sand patch test)	= 0,50 mm
Corrected ball penetration value	= 3 mm
ELT_1= 7,81 mm; V_{11} = 43 %;V_{b1}= 48,50 %	(determined from modified tray test)
ELT_2= 4,37 mm; V_{12} = 42 %;V_{b2}= 50,00 %	(determined from modified tray test)
10 % FACT value of aggregate (dry)	= 200 kN

Binder to be used is a 150/200 pen bitumen for both the tack coat and penetration coat and 60 % bitumen emulsion for fog spray.

(a)

$$\sum ELT = ELT_1 + ELT_2 = 7{,}81 + 4{,}37 = 12{,}18$$

$$ELT_d = 0{,}86(\sum ELT) + 0{,}19 = 0{,}86(12{,}18) + 0{,}19 = 10{,}66 \text{ mm}$$

(b)

$$F = \frac{(ELT\,(0{,}95V_{11} + 5) + ELT.V_{12})}{(\sum ELT)} \cdot \frac{(ELT_d)}{(\sum ELT)}$$

$$= \frac{(7{,}81\,[(0{,}95)\,(43{,}0) + 5] + 4{,}37\,(42)\,)}{12{,}18} \cdot \frac{(10{,}66)}{12{,}18}$$

$$= \frac{(7{,}81\,[(40{,}85) + 5] + 4{,}37\,(42)\,)}{12{,}18} \cdot \frac{(10{,}66)}{12{,}18}$$

$$= \underline{(358{,}09 + 183{,}54)} \cdot \underline{(10{,}66)}$$

12,18 12,18

= 38,919

V_d = 1,006F – 0,87
= 1,006 (38,919) – 0,87
= 39,153 – 0,87
= 38,28 %

(c) Embedment of aggregate (from Table K-4) = 1,100 mm

Embedment as a fraction of the ELT_d = 1,100/10,66
≅ 0,103

(d) Wear of aggregate (From Table K-5) = 0,850 mm

Wear as a fraction of ELT_d = 0,850 / 10,66
≅ 0,080

(e) Fractional void loss due to embedment (From Table K-6) = 0,215

(f) Fractional void loss due to wear (From Table K-6) = 0,174

(g) Fractional voids required for skid resistance = 0,70 / (0,3828 x 10,66)
(Required texture depth 0,7 mm) ≅ 0,172

(h) Total void loss = 0,215 + 0,174 + 0,172
= 0,561

(i) Available void fraction (if greater than 0,550 use 0,550) = 1 – 0,561
= 0,439

(j) Rolling embedment (50 per cent of total) = 0,50 x 1,100
= 0,55 mm

Rolling embedment as a fraction of ELT_d = 0,55/10,66
≅ 0,052

(k) Void loss due to rolling embedment (from Table K-6) = 0,119

(l) [3]Minimum voids to be filled to prevent initial stone loss = 0,55 – 0,119
= 0,431

(m) As the available void fraction is larger than the minimum required void fraction, the seal will have a

[3] In the case of double seals 55 per cent of the voids have to be filled with binder to ensure that the top layer of aggregate is covered at least halfway.

normal life.

Nominal quantity of cold binder (max.) = (0,431)(0,3828)(10,66)
≅ 1,79 ℓ/m^2

Nominal quantity of cold binder (min.) = (0,431) (0,3828) (10,66)
≅ 1,76 ℓ/m^2

(n) Additional binder required due to surface texture (from Table K-7) = 0,22 ℓ/m^2

(o) Total quantity cold binder required = 1,76 + 0,22
≅ 1,98 ℓ/m^2

(p) The success of a double seal depends largely on the combination of binders chosen and how the binder quantity is divided between the tack coat, penetration coat and fog spray. Normally it is recommended that 25 per cent of the total binder be applied as a fog spray. The remaining binder quantity (cold) is divided between the tack coat and penetration coat. This does not necessarily have to be divided in a 50/50 ratio. A 60/40 ratio may be used as long as the minimum application rate for any coat is not less than 0,65 ℓ/m^2 (hot) because binder distributors are calibrated from approximately 0,60 ℓ/m^2 Lower application rates could lead to streaking. Emulsions may be used for the tack and penetration coat to increase the total application rate. In such cases the stone should be spread before the emulsion has "broken".

Fog spray = (0,25)(1,98)
≅ 0,50 ℓ/m^2 residual binder

Remaining cold binder = 1,98 – 0,50
≅ 1,48 ℓ/m^2

Divide in 50/50 ratio = 0,74 ℓ/m^2 for tack and penetration coat

(q) Hot binder application rate for tack coat (80/100 pen bitumen) (See Table 6-5) = (0,74)(1,09)
≅ 0,81 ℓ/m^2

Hot binder application rate for penetration coat (150/200 pen bitumen) (See Table 6-5) = (0,74)(1,09)
≅ 0,81 ℓ/m^2

Hot binder application rate for fog spray (60 % emulsion) (See Table 6-5) = (0,50)(1,68)
≅ 0,84 ℓ/m^2

(r) Stone application rate for bottom layer = 1,0 (ELT$_1$(100 – V$_{11}$) / (100 – V$_{b1}$) x 10^{-3}

$= 1,0\ [7,81\ (100\text{-}43)\ /\ (100 – 48,5)] \times 10^{-3}$
$= 7,81\ (57)\ /\ (51,5) \times 10^{-3}$
$\cong 8,64 \times 10^{-3}\ \mathbf{m^3/m^2}$

Stone application rate for top layer $= 1,06\ [ELT_2(100–V_{12})/(100 – V_{b2})] \times 10^{-3}$
$= 1,06\ [4,37(100 – 42)/(100 – 50)] \times 10^{-3}$
$= 1,06\ [4,37(58)\ /\ (50)] \times 10^{-3}$
$\cong 5,37 \times 10^{-3}\ \mathbf{m^3/m^2}$

3.3 Calculation of shorter service life

If the available void fraction for normal real life is less than the minimum void fraction that has to be filled with binder the seal will have a reduced life expectancy. To calculate the shorter life expectancy of the seal, the following procedure is followed:

(a) Add the fractional void losses due to embedment and wear under traffic.

(b) Subtract the fractional void loss due to rolling embedment.

(c) Divide value by 10 to arrive at the fractional void loss per annum.

(d) Subtract the fractional void requirement for skid resistance from 0,500 in the case of single seals, and from 0,35 in the case of double seals to arrive at the available void fraction not filled with binder.

(e) Divide this value by the fractional void loss per annum (as calculated in step (c)) to determine the number of years of expected service life.

Example

If the ELT of the stone in a single seal is 7,00 mm instead of 7,81 mm it will be found that the fractional void losses due to embedment, wear, rolling embedment and skid resistance are equal to 0,193, 0,213, 0,105 and 0,305 respectively for a texture depth of 0,7 mm. This will lead to a reduced life expectancy because the available void fraction is equal to 0,315 and the minimum void fraction to be filled with binder is equal to 0,324.

Fractional void loss due to embedment and wear = 0,193 + 0,213
= 0,406

Fractional void loss due to rolling embedment (50% embedment) = 0,105

Fractional void loss in 10-year period = 0,406 – 0,105
= 0,301

Fractional void loss per annum	= 0,301 / 10
	= 0,030
Fractional void loss for normal skid resistance requirement (0,7 mm texture)	= 0,305
Available void fraction	= 0,580 – 0,305
(Max. Voids filled with binder : 42%)	= 0,275
Years of expected service	= 0,275 / 0,030
	≅ 9,17 years

4 DESIGN TABLES

Tables K-1 to K-7 were produced by computer and may therefore not be perfect from an editorial point of view.

The tables for single seal design (Table K-1) are based on the maximum available void fraction filled with binder being 42 per cent. In the case of the tables (Table K-2) for the double seal design, the corresponding value is 55 per cent.

In some of the following tables it will be seen that the “minimum” net cold binder required exceeds the “maximum” allowed for normal seal life. In such cases the figure appearing under “minimum” should be used, but a shorter service life may be expected.

Table K-1

Binder application rate (total) (single seal)

CORRECTED BALL-PENETRATION (mm) = 1,00 REQUIRED TEXTURE DEPTH (mm) = 0,3

AVERAGE LEAST DIMENSION (mm)

ADT/LANE	RATE	4	5	6	7	8	9	10	11	12
125	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,71	0,86	1,01	1,16	1,31	1,45	1,60	1,74	1,88
250	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,70	0,86	1,01	1,16	1,30	1,45	1,59	1,73	1,87
500	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,69	0,84	0,99	1,14	1,29	1,43	1,57	1,71	1,85
750	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,67	0,82	0,97	1,12	1,27	1,41	1,56	1,70	1,84
1000	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,65	0,80	0,96	1,10	1,25	1,40	1,54	1,68	1,82
2000	MAX	0,58	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,59	0,74	0,89	1,04	1,19	1,33	1,47	1,62	1,75
3000	MAX	0,41	0,72	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,51	0,66	0,81	0,96	1,10	1,25	1,39	1,53	1,67
4000	MAX		0,62	0,93	1,17	1,32	1,46	1,61	1,75	1,88
	MIN		0,60	0,75	0,90	1,04	1,19	1,33	1,47	1,61
5000	MAX		0,54	0,85	1,16	1,32	1,46	1,61	1,75	1,88
	MIN		0,56	0,71	0,86	1,00	1,14	1,29	1,43	1,57
10000	MAX			0,67	0,97	1,28	1,46	1,61	1,75	1,88
	MIN			0,59	0,73	0,87	1,01	1,16	1,30	1,43
20000	MAX			0,53	0,81	1,11	1,41	1,61	1,75	1,88
	MIN			0,5	0,62	0,75	0,89	1,03	1,17	1,31
40000	MAX				0,68	0,96	1,26	1,55	1,75	1,88
	MIN				0,51	0,64	0,78	0,92	1,05	1,19

TABLE K-1

Binder application rate (total) (single seal)

CORRECTED BALL-PENETRATION (mm) = 2 REQUIRED TEXTURE DEPTH (mm) = 0,3

		AVERAGE LEAST DIMENSION (mm)								
		4	5	6	7	8	9	10	11	12
ADT/LANE	RATE									
125	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,70	0,85	1,00	1,15	1,30	1,44	1,59	1,73	1,86
250	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,68	0,83	0,98	1,13	1,28	1,42	1,56	1,70	1,84
500	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,64	0,79	0,94	1,09	1,24	1,38	1,52	1,66	1,80
750	MAX	0,71	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,60	0,75	0,90	1,05	1,19	1,34	1,48	1,62	1,76
1000	MAX	0,61	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,56	0,71	0,86	1,01	1,16	1,30	1,44	1,58	1,72
2000	MAX		0,61	0,93	1,17	1,32	1,46	1,61	1,75	1,88
	MIN		0,57	0,71	0,86	1,00	1,15	1,29	1,43	1,57
3000	MAX			0,74	1,05	1,32	1,46	1,61	1,75	1,88
	MIN			0,62	0,76	0,91	1,05	1,19	1,33	1,47
4000	MAX			0,64	0,94	1,24	1,46	1,61	1,75	1,88
	MIN			0,56	0,70	0,84	0,98	1,12	1,26	1,40
5000	MAX			0,56	0,85	1,16	1,46	1,61	1,75	1,88
	MIN			0,51	0,65	0,79	0,93	1,07	1,21	1,34
10000	MAX				0,68	0,96	1,26	1,55	1,75	1,88
	MIN				0,51	0,65	0,78	0,92	1,05	1,19
20000	MAX				0,56	0,82	1,09	1,37	1,66	1,88
	MIN				0,50	0,52	0,65	0,78	0,91	1,04
40000	MAX					0,71	0,96	1,23	1,50	1,78
	MIN					0,50	0,52	0,65	0,78	0,90

TABLE K-1

Binder application rate (total) (single seal)

CORRECTED BALL-PENETRATION (mm) = 3,00 REQUIRED TEXTURE DEPTH (mm) = 0,3

		AVERAGE LEAST DIMENSION (mm)								
		4	5	6	7	8	9	10	11	12
ADT/LANE	RATE									
125	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,69	0,84	0,99	1,14	1,29	1,44	1,58	1,72	1,86
250	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,66	0,82	0,97	1,12	1,26	1,41	1,55	1,69	1,83
500	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,61	0,76	0,91	1,06	1,21	1,35	1,49	1,64	1,77
750	MAX	0,64	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,56	0,71	0,86	1,01	1,15	1,30	1,44	1,58	1,72
1000	MAX	0,53	0,86	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,51	0,66	0,81	0,95	1,10	1,25	1,39	1,53	1,67
2000	MAX			0,79	1,10	1,32	1,46	1,61	1,75	1,88
	MIN			0,62	0,76	0,91	1,05	1,19	1,33	1,47
3000	MAX			0,61	0,90	1,21	1,46	1,61	1,75	1,88
	MIN			0,52	0,66	0,80	0,94	1,08	1,22	1,36
4000	MAX			0,51	0,80	1,09	1,39	1,61	1,75	1,88
	MIN			0,50	0,59	0,73	0,87	1,01	1,14	1,28
5000	MAX				0,72	1,01	1,30	1,60	1,75	1,88
	MIN				0,54	0,68	0,81	0,95	1,09	1,22
10000	MAX				0,57	0,83	1,11	1,39	1,68	1,88
	MIN				0,50	0,53	0,66	0,79	0,92	1,05
20000	MAX					0,71	0,96	1,22	1,50	1,77
	MIN					0,50	0,52	0,64	0,77	0,90
40000	MAX					0,62	0,85	1,10	1,35	1,61
	MIN					0,50	0,50	0,51	0,63	0,76

TABLE K-1

Binder application rate (total) (single seal)

CORRECTED BALL-PENETRATION (mm) = 4,00 REQUIRED TEXTURE DEPTH (mm) = 0,3

		AVERAGE LEAST DIMENSION (mm)								
		4	5	6	7	8	9	10	11	12
ADT/LANE	RATE									
125	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,69	0,84	0,99	1,14	1,29	1,43	1,57	1,71	1,85
250	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,65	0,80	0,96	1,10	1,25	1,40	1,54	1,68	1,82
500	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,59	0,74	0,89	1,04	1,19	1,33	1,48	1,62	1,76
750	MAX	0,60	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,53	0,68	0,83	0,98	1,12	1,27	1,41	1,55	1,69
1000	MAX		0,80	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN		0,62	0,77	0,92	1,06	1,21	1,35	1,49	1,63
2000	MAX			0,70	1,00	1,32	1,46	1,61	1,75	1,88
	MIN			0,56	0,70	0,84	0,98	1,12	1,26	1,40
3000	MAX			0,53	0,81	1,11	1,41	1,61	1,75	1,88
	MIN			0,50	0,59	0,73	0,87	1,01	1,14	1,28
4000	MAX				0,71	1,00	1,29	1,59	1,75	1,88
	MIN				0,52	0,66	0,79	0,93	1,07	1,20
5000	MAX				0,64	0,92	1,20	1,49	1,75	1,88
	MIN				0,50	0,60	0,74	0,87	1,01	1,14
10000	MAX				0,51	0,76	1,02	1,29	1,57	1,86
	MIN				0,50	0,45	0,58	0,71	0,84	0,97
20000	MAX					0,65	0,89	1,14	1,40	1,67
	MIN					0,5	0,44	0,56	0,68	0,81
40000	MAX					0,57	0,79	1,02	1,27	1,52
	MIN					0,50	0,50	0,50	0,54	0,66

TABLE K-1

Binder application rate (total) (single seal)

CORRECTED BALL-PENETRATION (mm) = 1,00 REQUIRED TEXTURE DEPTH (mm) = 0,5

		AVERAGE LEAST DIMENSION (mm)								
		4	5	6	7	8	9	10	11	12
ADT/LANE	RATE									
125	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,71	0,86	1,01	1,16	1,31	1,45	1,60	1,74	1,88
250	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,70	0,86	1,01	1,16	1,30	1,45	1,59	1,73	1,87
500	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,69	0,84	0,99	1,14	1,29	1,43	1,57	1,71	1,85
750	MAX	0,65	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,67	0,82	0,97	1,12	1,27	1,41	1,56	1,70	1,84
1000	MAX	0,58	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,65	0,80	0,96	1,10	1,25	1,40	1,54	1,68	1,82
2000	MAX	0,38	0,70	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,59	0,74	0,89	1,04	1,19	1,33	1,47	1,62	1,75
3000	MAX	0,21	0,52	0,84	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,51	0,66	0,81	0,96	1,10	1,25	1,39	1,53	1,67
4000	MAX		0,42	0,73	1,05	1,32	1,46	1,61	1,75	1,88
	MIN		0,60	0,75	0,90	1,04	1,19	1,33	1,47	1,61
5000	MAX		0,34	0,65	0,96	1,28	1,46	1,61	1,75	1,88
	MIN		0,56	0,71	0,86	1,00	1,14	1,29	1,43	1,57
10000	MAX			0,47	0,77	1,08	1,39	1,61	1,75	1,88
	MIN			0,59	0,73	0,87	1,01	1,16	1,30	1,43
20000	MAX				0,61	0,91	1,21	1,52	1,75	1,88
	MIN				0,62	0,75	0,89	1,03	1,17	1,31
40000	MAX				0,48	0,76	1,06	1,35	1,65	1,88
	MIN				0,51	0,64	0,78	0,92	1,05	1,19

TABLE K-1

Binder application rate (total) (single seal)

CORRECTED BALL-PENETRATION (mm) = 2,00 REQUIRED TEXTURE DEPTH (mm) = 0,5

AVERAGE LEAST DIMENSION (mm)

ADT/LANE	RATE	4	5	6	7	8	9	10	11	12
125	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,70	0,85	1,00	1,15	1,30	1,44	1,59	1,73	1,86
250	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,68	0,83	0,98	1,13	1,28	1,42	1,56	1,70	1,84
500	MAX	0,62	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,64	0,79	0,94	1,09	1,24	1,38	1,52	1,66	1,80
750	MAX	0,51	0,85	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,60	0,75	0,90	1,05	1,19	1,34	1,48	1,62	1,76
1000	MAX	0,41	0,75	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,56	0,71	0,86	1,01	1,16	1,30	1,44	1,58	1,72
2000	MAX		0,41	0,73	1,05	1,32	1,46	1,61	1,75	1,88
	MIN		0,57	0,71	0,86	1,00	1,15	1,29	1,43	1,57
3000	MAX			0,54	0,85	1,16	1,46	1,61	1,75	1,88
	MIN			0,62	0,76	0,91	1,05	1,19	1,33	1,47
4000	MAX			0,44	0,74	1,04	1,36	1,61	1,75	1,88
	MIN			0,56	0,70	0,84	0,98	1,12	1,26	1,40
5000	MAX			0,36	0,65	0,96	1,26	1,58	1,75	1,88
	MIN			0,51	0,65	0,79	0,93	1,07	1,21	1,34
10000	MAX				0,48	0,76	1,06	1,35	1,66	1,88
	MIN				0,51	0,65	0,78	0,92	1,05	1,19
20000	MAX					0,62	0,89	1,17	1,46	1,75
	MIN					0,52	0,65	0,78	0,91	1,04
40000	MAX					0,51	0,76	1,03	1,30	1,58
	MIN					0,50	0,52	0,65	0,78	0,90

TABLE K-1

Binder application rate (total) (single seal)

CORRECTED BALL-PENETRATION (mm) = 3,00 REQUIRED TEXTURE DEPTH (mm) = 0,5

		AVERAGE LEAST DIMENSION (mm)								
		4	5	6	7	8	9	10	11	12
ADT/LANE	RATE									
125	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,69	0,84	0,99	1,14	1,29	1,44	1,58	1,72	1,86
250	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,66	0,82	0,97	1,12	1,26	1,41	1,55	1,69	1,83
500	MAX	0,57	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,61	0,76	0,91	1,06	1,21	1,35	1,49	1,64	1,77
750	MAX	0,44	0,78	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,56	0,71	0,86	1,01	1,15	1,30	1,44	1,58	1,72
1000	MAX	0,33	0,66	0,99	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,51	0,66	0,81	0,95	1,10	1,25	1,39	1,53	1,67
2000	MAX			0,59	0,90	1,22	1,46	1,61	1,75	1,88
	MIN			0,62	0,76	0,91	1,05	1,19	1,33	1,47
3000	MAX			0,41	0,70	1,01	1,32	1,61	1,75	1,88
	MIN			0,52	0,66	0,80	0,94	1,08	1,22	1,36
4000	MAX				0,60	0,89	1,19	1,50	1,75	1,88
	MIN				0,59	0,73	0,87	1,01	1,14	1,28
5000	MAX				0,52	0,81	1,10	1,40	1,71	1,88
	MIN				0,54	0,68	0,81	0,95	1,09	1,22
10000	MAX					0,63	0,91	1,19	1,48	1,77
	MIN					0,53	0,66	0,79	0,92	1,05
20000	MAX					0,51	0,76	1,02	1,30	1,57
	MIN					0,50	0,52	0,64	0,77	0,90
40000	MAX						0,65	0,90	1,15	1,41
	MIN						0,50	0,51	0,63	0,76

TABLE K-1

Binder application rate (total) (single seal)

CORRECTED BALL-PENETRATION (mm) = 4,00 REQUIRED TEXTURE DEPTH (mm) = 0,5

		AVERAGE LEAST DIMENSION (mm)								
		4	5	6	7	8	9	10	11	12
ADT/LANE	RATE									
125	MAX	0,72	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,69	0,84	0,99	1,14	1,29	1,43	1,57	1,71	1,85
250	MAX	0,70	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,65	0,80	0,96	1,10	1,25	1,40	1,54	1,68	1,82
500	MAX	0,54	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,59	0,74	0,89	1,04	1,19	1,33	1,48	1,62	1,76
750	MAX	0,40	0,73	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,53	0,68	0,83	0,98	1,12	1,27	1,41	1,55	1,69
1000	MAX		0,60	0,93	1,17	1,32	1,46	1,61	1,75	1,88
	MIN		0,62	0,77	0,92	1,06	1,21	1,35	1,49	1,63
2000	MAX			0,50	0,80	1,12	1,43	1,61	1,75	1,88
	MIN			0,56	0,700	0,84	0,98	1,12	1,26	1,40
3000	MAX				0,61	0,91	1,21	1,52	1,75	1,88
	MIN				0,59	0,73	0,87	1,01	1,14	1,28
4000	MAX				0,51	0,80	1,09	1,39	1,69	1,88
	MIN				0,52	0,66	0,79	0,93	1,07	1,20
5000	MAX					0,72	1,00	1,29	1,59	1,88
	MIN					0,60	0,74	0,87	1,01	1,14
10000	MAX					0,56	0,82	1,09	1,37	1,66
	MIN					0,50	0,58	0,71	0,84	0,97
20000	MAX						0,69	0,94	1,20	1,47
	MIN						0,50	0,56	0,68	0,81
40000	MAX						0,59	0,82	1,07	1,32
	MIN						0,50	0,50	0,54	0,66

TABLE K-1

Binder application rate (total) (single seal)

CORRECTED BALL PENETRATION (mm) = 1 REQUIRED TEXTURE DEPTH (mm) = 0,7

AVERAGE LEAST DIMENSION (mm)

ADT/LANE	RATE	4	5	6	7	8	9	10	11	12
125	MAX	0,64	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,71	0,86	1,01	1,16	1,31	1,45	1,60	1,74	1,88
250	MAX	0,60	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,70	0,86	1,01	1,16	1,30	1,45	1,59	1,73	1,87
500	MAX	0,52	0,86	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,69	0,84	0,99	1,14	1,29	1,43	1,57	1,71	1,85
750	MAX	0,45	0,79	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,67	0,82	0,97	1,12	1,27	1,41	1,56	1,70	1,84
1000	MAX	0,38	0,72	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,65	0,80	0,96	1,10	1,25	1,40	1,54	1,68	1,82
2000	MAX	0,18	0,50	0,83	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,59	0,74	0,89	1,04	1,19	1,33	1,47	1,62	1,75
3000	MAX	0,01	0,32	0,64	0,97	1,30	1,46	1,61	1,75	1,88
	MIN	0,51	0,66	0,81	0,96	1,10	1,25	1,39	1,53	1,67
4000	MAX		0,22	0,53	0,85	1,18	1,46	1,61	1,75	1,88
	MIN		0,60	0,75	0,90	1,04	1,19	1,33	1,47	1,61
5000	MAX		0,14	0,45	0,76	1,08	1,41	1,61	1,75	1,88
	MIN		0,56	0,71	0,86	1,00	1,14	1,29	1,43	1,57
10000	MAX			0,27	0,57	0,88	1,19	1,51	1,75	1,88
	MIN			0,59	0,73	0,87	1,01	1,16	1,30	1,43
20000	MAX				0,41	0,71	1,01	1,32	1,63	1,88
	MIN				0,62	0,75	0,89	1,03	1,17	1,31
40000	MAX				0,28	0,56	0,86	1,15	1,45	1,76
	MIN				0,51	0,64	0,78	0,92	1,05	1,19

TABLE K-1

Binder application rate (total) (single seal)

CORRECTED BALL-PENETRATION (mm) = 2,00 REQUIRED TEXTURE DEPTH (mm) = 0,7

		AVERAGE LEAST DIMENSION (mm)								
		4	5	6	7	8	9	10	11	12
ADT/LANE	RATE									
125	MAX	0,61	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,70	0,85	1,00	1,15	1,30	1,44	1,59	1,73	1,86
250	MAX	0,54	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,68	0,83	0,98	1,13	1,28	1,42	1,56	1,70	1,84
500	MAX	0,42	0,77	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,64	0,79	0,94	1,09	1,24	1,38	1,52	1,66	1,80
750	MAX	0,31	0,65	1,00	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,60	0,75	0,90	1,05	1,19	1,34	1,48	1,62	1,76
1000	MAX	0,21	0,55	0,89	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,56	0,71	0,86	1,01	1,16	1,30	1,44	1,58	1,72
2000	MAX		0,21	0,53	0,85	1,18	1,46	1,61	1,75	1,88
	MIN		0,57	0,71	0,86	1,00	1,15	1,29	1,43	1,57
3000	MAX			0,34	0,65	0,96	1,28	1,61	1,75	1,88
	MIN			0,62	0,76	0,91	1,05	1,19	1,33	1,47
4000	MAX			0,24	0,54	0,84	1,16	1,47	1,75	1,88
	MIN			0,56	0,70	0,84	0,98	1,12	1,26	1,40
5000	MAX			0,16	0,45	0,76	1,06	1,38	1,69	1,88
	MIN			0,51	0,65	0,79	0,93	1,07	1,21	1,34
10000	MAX				0,28	0,56	0,86	1,15	1,46	1,76
	MIN				0,51	0,65	0,78	0,92	1,05	1,19
20000	MAX					0,42	0,69	0,97	1,26	1,55
	MIN					0,52	0,65	0,78	0,91	1,04
40000	MAX						0,56	0,83	1,10	1,38
	MIN						0,52	0,65	0,78	0,9

TABLE K-1

Binder application rate (total) (single seal)

CORRECTED BALL-PENETRATION (mm) = 3,00 REQUIRED TEXTURE DEPTH (mm) = 0,7

		AVERAGE LEAST DIMENSION (mm)								
		4	5	6	7	8	9	10	11	12
ADT/LANE	RATE									
125	MAX	0,60	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,69	0,84	0,99	1,14	1,29	1,44	1,58	1,72	1,86
250	MAX	0,52	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,66	0,82	0,97	1,12	1,26	1,41	1,55	1,69	1,83
500	MAX	0,37	0,72	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,61	0,76	0,91	1,06	1,21	1,35	1,49	1,64	1,77
750	MAX	0,24	0,58	0,92	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,56	0,71	0,86	1,01	1,15	1,30	1,44	1,58	1,72
1000	MAX	0,13	0,46	0,79	1,13	1,32	1,46	1,61	1,75	1,88
	MIN	0,51	0,66	0,81	0,95	1,10	1,25	1,39	1,53	1,67
2000	MAX			0,39	0,70	1,02	1,34	1,61	1,75	1,88
	MIN			0,62	0,76	0,91	1,05	1,19	1,33	1,47
3000	MAX			0,21	0,50	0,81	1,12	1,43	1,75	1,88
	MIN			0,52	0,66	0,80	0,94	1,08	1,22	1,36
4000	MAX				0,40	0,69	0,99	1,30	1,61	1,88
	MIN				0,59	0,73	0,87	1,01	1,14	1,28
5000	MAX				0,32	0,61	0,90	1,20	1,51	1,81
	MIN				0,54	0,68	0,81	0,95	1,09	1,22
10000	MAX					0,43	0,71	0,99	1,28	1,57
	MIN					0,53	0,66	0,79	0,92	1,05
20000	MAX						0,56	0,82	1,10	1,37
	MIN						0,52	0,64	0,77	0,90
40000	MAX							0,70	0,95	1,21
	MIN							0,51	0,63	0,76

TABLE K-1

Binder application rate (total) (single seal)

CORRECTED BALL-PENETRATION (mm) = 4,00 REQUIRED TEXTURE DEPTH (mm) = 0,7

AVERAGE LEAST DIMENSION (mm)

ADT/LANE	RATE	4	5	6	7	8	9	10	11	12
125	MAX	0,59	0,87	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,69	0,84	0,99	1,14	1,29	1,43	1,57	1,71	1,85
250	MAX	0,50	0,85	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,65	0,80	0,96	1,10	1,25	1,40	1,54	1,68	1,82
500	MAX	0,34	0,68	1,02	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,59	0,74	0,89	1,04	1,19	1,33	1,48	1,62	1,76
750	MAX	0,20	0,53	0,87	1,17	1,32	1,46	1,61	1,75	1,88
	MIN	0,53	0,68	0,83	0,98	1,12	1,27	1,41	1,55	1,69
1000	MAX		0,40	0,73	1,06	1,32	1,46	1,61	1,75	1,88
	MIN		0,62	0,77	0,92	1,06	1,21	1,35	1,49	1,63
2000	MAX			0,30	0,60	0,92	1,23	1,55	1,75	1,88
	MIN			0,56	0,70	0,84	0,98	1,12	1,26	1,40
3000	MAX				0,41	0,71	1,01	1,32	1,63	1,88
	MIN				0,59	0,73	0,87	1,01	1,14	1,28
4000	MAX				0,31	0,60	0,89	1,19	1,49	1,80
	MIN				0,52	0,66	0,79	0,93	1,07	1,20
5000	MAX					0,52	0,80	1,09	1,39	1,69
	MIN					0,60	0,74	0,87	1,01	1,14
10000	MAX						0,62	0,89	1,17	1,46
	MIN						0,58	0,71	0,84	0,97
20000	MAX							0,74	1,00	1,27
	MIN							0,56	0,68	0,81
40000	MAX							0,62	0,87	1,12
	MIN							0,50	0,54	0,66

TABLE K-2

Binder application rate (total) (double seal)

CORRECTED BALL-PENETRATION (mm) = 1,00 REQUIRED TEXTURE DEPTH (mm) = 0,3

		AVERAGE LEAST DIMENSION (mm)											
		8	9	10	11	12	13	14	15	16	17	18	19
ADT/LANE	RATE												
125	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,83	1,98	2,11	2,24	2,37	2,48	2,59	2,70	2,80	2,90	2,99	3,09
250	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,82	1,97	2,11	2,23	2,36	2,47	2,58	2,69	2,79	2,89	2,99	3,08
500	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,81	1,95	2,09	2,22	2,34	2,46	2,57	2,67	2,78	2,88	2,97	3,06
750	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,79	1,93	2,07	2,20	2,32	2,44	2,55	2,66	2,76	2,86	2,96	3,05
1000	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,77	1,91	2,05	2,18	2,31	2,42	2,54	2,64	2,75	2,84	2,94	3,04
2000	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,69	1,84	1,98	2,11	2,24	2,36	2,47	2,58	2,68	2,78	2,88	2,98
3000	MAX	1,77	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,60	1,75	1,89	2,02	2,15	2,27	2,39	2,50	2,60	2,70	2,80	2,90
4000	MAX	1,64	1,91	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,53	1,68	1,83	1,96	2,09	2,21	2,33	2,44	2,55	2,65	2,75	2,85
5000	MAX	1,53	1,80	2,07	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,49	1,64	1,78	1,91	2,04	2,17	2,28	2,39	2,50	2,61	2,71	2,80
10000	MAX	1,31	1,57	1,83	2,08	2,32	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,34	1,49	1,64	1,77	1,90	2,03	2,15	2,26	2,37	2,48	2,58	2,68
20000	MAX	1,12	1,38	1,63	1,87	2,11	2,34	2,56	2,71	2,81	2,91	3,00	3,09
	MIN	1,21	1,36	1,50	1,64	1,77	1,90	2,02	2,14	2,25	2,35	2,46	2,56
40000	MAX	0,97	1,21	1,46	1,70	1,93	2,16	2,38	2,59	2,80	2,91	3,00	3,09
	MIN	1,09	1,24	1,38	1,52	1,65	1,78	1,90	2,01	2,13	2,24	2,34	2,44

TABLE K-2

Binder application rate (total) (double seal)

CORRECTED BALL-PENETRATION (mm) = 2,00

REQUIRED TEXTURE DEPTH (mm) = 0,3

AVERAGE LEAST DIMENSION (mm)

ADT/LANE	RATE	8	9	10	11	12	13	14	15	16	17	18	19
125	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,82	1,96	2,10	2,23	2,35	2,47	2,58	2,69	2,79	2,89	2,98	3,08
250	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,80	1,94	2,08	2,21	2,33	2,45	2,56	2,67	2,77	2,87	2,96	3,06
500	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,75	1,90	2,03	2,16	2,29	2,41	2,52	2,63	2,73	2,83	2,93	3,02
750	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,70	1,85	1,99	2,12	2,25	2,37	2,48	2,59	2,69	2,79	2,89	2,98
1000	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,66	1,81	1,95	2,08	2,21	2,33	2,44	2,55	2,65	2,75	2,85	2,95
2000	MAX	1,64	1,91	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,49	1,64	1,78	1,92	2,05	2,17	2,29	2,40	2,50	2,61	2,71	2,81
3000	MAX	1,40	1,67	1,93	2,18	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,38	1,53	1,67	1,81	1,94	2,06	2,18	2,30	2,41	2,51	2,61	2,71
4000	MAX	1,27	1,53	1,79	2,04	2,28	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,30	1,45	1,60	1,74	1,87	1,99	2,11	2,23	2,34	2,44	2,55	2,65
5000	MAX	1,17	1,43	1,69	1,93	2,17	2,40	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,25	1,40	1,54	1,68	1,81	1,94	2,06	2,17	2,28	2,39	2,49	2,60
10000	MAX	0,97	1,21	1,46	1,70	1,93	2,16	2,38	2,59	2,80	2,91	3,00	3,09
	MIN	1,09	1,24	1,38	1,52	1,65	1,78	1,90	2,01	2,13	2,24	2,34	2,44
20000	MAX		1,05	1,28	1,50	1,73	1,95	2,16	2,37	2,57	2,77	2,97	3,09
	MIN		1,09	1,23	1,37	1,50	1,63	1,75	1,87	1,98	2,09	2,20	2,30
40000	MAX			1,13	1,35	1,56	1,77	1,98	2,18	2,38	2,58	2,77	2,95
	MIN			1,10	1,23	1,36	1,49	1,61	1,73	1,84	1,95	2,06	2,16

TABLE K-2

Binder application rate (total) (double seal)

CORRECTED BALL-PENETRATION (mm) = 3,00 | REQUIRED TEXTURE DEPTH (mm) = 0,3

AVERAGE LEAST DIMENSION (mm)

ADT/LANE	RATE	8	9	10	11	12	13	14	15	16	17	18	19
125	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,81	1,96	2,09	2,22	2,35	2,46	2,57	2,68	2,78	2,88	2,98	3,07
250	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,78	1,93	2,06	2,19	2,32	2,43	2,55	2,65	2,76	2,85	2,95	3,04
500	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,72	1,86	2,00	2,13	2,26	2,38	2,49	2,60	2,70	2,80	2,9	3
750	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,66	1,80	1,94	2,08	2,20	2,32	2,44	2,55	2,65	2,75	2,85	2,95
1000	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,60	1,75	1,89	2,02	2,15	2,27	2,38	2,49	2,60	2,70	2,8	2,9
2000	MAX	1,46	1,73	1,99	2,24	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,38	1,53	1,67	1,81	1,94	2,06	2,18	2,30	2,41	2,51	2,61	2,71
3000	MAX	1,23	1,49	1,75	1,99	2,23	2,46	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,26	1,41	1,56	1,69	1,82	1,95	2,07	2,18	2,30	2,40	2,51	2,61
4000	MAX	1,10	1,36	1,61	1,85	2,09	2,32	2,54	2,71	2,81	2,91	3	3,09
	MIN	1,18	1,33	1,48	1,61	1,75	1,87	1,99	2,11	2,22	2,33	2,43	2,53
5000	MAX	1,01	1,26	1,51	1,75	1,98	2,21	2,43	2,65	2,81	2,91	3	3,09
	MIN	1,12	1,27	1,42	1,56	1,69	1,81	1,93	2,05	2,16	2,27	2,38	2,48
10000	MAX		1,06	1,29	1,52	1,75	1,97	2,18	2,39	2,60	2,79	2,99	3,09
	MIN		1,11	1,25	1,38	1,52	1,64	1,76	1,88	1,99	2,10	2,21	2,31
20000	MAX			1,13	1,34	1,56	1,77	1,97	2,18	2,37	2,57	2,76	2,95
	MIN			1,10	1,23	1,36	1,48	1,61	1,72	1,84	1,95	2,05	2,16
40000	MAX			1,01	1,21	1,41	1,60	1,80	2,00	2,19	2,38	2,56	2,75
	MIN			1,00	1,09	1,22	1,34	1,46	1,58	1,69	1,80	1,91	2,01

TABLE K-2

Binder application rate (total) (double seal)

CORRECTED BALL-PENETRATION (mm) = 4,00 REQUIRED TEXTURE DEPTH (mm) = 0,3

AVERAGE LEAST DIMENSION (mm)

ADT/LANE	RATE	8	9	10	11	12	13	14	15	16	17	18	19
125	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,81	1,95	2,09	2,22	2,34	2,46	2,57	2,67	2,78	2,88	2,97	3,06
250	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,77	1,91	2,05	2,18	2,31	2,42	2,54	2,64	2,75	2,84	2,94	3,04
500	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,69	1,84	1,98	2,11	2,24	2,36	2,47	2,58	2,68	2,78	2,88	2,98
750	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,62	1,77	1,91	2,05	2,17	2,29	2,41	2,52	2,62	2,72	2,82	2,92
1000	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,55	1,70	1,85	1,98	2,11	2,23	2,35	2,46	2,56	2,67	2,77	2,86
2000	MAX	1,35	1,61	1,87	2,12	2,36	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,30	1,45	1,60	1,74	1,87	1,99	2,11	2,23	2,34	2,44	2,55	2,65
3000	MAX	1,12	1,38	1,63	1,87	2,11	2,34	2,56	2,71	2,81	2,91	3	3,09
	MIN	1,18	1,33	1,48	1,61	1,75	1,87	1,99	2,11	2,22	2,33	2,43	2,53
4000	MAX	1,00	1,25	1,50	1,74	1,97	2,20	2,42	2,63	2,81	2,91	3	3,09
	MIN	1,10	1,25	1,39	1,53	1,66	1,79	1,91	2,03	2,14	2,25	2,35	2,46
5000	MAX	0,92	1,16	1,40	1,63	1,86	2,09	2,31	2,52	2,73	2,91	3	3,09
	MIN	1,04	1,19	1,33	1,47	1,60	1,73	1,85	1,97	2,08	2,19	2,3	2,4
10000	MAX		0,97	1,19	1,42	1,63	1,85	2,06	2,27	2,47	2,66	2,86	3,05
	MIN		1,02	1,16	1,29	1,43	1,55	1,67	1,79	1,90	2,01	2,12	2,23
20000	MAX			1,05	1,25	1,45	1,66	1,86	2,06	2,25	2,44	2,63	2,81
	MIN			1,01	1,14	1,26	1,39	1,51	1,63	1,74	1,85	1,96	2,06
40000	MAX				1,13	1,32	1,51	1,70	1,89	2,07	2,25	2,44	2,61
	MIN				1	1,12	1,24	1,36	1,47	1,59	1,70	1,8	1,91

TABLE K-2

Binder application rate (total) (double seal)

CORRECTED BALL-PENETRATION (mm) = 1,00 REQUIRED TEXTURE DEPTH (mm) =0,5

AVERAGE LEAST DIMENSION (mm)

ADT/LANE	RATE	8	9	10	11	12	13	14	15	16	17	18	19
125	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,83	1,98	2,11	2,24	2,37	2,48	2,59	2,70	2,80	2,90	2,99	3,09
250	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,82	1,97	2,11	2,23	2,36	2,47	2,58	2,69	2,79	2,89	2,99	3,08
500	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,81	1,95	2,09	2,22	2,34	2,46	2,57	2,67	2,78	2,88	2,97	3,06
750	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,79	1,93	2,07	2,20	2,32	2,44	2,55	2,66	2,76	2,86	2,96	3,05
1000	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,77	1,91	2,05	2,18	2,31	2,42	2,54	2,64	2,75	2,84	2,94	3,04
2000	MAX	1,80	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,69	1,84	1,98	2,11	2,24	2,36	2,47	2,58	2,68	2,78	2,88	2,98
3000	MAX	1,57	1,84	2,10	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,60	1,75	1,89	2,02	2,15	2,27	2,39	2,50	2,60	2,70	2,80	2,90
4000	MAX	1,44	1,71	1,97	2,22	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,53	1,68	1,83	1,96	2,09	2,21	2,33	2,44	2,55	2,65	2,75	2,85
5000	MAX	1,33	1,60	1,87	2,12	2,36	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,49	1,64	1,78	1,91	2,04	2,17	2,28	2,39	2,50	2,61	2,71	2,80
10000	MAX	1,11	1,37	1,63	1,88	2,12	2,35	2,58	2,71	2,81	2,91	3,00	3,09
	MIN	1,34	1,49	1,64	1,77	1,90	2,03	2,15	2,26	2,37	2,48	2,58	2,68
20000	MAX	0,92	1,18	1,43	1,67	1,91	2,14	2,36	2,58	2,79	2,91	3,00	3,09
	MIN	1,21	1,36	1,50	1,64	1,77	1,90	2,02	2,14	2,25	2,35	2,46	2,56
40000	MAX	0,77	1,01	1,26	1,50	1,73	1,96	2,18	2,39	2,60	2,80	2,99	3,09
	MIN	1,09	1,24	1,38	1,52	1,65	1,78	1,90	2,01	2,13	2,24	2,34	2,44

TABLE K-2

Binder application rate (total) (double seal)

CORRECTED BALL-PENETRATION (mm) = 2,00 REQUIRED TEXTURE DEPTH (mm) = 0,5

		AVERAGE LEAST DIMENSION (mm)											
		8	9	10	11	12	13	14	15	16	17	18	19
ADT/LANE	RATE												
125	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,82	1,96	2,10	2,23	2,35	2,47	2,58	2,69	2,79	2,89	2,98	3,08
250	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,80	1,94	2,08	2,21	2,33	2,45	2,56	2,67	2,77	2,87	2,96	3,06
500	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,75	1,90	2,03	2,16	2,29	2,41	2,52	2,63	2,73	2,83	2,93	3,02
750	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,70	1,85	1,99	2,12	2,25	2,37	2,48	2,59	2,69	2,79	2,89	2,98
1000	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,66	1,81	1,95	2,08	2,21	2,33	2,44	2,55	2,65	2,75	2,85	2,95
2000	MAX	1,44	1,71	1,97	2,22	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,49	1,64	1,78	1,92	2,05	2,17	2,29	2,40	2,50	2,61	2,71	2,81
3000	MAX	1,20	1,47	1,73	1,98	2,22	2,45	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,38	1,53	1,67	1,81	1,94	2,06	2,18	2,30	2,41	2,51	2,61	2,71
4000	MAX	1,07	1,33	1,59	1,84	2,08	2,31	2,53	2,71	2,81	2,91	3	3,09
	MIN	1,30	1,45	1,60	1,74	1,87	1,99	2,11	2,23	2,34	2,44	2,55	2,65
5000	MAX	0,97	1,23	1,49	1,73	1,97	2,20	2,43	2,64	2,81	2,91	3	3,09
	MIN	1,25	1,40	1,54	1,68	1,81	1,94	2,06	2,17	2,28	2,39	2,49	2,6
10000	MAX	0,77	1,01	1,26	1,50	1,73	1,96	2,18	2,39	2,60	2,80	2,99	3,09
	MIN	1,09	1,24	1,38	1,52	1,65	1,78	1,90	2,01	2,13	2,24	2,34	2,44
20000	MAX		0,85	1,08	1,30	1,53	1,75	1,96	2,17	2,37	2,57	2,77	2,96
	MIN		1,09	1,23	1,37	1,50	1,63	1,75	1,87	1,98	2,09	2,2	2,3
40000	MAX			0,93	1,15	1,36	1,57	1,78	1,98	2,18	2,38	2,57	2,75
	MIN			1,10	1,23	1,36	1,49	1,61	1,73	1,84	1,95	2,06	2,16

TABLE K-2

Binder application rate (total) (double seal)

CORRECTED BALL-PENETRATION (mm) = 3,00 REQUIRED TEXTURE DEPTH (mm) = 0,5

AVERAGE LEAST DIMENSION (mm)

ADT/LANE	RATE	8	9	10	11	12	13	14	15	16	17	18	19
125	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,81	1,96	2,09	2,22	2,35	2,46	2,57	2,68	2,78	2,88	2,98	3,07
250	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,78	1,93	2,06	2,19	2,32	2,43	2,55	2,65	2,76	2,85	2,95	3,04
500	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,72	1,86	2,00	2,13	2,26	2,38	2,49	2,6	2,7	2,80	2,9	3
750	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,66	1,80	1,94	2,08	2,20	2,32	2,44	2,55	2,65	2,75	2,85	2,95
1000	MAX	1,76	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,6	1,75	1,89	2,02	2,15	2,27	2,38	2,49	2,6	2,70	2,8	2,9
2000	MAX	1,26	1,53	1,79	2,04	2,28	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,38	1,53	1,67	1,81	1,94	2,06	2,18	2,3	2,41	2,51	2,61	2,71
3000	MAX	1,03	1,29	1,55	1,79	2,03	2,26	2,49	2,7	2,81	2,91	3	3,09
	MIN	1,26	1,41	1,56	1,69	1,82	1,95	2,07	2,18	2,3	2,40	2,51	2,61
4000	MAX	0,90	1,16	1,41	1,65	1,89	2,12	2,34	2,56	2,77	2,91	3	3,09
	MIN	1,18	1,33	1,48	1,61	1,75	1,87	1,99	2,11	2,22	2,33	2,43	2,53
5000	MAX	0,81	1,06	1,31	1,55	1,78	2,01	2,23	2,45	2,65	2,86	3	3,09
	MIN	1,12	1,27	1,42	1,56	1,69	1,81	1,93	2,05	2,16	2,27	2,38	2,48
10000	MAX		0,86	1,09	1,32	1,55	1,77	1,98	2,19	2,4	2,59	2,79	2,98
	MIN		1,11	1,25	1,38	1,52	1,64	1,76	1,88	1,99	2,10	2,21	2,31
20000	MAX			0,93	1,14	1,36	1,57	1,77	1,98	2,17	2,37	2,56	2,75
	MIN			1,10	1,23	1,36	1,48	1,61	1,72	1,84	1,95	2,05	2,16
40000	MAX				1,01	1,21	1,40	1,60	1,8	1,99	2,18	2,36	2,55
	MIN				1,09	1,22	1,34	1,46	1,58	1,69	1,80	1,91	2,01

TABLE K-2

Binder application rate (total) (double seal)

CORRECTED BALL-PENETRATION (mm) = 4,00 REQUIRED TEXTURE DEPTH (mm) = 0,5

AVERAGE LEAST DIMENSION (mm)

ADT/LANE	RATE	8	9	10	11	12	13	14	15	16	17	18	19
125	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,81	1,95	2,09	2,22	2,34	2,46	2,57	2,67	2,78	2,88	2,97	3,06
250	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,77	1,91	2,05	2,18	2,31	2,42	2,50	2,64	2,75	2,84	2,94	3,04
500	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,69	1,84	1,98	2,11	2,24	2,36	2,47	2,58	2,68	2,78	2,88	2,98
750	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,62	1,77	1,91	2,05	2,17	2,29	2,41	2,52	2,62	2,72	2,82	2,92
1000	MAX	1,68	1,96	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,55	1,70	1,85	1,98	2,11	2,23	2,35	2,46	2,56	2,67	2,77	2,86
2000	MAX	1,15	1,41	1,67	1,92	2,16	2,39	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,30	1,45	1,60	1,74	1,87	1,99	2,11	2,23	2,34	2,44	2,55	2,65
3000	MAX	0,92	1,18	1,43	1,67	1,91	2,14	2,36	2,58	2,79	2,91	3,00	3,09
	MIN	1,18	1,33	1,48	1,61	1,75	1,87	1,99	2,11	2,22	2,33	2,43	2,53
4000	MAX	0,80	1,05	1,30	1,54	1,77	2,00	2,22	2,43	2,64	2,84	3,00	3,09
	MIN	1,10	1,25	1,39	1,53	1,66	1,79	1,91	2,03	2,14	2,25	2,35	2,46
5000	MAX	0,72	0,96	1,20	1,43	1,66	1,89	2,11	2,32	2,53	2,73	2,92	3,09
	MIN	1,04	1,19	1,33	1,47	1,60	1,73	1,85	1,97	2,08	2,19	2,30	2,40
10000	MAX		0,77	0,99	1,22	1,43	1,65	1,86	2,07	2,27	2,46	2,66	2,85
	MIN		1,02	1,16	1,29	1,43	1,55	1,67	1,79	1,90	2,01	2,12	2,23
20000	MAX			0,85	1,05	1,25	1,46	1,66	1,86	2,05	2,24	2,43	2,61
	MIN			1,01	1,14	1,26	1,39	1,51	1,63	1,74	1,85	1,96	2,06
40000	MAX				0,93	1,12	1,31	1,50	1,69	1,87	2,05	2,24	2,41
	MIN				1,00	1,12	1,24	1,36	1,47	1,59	1,70	1,80	1,91

TABLE K-2

Binder application rate (total) (double seal)

CORRECTED BALL-PENETRATION (mm) = 1,00 REQUIRED TEXTURE DEPTH (mm) = 0,7

		AVERAGE LEAST DIMENSION (mm)											
		8	9	10	11	12	13	14	15	16	17	18	19
ADT/LANE	RATE												
125	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,83	1,98	2,11	2,24	2,37	2,48	2,59	2,70	2,80	2,90	2,99	3,09
250	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,82	1,97	2,11	2,23	2,36	2,47	2,58	2,69	2,79	2,89	2,99	3,08
500	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,81	1,95	2,09	2,22	2,34	2,46	2,57	2,67	2,78	2,88	2,97	3,06
750	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,79	1,93	2,07	2,20	2,32	2,44	2,55	2,66	2,76	2,86	2,96	3,05
1000	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,77	1,91	2,05	2,18	2,31	2,42	2,54	2,64	2,75	2,84	2,94	3,04
2000	MAX	1,60	1,87	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,69	1,84	1,98	2,11	2,24	2,36	2,47	2,58	2,68	2,78	2,88	2,98
3000	MAX	1,37	1,64	1,90	2,15	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,60	1,75	1,89	2,02	2,15	2,27	2,39	2,50	2,60	2,70	2,80	2,90
4000	MAX	1,24	1,51	1,77	2,02	2,26	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,53	1,68	1,83	1,96	2,09	2,21	2,33	2,44	2,55	2,65	2,75	2,85
5000	MAX	1,13	1,40	1,67	1,92	2,16	2,39	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,49	1,64	1,78	1,91	2,04	2,17	2,28	2,39	2,50	2,61	2,71	2,80
10000	MAX	0,91	1,17	1,43	1,68	1,92	2,15	2,38	2,59	2,80	2,91	3,00	3,09
	MIN	1,34	1,49	1,64	1,77	1,90	2,03	2,15	2,26	2,37	2,48	2,58	2,68
20000	MAX	0,72	0,98	1,23	1,47	1,71	1,94	2,16	2,38	2,59	2,79	2,99	3,09
	MIN	1,21	1,36	1,50	1,64	1,77	1,90	2,02	2,14	2,25	2,35	2,46	2,56
40000	MAX	0,57	0,81	1,06	1,30	1,53	1,76	1,98	2,19	2,40	2,60	2,79	2,99
	MIN	1,09	1,24	1,38	1,52	1,65	1,78	1,90	2,01	2,13	2,24	2,34	2,44

TABLE K-2

Binder application rate (total) (double seal)

CORRECTED BALL-PENETRATION (mm) = 2,00 REQUIRED TEXTURE DEPTH (mm) = 0,7

AVERAGE LEAST DIMENSION (mm)

ADT/LANE	RATE	8	9	10	11	12	13	14	15	16	17	18	19
125	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,82	1,96	2,10	2,23	2,35	2,47	2,58	2,69	2,79	2,89	2,98	3,08
250	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,80	1,94	2,08	2,21	2,33	2,45	2,56	2,67	2,77	2,87	2,96	3,06
500	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,75	1,90	2,03	2,16	2,29	2,41	2,52	2,63	2,73	2,83	2,93	3,02
750	MAX	1,80	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,70	1,85	1,99	2,12	2,25	2,37	2,48	2,59	2,69	2,79	2,89	2,98
1000	MAX	1,67	1,94	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,66	1,81	1,95	2,08	2,21	2,33	2,44	2,55	2,65	2,75	2,85	2,95
2000	MAX	1,24	1,51	1,77	2,02	2,26	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,49	1,64	1,78	1,92	2,05	2,17	2,29	2,40	2,50	2,61	2,71	2,81
3000	MAX	1,00	1,27	1,53	1,78	2,02	2,25	2,48	2,69	2,81	2,91	3,00	3,09
	MIN	1,38	1,53	1,67	1,81	1,94	2,06	2,18	2,30	2,41	2,51	2,61	2,71
4000	MAX	0,87	1,13	1,39	1,64	1,88	2,11	2,33	2,55	2,76	2,91	3,00	3,09
	MIN	1,30	1,45	1,60	1,74	1,87	1,99	2,11	2,23	2,34	2,44	2,55	2,65
5000	MAX	0,77	1,03	1,29	1,53	1,77	2,00	2,23	2,44	2,65	2,85	3,00	3,09
	MIN	1,25	1,40	1,54	1,68	1,81	1,94	2,06	2,17	2,28	2,39	2,49	2,60
10000	MAX	0,57	0,81	1,06	1,30	1,53	1,76	1,98	2,19	2,40	2,60	2,79	2,99
	MIN	1,09	1,24	1,38	1,52	1,65	1,78	1,90	2,01	2,13	2,24	2,34	2,44
20000	MAX		0,65	0,88	1,10	1,33	1,55	1,76	1,97	2,17	2,37	2,57	2,76
	MIN		1,09	1,23	1,37	1,50	1,63	1,75	1,87	1,98	2,09	2,20	2,30
40000	MAX			0,73	0,95	1,16	1,37	1,58	1,78	1,98	2,18	2,37	2,55
	MIN			1,10	1,23	1,36	1,49	1,61	1,73	1,84	1,95	2,06	2,16

TABLE K-2

Binder application rate (total) (double seal)

CORRECTED BALL-PENETRATION (mm) = 3,00 REQUIRED TEXTURE DEPTH (mm) = 0,7

AVERAGE LEAST DIMENSION (mm)

ADT/LANE	RATE	8	9	10	11	12	13	14	15	16	17	18	19
125	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,81	1,96	2,09	2,22	2,35	2,46	2,57	2,68	2,78	2,88	2,98	3,07
250	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,78	1,93	2,06	2,19	2,32	2,43	2,55	2,65	2,76	2,85	2,95	3,04
500	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,72	1,86	2,00	2,13	2,26	2,38	2,49	2,60	2,70	2,80	2,9	3
750	MAX	1,71	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,66	1,80	1,94	2,08	2,20	2,32	2,44	2,55	2,65	2,75	2,85	2,95
1000	MAX	1,56	1,83	2,10	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3	3,09
	MIN	1,60	1,75	1,89	2,02	2,15	2,27	2,38	2,49	2,60	2,70	2,8	2,9
2000	MAX	1,06	1,33	1,59	1,84	2,08	2,31	2,54	2,71	2,81	2,91	3	3,09
	MIN	1,38	1,53	1,67	1,81	1,94	2,06	2,18	2,30	2,41	2,51	2,61	2,71
3000	MAX	0,83	1,09	1,35	1,59	1,83	2,06	2,29	2,50	2,71	2,91	3	3,09
	MIN	1,26	1,41	1,56	1,69	1,82	1,95	2,07	2,18	2,30	2,40	2,51	2,61
4000	MAX	0,70	0,96	1,21	1,45	1,69	1,92	2,14	2,36	2,57	2,77	2,96	3,09
	MIN	1,18	1,33	1,48	1,61	1,75	1,87	1,99	2,11	2,22	2,33	2,43	2,53
5000	MAX	0,61	0,86	1,11	1,35	1,58	1,81	2,03	2,25	2,45	2,66	2,85	3,04
	MIN	1,12	1,27	1,42	1,56	1,69	1,81	1,93	2,05	2,16	2,27	2,38	2,48
10000	MAX		0,66	0,89	1,12	1,35	1,57	1,78	1,99	2,20	2,39	2,59	2,78
	MIN		1,11	1,25	1,38	1,52	1,64	1,76	1,88	1,99	2,10	2,21	2,31
20000	MAX			0,73	0,94	1,16	1,37	1,57	1,78	1,97	2,17	2,36	2,55
	MIN			1,10	1,23	1,36	1,48	1,61	1,72	1,84	1,95	2,05	2,16
40000	MAX				0,81	1,01	1,20	1,40	1,60	1,79	1,98	2,16	2,35
	MIN				1,09	1,22	1,34	1,46	1,58	1,69	1,8	1,91	2,01

TABLE K-2

Binder application rate (total) (double seal)

CORRECTED BALL-PENETRATION (mm) = 4,00 REQUIRED TEXTURE DEPTH (mm) = 0,7

AVERAGE LEAST DIMENSION (mm)

ADT/LANE	RATE	8	9	10	11	12	13	14	15	16	17	18	19
125	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,81	1,95	2,09	2,22	2,34	2,46	2,57	2,67	2,78	2,88	2,97	3,06
250	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,77	1,91	2,05	2,18	2,31	2,42	2,54	2,64	2,75	2,84	2,94	3,04
500	MAX	1,84	1,99	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,69	1,84	1,98	2,11	2,24	2,36	2,47	2,58	2,68	2,78	2,88	2,98
750	MAX	1,65	1,93	2,12	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,62	1,77	1,91	2,05	2,17	2,29	2,41	2,52	2,62	2,72	2,82	2,92
1000	MAX	1,48	1,76	2,02	2,25	2,37	2,49	2,60	2,71	2,81	2,91	3,00	3,09
	MIN	1,55	1,70	1,85	1,98	2,11	2,23	2,35	2,46	2,56	2,67	2,77	2,86
2000	MAX	0,95	1,21	1,47	1,72	1,96	2,19	2,42	2,63	2,81	2,91	3,00	3,09
	MIN	1,30	1,45	1,60	1,74	1,87	1,99	2,11	2,23	2,34	2,44	2,55	2,65
3000	MAX	0,72	0,98	1,23	1,47	1,71	1,94	2,16	2,38	2,59	2,79	2,98	3,09
	MIN	1,18	1,33	1,48	1,61	1,75	1,87	1,99	2,11	2,22	2,33	2,43	2,53
4000	MAX	0,60	0,85	1,10	1,34	1,57	1,80	2,02	2,23	2,44	2,64	2,84	3,03
	MIN	1,10	1,25	1,39	1,53	1,66	1,79	1,91	2,03	2,14	2,25	2,35	2,46
5000	MAX	0,52	0,76	1,00	1,23	1,46	1,69	1,91	2,12	2,33	2,53	2,72	2,91
	MIN	1,04	1,19	1,33	1,47	1,60	1,73	1,85	1,97	2,08	2,19	2,30	2,40
10000	MAX		0,57	0,79	1,02	1,23	1,45	1,66	1,87	2,07	2,26	2,46	2,65
	MIN		1,02	1,16	1,29	1,43	1,55	1,67	1,79	1,90	2,01	2,12	2,23
20000	MAX			0,65	0,85	1,05	1,26	1,46	1,66	1,85	2,04	2,23	2,41
	MIN			1,01	1,14	1,26	1,39	1,51	1,63	1,74	1,85	1,96	2,06
40000	MAX				0,73	0,92	1,11	1,30	1,49	1,67	1,85	2,04	2,21
	MIN				1,00	1,12	1,24	1,36	1,47	1,59	1,70	1,80	1,91

TABLE K-3

STONE SPREAD RATE (LAYERS 1 AND 2) ($x10^{-3}$ m^3/m^2) FOR RATIONAL SEAL DESIGN*

AVERAGE LEAST DIMENSION OF STONE (mm)

FLAKINESS INDEX	3,00	4,00	5,00	6,00	7,00	8,00	9,00	10,00	11,00	12,00
0	3,23	4,17	5,13	6,10	7,09	8,09	9,10	10,13	11,17	12,23
5	3,26	4,21	5,17	6,15	7,15	8,15	9,17	10,21	11,26	12,33
10	3,28	4,24	5,21	6,20	7,20	8,22	9,25	10,29	11,35	12,42
15	3,31	4,27	5,26	6,25	7,26	8,28	9,32	10,37	11,44	12,52
20	3,34	4,31	5,30	6,30	7,32	8,35	9,40	10,46	11,53	12,62
25	3,36	4,34	5,34	6,35	7,38	8,42	9,47	10,54	11,63	12,72
30	3,39	4,38	5,38	6,40	7,44	8,49	9,55	10,63	11,72	12,83
35	3,42	4,42	5,43	6,46	7,50	8,56	9,63	10,72	11,82	12,93
40	3,45	4,45	5,47	6,51	7,56	8,63	9,71	10,80	11,92	13,04

* In the case of double seals reduce the spread rate of the first layer by 5%

TABLE K-4

EMBEDMENT DUE TO TRAFFIC AS DETERMINED BY THE BALL PENETRATION TEST (MM)

AVERAGE DAILY TRAFFIC (EQUIVALENT LIGHT VEHICLES/LANE/DAY)

CORRECTED BALL_PEN (mm)	125	250	500	750	1 000	2 000	3 000	4 000	5 000	10 000	20 000	40 000
0,75	0,006	0,012	0,024	0,036	0,048	0,095	0,244	0,349	0,431	0,684	0,938	1,192
1,00	0,016	0,031	0,063	0,094	0,126	0,252	0,421	0,542	0,635	0,925	1,215	1,505
1,25	0,023	0,047	0,093	0,140	0,187	0,373	0,559	0,691	0,793	1,111	1,429	1,747
1,50	0,030	0,059	0,118	0,177	0,236	0,472	0,672	0,813	0,923	1,264	1,605	1,946
1,75	0,035	0,070	0,139	0,209	0,278	0,556	0,767	0,916	1,032	1,393	1,753	2,113
2,00	0,039	0,079	0,157	0,236	0,314	0,629	0,849	1,006	1,127	1,504	1,881	2,259
2,25	0,043	0,087	0,173	0,260	0,346	0,693	0,922	1,085	1,211	1,603	1,995	2,387
2,50	0,047	0,094	0,187	0,281	0,375	0,750	0,987	1,155	1,286	1,691	2,096	2,501
2,75	0,050	0,100	0,200	0,301	0,401	0,802	1,046	1,219	1,353	1,771	2,188	2,605
3,00	0,053	0,106	0,212	0,318	0,425	0,849	1,100	1,277	1,415	1,843	2,271	2,700
3,25	0,056	0,112	0,223	0,335	0,446	0,893	1,149	1,331	1,472	1,910	2,348	2,787
3,50	0,058	0,117	0,233	0,350	0,466	0,933	1,195	1,380	1,525	1,972	2,420	2,867
3,75	0,061	0,121	0,243	0,364	0,485	0,970	1,237	1,427	1,574	2,030	2,486	2,942
4,00	0,063	0,126	0,251	0,377	0,503	1,005	1,277	1,470	1,619	2,084	2,548	3,013
4,25	0,065	0,130	0,260	0,389	0,519	1,038	1,315	1,510	1,662	2,134	2,607	3,079
4,50	0,067	0,134	0,267	0,401	0,535	1,069	1,350	1,549	1,703	2,182	2,661	3,141
4,75	0,069	0,137	0,275	0,412	0,549	1,099	1,383	1,585	1,741	2,227	2,714	3,200
5,00	0,070	0,141	0,282	0,423	0,563	1,127	1,415	1,619	1,778	2,270	2,763	3,255
5,25	0,072	0,144	0,288	0,432	0,577	1,153	1,445	1,652	1,812	2,311	2,810	3,308
5,50	0,074	0,147	0,295	0,442	0,589	1,179	1,474	1,683	1,846	2,350	2,855	3,359
5,75	0,075	0,150	0,301	0,451	0,601	1,203	1,501	1,713	1,877	2,387	2,897	3,407
6,00	0,077	0,153	0,306	0,460	0,613	1,226	1,527	1,741	1,907	2,423	2,938	3,454
6,25	0,078	0,156	0,312	0,468	0,624	1,248	1,553	1,769	1,936	2,457	2 977	3,498
6,50	0,079	0,159	0,317	0,476	0,635	1,269	1,577	1,795	1,964	2,490	3,015	3,541
6,75	0,081	0,161	0,322	0,484	0,645	1,290	1,600	1,820	1,991	2,521	3,051	3,582
7,00	0,082	0,164	0,327	0,491	0,655	1,310	1,623	1,845	2,017	2,552	3,086	3,621
7,25	0,083	0,166	0,332	0,498	0,664	1,329	1,644	1,868	2,042	2,581	3,120	3,660
7,50	0,084	0,168	0,337	0,505	0,674	1,347	1,665	1,891	2,066	2,609	3,153	3,696
7,75	0,085	0,171	0,341	0,512	0,683	1,365	1,685	1,913	2,089	2,637	3,184	3,732
8,00	0,086	0,173	0,346	0,518	0,691	1,382	1,705	1,934	2,112	2,663	3,215	3,767

TABLE K-5

ESTIMATED WEAR UNDER CONSTRUCTION ROLLING AND TRAFFIC (10 YEAR LIFE)(MM)

AVERAGE DAILY TRAFFIC (EQUIVALENT LIGHT VEHICLES/LANE/DAY)

10% FACT	125	250	500	750	1 000	2 000	3 000	4 000	5 000	10 000	20 000	40 000
150	0,461	0,495	0,559	0,618	0,671	0,832	0,909	0,935	0,961	0,961	0,961	0,961
160	0,448	0,482	0,547	0,605	0,659	0,820	0,897	0,923	0,949	0,949	0,949	0,949
170	0,436	0,470	0,534	0,593	0,647	0,808	0,885	0,911	0,937	0,937	0,937	0,937
180	0,424	0,458	0,523	0,581	0,635	0,796	0,873	0,899	0,925	0,925	0,925	0,925
190	0,413	0,447	0,511	0,570	0,623	0,785	0,861	0,887	0,913	0,913	0,913	0,913
200	0,401	0,435	0,499	0,558	0,612	0,773	0,850	0,876	0,902	0,902	0,902	0,902
210	0,390	0,424	0,488	0,547	0,600	0,762	0,838	0,864	0,890	0,890	0,890	0,890
220	0,378	0,412	0,477	0,535	0,589	0,750	0,827	0,853	0,879	0,879	0,879	0,879
230	0,367	0,401	0,465	0,524	0,578	0,739	0,816	0,842	0,868	0,868	0,868	0,868
240	0,356	0,390	0,454	0,513	0,567	0,728	0,805	0,831	0,857	0,857	0,857	0,857
250	0,345	0,379	0,444	0,502	0,556	0,717	0,794	0,820	0,846	0,846	0,846	0,846
260	0,335	0,369	0,433	0,492	0,545	0,707	0,783	0,809	0,835	0,835	0,835	0,835
270	0,324	0,358	0,422	0,481	0,535	0,696	0,773	0,799	0,825	0,825	0,825	0,825
280	0,314	0,348	0,412	0,471	0,524	0,686	0,762	0,788	0,814	0,814	0,814	0,814
290	0,304	0,338	0,402	0,461	0,514	0,675	0,752	0,778	0,804	0,804	0,804	0,804
300	0,293	0,328	0,392	0,451	0,504	0,665	0,742	0,768	0,794	0,794	0,794	0,794
310	0,284	0,318	0,382	0,441	0,494	0,655	0,732	0,758	0,784	0,784	0,784	0,784
320	0,274	0,308	0,372	0,431	0,484	0,646	0,722	0,748	0,774	0,774	0,774	0,774
330	0,264	0,298	0,362	0,421	0,475	0,636	0,713	0,739	0,765.	0,765	0,765	0,765
340	0,255	0,289	0,353	0,412	0,465	0,627	0,703	0,729	0,755	0,755	0,755	0,755
350	0,245	0,279	0,344	0,402	0,456	0,617	0,694	0,720	0,746	0,746	0,746	0,746

TABLE K-6

FRACTIONAL VOID-LOSS DUE TO EMBEDMENT OR WEAR

EMBEDMENT OR WEAR AS FRACTION OF ELT

FRACTIONAL EMBEDMENT OR WEAR	0,000	0,001	0,002	0,003	0,004	0,005	0,006	0.007	0,008	0,009
0,00	0,000	0,003	0,005	0,008	0,010	0,013	0,015	0,017	0,020	0,022
0,01	0,025	0,027	0,030	0,032	0,035	0,037	0,039	0,042	0,044	0,046
0,02	0,049	0,051	0,053	0,056	0,058	0,060	0,063	0,065	0,067	0,070
0,03	0,072	0,074	0,076	0,079	0,081	0,083	0,085	0,087	0,090	0,092
0,04	0,094	0,096	0,098	0,100	0,103	0,105	0,107	0,109	0,111	0,113
0,05	0,115	0,117	0,119	0,122	0,124	0,126	0,128	0,130	0,132	0,134
0,06	0,136	0,138	0,140	0,142	0,144	0,146	0,148	0,150	0,152	0,154
0,07	0,156	0,157	0,159	0,161	0,163	0,165	0,167	0,169	0,171	0,173
0,08	0,174	0,176	0,178	0,180	0,182	0,184	0,185	0,187	0,189	0,191
0,09	0,193	0,194	0,196	0,198	0,200	0,201	0,203	0,205	0,207	0,208
0,10	0,210	0,212	0,213	0,215	0,217	0,218	0,220	0,222	0,223	0,225
0,11	0,227	0,228	0,230	0,232	0,233	0,235	0,236	0,238	0,239	0,241
0,12	0,243	0,244	0,246	0,247	0,249	0,250	0,252	0,253	0,255	0,256
0,13	0,258	0,259	0,261	0,262	0,264	0,265	0,267	0,268	0,270	0,271
0,14	0,272	0,274	0,275	0,277	0,278	0,279	0,281	0,282	0,284	0,285
0,15	0,286	0,288	0,289	0,290	0,292	0,293	0,294	0,296	0,297	0,298
0,16	0,300	0,301	0,302	0,303	0,305	0,306	0,307	0,308	0,310	0,311
0,17	0,312	0,313	0,315	0,316	0,317	0,318	0,320	0,321	0,322	0,323
0,18	0,324	0,325	0,327	0,328	0,329	0,330	0,331	0,332	0,333	0,335
0,19	0,336	0,337	0,338	0,339	0,340	0,341	0,342	0,343	0,344	0,346
0,20	0,347	0,348	0,349	0,350	0,351	0,352	0,353	0,354	0,355	0,356
0,21	0,357	0,358	0,359	0,360	0,361	0,362	0,363	0,364	0,365	0,366
0,22	0,367	0,368	0,369	0,370	0,370	0,371	0,372	0,373	0,374	0,375
0,23	0,376	0,377	0,378	0,379	0,380	0,380	0,381	0,382	0,383	0,384
0,24	0,385	0,386	0,386	0,387	0,388	0,389	0,390	0,391	0,391	0,392
0,25	0,393	0,394	0,395	0,395	0,396	0,397	0,398	0,399	0,399	0,400
0,26	0,401	0,402	0,402	0,403	0,404	0,405	0,405	0,406	0,407	0,408
0,27	0,408	0,409	0,410	0,410	0,411	0,412	0,413	0,413	0,414	0,415
0,28	0,415	0,416	0,417	0,417	0,418	0,419	0,419	0,420	0,421	0,421
0,29	0,422	0,423	0,423	0,424	0,424	0,425	0,426	0,426	0,427	0,428
0,30	0,428	0,429	0,429	0,430	0,431	0,431	0,432	0,432	0,433	0,433
0,31	0,434	0,435	0,435	0,436	0,436	0,437	0,437	0,438	0,438	0,439
0,32	0,439	0,440	0,441	0,441	0,442	0,442	0,443	0,443	0,444	0,444
0,33	0,445	0,445	0,446	0,446	0,447	0,447	0,448	0,448	0,449	0,449
0,34	0,449	0,450	0,450	0,451	0,451	0,452	0,452	0,453	0,453	0,454
0,35	0,454	0,454	0,455	0,455	0,456	0,456	0,457	0,457	0,457	0,458

TABLE K-6

FRACTIONAL VOID-LOSS DUE TO EMBEDMENT OR WEAR

EMBEDMENT OR WEAR AS FRACTION OF ELT

FRACTIONAL EMBEDMENT OR WEAR	0,000	0,001	0,002	0,003	0,004	0,005	0,006	0.007	0,008	0,009
0,36	0,458	0,459	0,459	0,460	0,460	0,460	0,461	0,461	0,462	0,462
0,37	0,462	0,463	0,463	0,463	0,464	0,464	0,465	0,465	0,465	0,466
0,38	0,466	0,466	0,467	0,467	0,468	0,468	0,468	0,469	0,469	0,469
0,39	0,470	0,470	0,470	0,471	0,471	0,471	0,472	0,472	0,472	0,473
0,40	0,473	0,473	0,474	0,474	0,474	0,475	0,475	0,475	0,476	0,476
0,41	0,476	0,476	0,477	0,477	0,477	0,478	0,478	0,478	0,479	0,479
0,42	0,479	0,479	0,480	0,480	0,480	0,481	0,481	0,481	0,481	0,482
0,43	0,482	0,482	0,483	0,483	0,483	0,483	0,484	0,484	0,484	0,485
0,44	0,485	0,485	0,485	0,486	0,486	0,486	0,486	0,487	0,487	0,487
0,45	0,487	0,488	0,488	0,488	0,488	0,489	0,489	0,489	0,489	0,490
0,46	0,490	0,490	0,490	0,491	0,491	0,491	0,491	0,492	0,492	0,492
0,47	0,492	0,493	0,493	0,493	0,493	0,494	0,494	0,494	0,494	0,495
0,48	0,495	0,495	0,495	0,495	0,496	0,496	0,496	0,496	0,497	0,497
0,49	0,497	0,497	0,498	0,498	0,498	0,498	0,499	0,499	0,499	0,499
0,50	0,499	0,500	0,500	0,500	0,500	0,501	0,501	0,501	0,501	0,502
0,51	0,502	0,502	0,502	0,503	0,503	0,503	0,503	0,504	0,504	0,504
0,52	0,504	0,504	0,505	0,505	0,505	0,505	0,506	0,506	0,506	0,506
0,53	0,507	0,507	0,507	0,507	0,508	0,508	0,508	0,508	0,509	0,509
0,54	0,509	0,509	0,510	0,510	0,510	0,510	0,511	0,511	0,511	0,511
0,55	0,512	0,512	0,512	0,512	0,513	0,513	0,513	0,513	0,514	0,514
0,56	0,514	0,514	0,515	0,515	0,515	0,516	0,516	0,516	0,516	0,517
0,57	0,517	0,517	0,518	0,518	0,518	0,518	0,519	0,519	0,519	0,520
0,58	0,520	0,520	0,520	0,521	0,521	0,521	0,522	0,522	0,522	0,523
0,59	0,523	0,523	0,523	0,524	0,524	0,524	0,525	0,525	0,525	0,526
0,60	0,526	0,526	0,527	0,527	0,527	0,528	0,528	0,528	0,529	0,529
0,61	0,529	0,530	0,530	0,530	0,531	0,531	0,531	0,532	0,532	0,533
0,62	0,533	0,533	0,534	0,534	0,534	0,535	0,535	0,536	0,536	0,536
0,63	0,537	0,537	0,537	0,538	0,538	0,539	0,539	0,539	0,540	0,540
0,64	0,541	0,541	0,542	0,542	0,542	0,543	0,543	0,544	0,544	0,545
0,65	0,545	0,545	0,546	0,546	0,547	0,547	0,548	0,548	0,549	0,549
0,66	0,550	0,550	0,550	0,551	0,551	0,552	0,552	0,553	0,553	0,554
0,67	0,554	0,555	0,555	0,556	0,556	0,557	0,557	0,558	0,558	0,559
0,68	0,560	0,560	0,561	0,561	0,562	0,562	0,563	0,563	0,564	0,564
0,69	0,565	0,566	0,566	0,567	0,567	0,568	0,568	0,569	0,570	0,570
0,70	0,571	0,571	0,572	0,573	0,573	0,574	0,575	0,575	0,576	0,576
0,71	0,577	0,578	0,578	0,579	0,580	0,580	0,581	0,582	0,582	0,583
0,72	0,584	0,584	0,585	0,586	0,586	0,587	0,588	0,589	0,589	0,590
0,73	0,591	0,591	0,592	0,593	0,594	0,594	0,595	0,596	0,597	0,597
0,74	0,598	0,599	0,600	0,600	0,601	0,602	0,603	0,604	0,604	0,605
0,75	0,606	0,607	0,608	0,608	0,609	0,610	0,611	0,612	0,613	0,613
0,76	0,614	0,615	0,616	0,617	0,618	0,619	0,619	0,620	0,621	0,622
0,77	0,623	0,624	0,625	0,626	0,627	0,628	0,629	0,629	0,630	0,631
0,78	0,632	0,633	0,634	0,635	0,636	0,637	0,638	0,639	0,640	0,641
0,79	0,642	0,643	0,644	0,645	0,646	0,647	0,648	0,649	0,650	0,651
0,80	0,652	0,653	0,655	0,656	0,657	0,658	0,659	0,660	0,661	0,662
0,81	0,663	0,664	0,666	0,667	0,668	0,669	0,670	0,671	0,672	0,674
0,82	0,675	0,676	0,677	0,678	0,679	0,681	0,682	0,683	0,684	0,686
0,83	0,687	0,688	0,689	0,691	0,692	0,693	0,694	0,696	0,697	0,698
0,84	0,699	0,701	0,702	0,703	0,705	0,706	0,707	0,709	0,710	0,711
0,85	0,713	0,714	0,715	0,717	0,718	0,720	0,721	0,722	0,724	0,725
0,86	0,727	0,728	0,729	0,731	0,732	0,734	0,735	0,737	0,738	0,740
0,87	0,741	0,743	0,744	0,746	0,747	0,749	0,750	0,752	0,753	0,755
0,88	0,756	0,758	0,760	0,761	0,763	0,764	0,766	0,767	0,769	0,771
0,89	0,772	0,774	0,776	0,777	0,779	0,781	0,782	0,784	0,786	0,787
0,90	0,789	0,791	0,792	0,794	0,796	0,798	0,799	0,801	0,803	0,805
0,91	0,806	0,808	0,810	0,812	0,814	0,815	0,817	0,819	0,821	0,823
0,92	0,825	0,826	0,828	0,830	0,832	0,834	0,836	0,838	0,840	0,842
0,93	0,843	0,845	0,847	0,849	0,851	0,853	0,855	0,857	0,859	0,861
0,94	0,863	0,865	0,867	0,869	0,871	0,873	0,875	0,877	0,880	0,882
0,95	0,884	0,886	0,888	0,890	0,892	0,894	0,896	0,899	0,901	0,903
0,96	0,905	0,907	0,909	0,912	0,914	0,916	0,918	0,920	0,923	0,925
0,97	0,927	0,929	0,932	0,934	0,936	0,939	0,941	0,943	0,946	0,948
0,98	0,950	0,953	0,955	0,957	0,960	0,962	0,964	0,967	0,969	0,972
0,99	0,974	0,977	0,979	0,982	0,984	0,986	0,989	0,991	0,994	0,996
1,00	0,999	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

TABLE K-7

ADDITIONAL COLD BINDER REQUIRED FOR SURFACE TEXTURE (L/SQ.M)

AVERAGE DAILY TRAFFIC (EQUIVALENT LIGHT VEHICLES/LANE/DAY)

TEXTURE DEPTH(mm)	125	250	500	750	1 000	2 000	3 000	4 000	5 000	10 000 OR MORE
0,10	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08
0,11	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09
0.12	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
0,13	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
0,14	0,11	0,11	0,11	0,11	0,11	0,11	0,11	0,11	0,11	0,11
0,15	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,11
0,16	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,11
0,17	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,11
0,18	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,11
0,19	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,11
0,20	0,16	0,16	0,16	0,16	0,16	0,16	0,16	0,16	0,16	0,11
0,21	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,16	0,11
0,22	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,11
0,23	0,18	0,18	0,18	0,18	0,18	0,18	0,18	0,18	0,17	0,11
0,24	0,19	0,19	0,19	0,19	0,19	0,19	0,19	0,18	0,17	0,11
0,25	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,18	0,17	0,11
0,26	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,19	0,17	0,11
0,27	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,19	0,17	0,11
0,28	0,22	0,22	0,22	0,.22	0,22	0,22	0,21	0,19	0,17	0,11
0,29	0,23	0,23	0,23	0,23	0,23	0,23	0,21	0,19	0,17	0,11
0,30	0,24	0,24	0,24	0,24	0,24	0,24	0,21	0,19	0,17	0,11
0,31	0,25	0,25	0,25	0,25	0,25	0,24	0,19	0,19	0,17	0,12
0,32	0,25	0,25	0,25	0,25	0,25	0,24	0,21	0,19	0,17	0,12
0,33	0,26	0,26	0,26	0,26	0,26	0,24	0,21	0,19	0,17	0,12
0,34	0,27	0,27	0,27	0,27	0,27	0,24	0,21	0,19	0,17	0,12
0,35	0,28	0,28	0,28	0,28	0,28	0,24	0,21	0,19	0,17	0,12
0,36	0,29	0,29	0,29	0,29	0,29	0,24	0,21	0,19	0,17	0,12
0,37	0,29	0,29	0,29	0,29	0,29	0,25	0,21	0,19	0,17	0,12
0,38	0,30	0,30	0,30	0,30	0,30	0,25	0,21	0,19	0,17	0,12
0,39	0,31	0,31	0,31	0,31	0,30	0,25	0,21	0,19	0,17	0,12
0,40	0,32	0,32	0,32	0,32	0,30	0,25	0,21	0,19	0,17	0,12
0,41	0,32	0,32	0,32	0,32	0,30	0,25	0,22	0,19	0,17	0,12
0,42	0,33	0,33	0,33	0,32	0,30	0,25	0,22	0,19	0,18	0,12
0,43	0,34	0,34	0,34	0,33	0,30	0,25	0,22	0,19	0,18	0,12
0,44	0,35	0,35	0,35	0,33	0,30	0,25	0,22	0,19	0,18	0,12
0,45	0,36	0,36	0,36	0,33	0,30	0,25	0,22	0,19	0,18	0,12
0,46	0,36	0,36	0,36	0,33	0,30	0,25	0,22	0,20	0,18	0,12
0,47	0,37	0,37	0,36	0,33	0,30	0,25	0,22	0,20	0,18	0,12
0,48	0,38	0,38	0,36	0,33	0,31	0,25	0,22	0,20	0,18	0,12
0,49	0,39	0,39	0,36	0,33	0,31	0,25	0,22	0,20	0,18	0,12
0,50	0,40	0,40	0,36	0,33	0,31	0,25	0,22	0,20	0,18	0,12
0,51	0,40	0,40	0,36	0,33	0,31	0,25	0,22	0,20	0,18	0,13
0,52	0,41	0,41	0,36	0,33	0,31	0,25	0,22	0,20	0,18	0,13
0,53	0,42	0,42	0,36	0,33	0,31	0,25	0,22	0,20	0,18	0,13
0,54	0,43	0,42	0,36	0,33	0,31	0,25	0,22	0,20	0,18	0,13
0,55	0,44	0,42	0,36	0,33	0,31	0,25	0,22	0,20	0,18	0,13
0,56	0,44	0,42	0,36	0,33	0,31	0,25	0,22	0,20	0,18	0,13
0,57	0,45	0,42	0,36	0,33	0,31	0,26	0,22	0,20	0,18	0,13
0,58	0,46	0,42	0,36	0,33	0,31	0,26	0,22	0,20	0,18	0,13
0,59	0,47	0,42	0,37	0,33	0,31	0,26	0,22	0,20	0,18	0,13
0,60	0,47	0,42	0,37	0,33	0,31	0,26	0,22	0,20	0,18	0,13

APPENDIX L

THE MODIFIED TRAY TEST

The test equipment consists of a circular tray with an area of 0,05 m^2 and a wall height of 50 mm, and of a shoulder piece which fits snugly on top of the tray, has the same internal diameter as the tray and is fitted to a loose-fitting cloth membrane. The purpose of the membrane is to prevent the "density sand" flowing into the voids between the stones.

Volume of stone plus voids	V_3	=	V_1 - V_2
		=	(M_1 - M_2) / BDS (see Figure L-1)
where	BDS	=	bulk density of the sand
Effective layer thickness (ELT) of the stone layer		=	V_3 / A
where	A	=	area of tray.
Void content in stone layer	(V_P)	=	(V_3 - V_{stone}) / V_3 x 100 %
		=	(V_3 – M_S / RDS) / V_3 x 100 %
where	RDS	=	relative density of stone
	M_S	=	mass of stone sample

The practical spread rate of the stone and the bulk void content of the aggregate are determined by taking the stone sample from the modified tray test and pouring it into a plastic measuring cylinder (2 000 m ℓ capacity) and determining the bulk volume of the sample. Repeat a number of times and determine the average bulk volume of the stone sample.

The practical spread rate of the stone		=	V_4 / A x 10^{-3}(m^3/m^2)
where	V_4	=	bulk volume of the tray test sample (ℓ)
	A	=	area of the tray (m^2)
The bulk void content	(V_b)	=	(V_4 – V_{stone}) / V_4 x 100 %
		=	(V_4 – M_S / RDS) / V_4 x 100 %
Theoretical spread rate	=	ELT(100 – V_l) / (100 – V_b) x 10^{-3}(m^3/m^2)	

If there is a close agreement between the values of the theoretical and practical spread rates, the test data are most likely correct; if not, there was probably an error in the procedure or calculations.

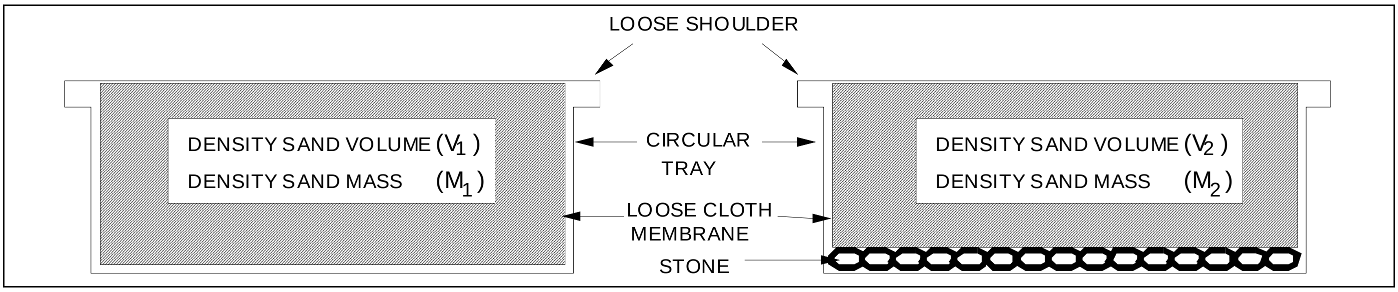


Figure L-1 Schematic illustration of the modified tray test