Guide to Pavement Technology Part 4K

Selection and Design of Sprayed Seals

Austroads

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Austroads

Sydney 2019

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Abstract

Guide to Pavement Technology Part 4K: Selection and Design of Sprayed Seals is a guide to the procedures for the selection and design of sprayed seals.

This is an update of previous Austroads procedures based on the philosophy of filling up voids in the aggregate matrix with binder, to a depth of about one half to two thirds the height of the aggregate when laying on its least dimension.

The Guide discusses the historical background and operational environment of sprayed seals, alongside design, selection and construction procedures for various types of sprayed seals.

Keywords

Sprayed seal, design, design traffic, aggregate, bituminous binder, average least dimension, embedment, surface texture, geotextiles, bitumen, polymer modified binders, bitumen emulsions, single/single seal, double/double seal, chip seal.

Edition 1.3 published November 2019

Corrections made to Table 6.4, Table C3, Section 5.5.4 and Section E.1.6.

Edition 1.2 published October 2018

Corrections to light vehicle values in Table C 2: Vehicle volume by lane.

Edition 1.1 published September 2018

Corrections to cross references in Sections 5.5.1 and 5.5.2, and binder absorption allowances in Appendix F 4.3.

First edition published August 2018

This Guide was previously published as *Guide to Pavement Technology Part 4K: Seals*. This new edition of the Guide has been restructured and content updated to improve overall readability and usability, and incorporates sprayed seal design (Sections 5 and 6), which was previously published in a separate document.

The terminology used to describe sprayed seal treatment types has been updated, with some name substitutions and additions, and inclusion of different material usage based on the findings of recent Austroads studies (Section 3). New information for selecting sprayed seals is included (Section 4). Various updates to design parameters have been updated to reflect current practice (Section 6).

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About Austroads

Austroads is the peak organisation of Australasian road transport and traffic agencies.

Austroads' purpose is to support our member organisations to deliver an improved Australasian road transport network. To succeed in this task, we undertake leading-edge road and transport research which underpins our input to policy development and published guidance on the design, construction and management of the road network and its associated infrastructure.

Austroads provides a collective approach that delivers value for money, encourages shared knowledge and drives consistency for road users.

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- Department of Infrastructure, Planning and Logistics Northern Territory
- Transport Canberra and City Services Directorate, Australian Capital Territory
- The Department of Infrastructure, Transport, Cities and Regional Development
- Australian Local Government Association
- New Zealand Transport Agency.

ISBN 978-1-925854-70-1

Austroads Project No. TT1850

Austroads Publication No. AGPT04K-18

Pages 120

Acknowledgements

This guide was prepared with the assistance of an action group from the Austroads Bituminous Surfacings Working Group, comprising of Robert Busuttil (VicRoads), Steve Halligan (MRWA) and Shawn Mumford (Downer Group). The previous version of this guide was prepared by Walter Holtrop, John Rebbechi and Allan Alderson.

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1. Introduction

1.1 Background

1.1.1 The Nature of Sprayed Seals

In its most basic form, a sprayed seal consists of a single layer of bitumen that is sprayed as a hot liquid, which is immediately followed by the application of a single layer of crushed aggregate.

Sprayed seals are an important component in the road system in Australia and New Zealand (Figure 1.1). Much of Australia is sparsely populated with large distances between centres of population. Providing a network of sealed roads has necessitated the development of outstanding skills in low-cost road construction and maintenance techniques, particularly the use of thin sprayed bituminous treatments on pavements constructed from locally available materials (often of marginal quality) or crushed rock. Similarly, in New Zealand, a relatively small population base has driven the need for low-cost road building.

Figure 1.1: Sprayed seals are an important element of the Australasian road system

Source: ARRB.

Sprayed seals are an economical surfacing and the techniques developed in Australia and New Zealand allow them to be used effectively as treatments on roads carrying several thousand vehicles per day.

The Australian road system comprises some 810 000 km of roads, of which 330 000 km are surfaced with sprayed seals, asphalt or concrete (Austroads 2005a). The New Zealand road system comprises some 92 000 km, of which 59 000 km are surfaced (Austroads 2005a). In both countries, sprayed seals are the predominant surfacing type in rural areas. Sprayed seals account for around 70% of the total length of all surfaced roads. In urban areas, asphalt and concrete surfaces predominate due to their structural strength, durability, improved resistance to surface stresses and lower maintenance.

Sprayed seals are held in place by a combination of adhesion between binder and aggregate, mechanical interlock between adjoining aggregate particles, adhesion to the underlying base and binder rising up and filling the space between aggregates.

Traffic has a major effect on the performance of sprayed seals. Under heavy traffic, aggregate particles become closely packed and are re-oriented so that they lie substantially on their broadest dimension with the least dimension vertical. Under light traffic (less than about 200 v/l/d), aggregate particles remain in a more random arrangement, with greater space between the aggregate particles, so that the amount of binder required to fill up the space to effectively hold the aggregate in place, without the risk of flushing, may be up to twice that required for the same size aggregate on a heavily trafficked road. Traffic volume and aggregate size are, therefore, primary factors used in the design of sprayed seal binder application rates.

Other factors affecting the design of binder application rates for sprayed seals include adjustments for aggregate shape and special traffic conditions, allowances for texture of the existing surface, possible embedment of aggregate into the substrate, and/or absorption of binder into the pavement or aggregate.

The most common form of sprayed seal is a single application of hot bituminous binder and a single application of aggregate (Figure 1.2 and Figure 1.3). This may be used as a retreatment of an existing bituminous surface, or on a granular pavement that has been primed or initially sealed. Priming and initial seals generally involve the use of cutback bitumen (to reduce viscosity of the binder) to obtain the necessary penetration and/or adhesion to the underlying pavement.

Figure 1.2: Spraying bituminous binder

Source: ARRB.

Figure 1.3: Spreading aggregate

Source: ARRB.

In some cases, multiple applications of binder and aggregate are used to provide more substantial treatments.

Bitumen binders can also be modified with the addition of polymers or crumb rubber to provide improved aggregate retention in areas of high stress, or a thicker, more flexible membrane for improved waterproofing and reduction in crack reflection. Multigrade bitumens are another form of modified bitumen for special applications.

Hot bituminous binders may be cut back with a cutter oil, such as kerosene, to temporarily reduce viscosity and enhance aggregate adhesion in cool conditions. More cutter oil is used for initial seal binders to assist with adhesion to a base. Greater proportions of cutter oil are added to make lower viscosity products for priming.

A further means of liquefying bitumen is by emulsification. Such binders can be sprayed at ambient temperatures or warmed to temperatures up to 90 °C. Emulsions can be used in sprayed seals for many of the applications of hot bitumen. The advantages include less heating, reduced use of cutter oils in cool conditions and improved adhesion to damp surfaces in some circumstances. The disadvantages include a higher cost due to the expense of emulsification and a slower rate of strength gain that increases the time before seals can be trafficked, particularly in cooler conditions.

All binders used in sprayed sealing work are derived from oils obtained from the refining of crude oil. Other products formerly used in sprayed sealing work included tars obtained from the destructive distillation of coal. Town gasworks provided a cheap source of tars that were widely used for priming and initial sealing due to superior penetration and adhesion properties. Poor durability and poor temperature susceptibility made tars largely unsuitable as sealing binders. With the introduction of natural gas and liquefied petroleum gas, the manufacturing of gas from coal gradually ceased. At around the same time it was also realised that tars posed a serious health risk, and are no longer used for sprayed sealing work, regardless of availability and cost.

On a strong pavement, the performance of sprayed seals deteriorates through gradual hardening of the binder. Eventually the seal will require maintenance intervention due to loss of aggregate or minor surface cracking which may result in a weakening of the underlying pavement. Damage to the underlying pavement is likely to require substantial repairs. A system of planned periodic maintenance to resurface sprayed seals before they reach a critical level of deterioration (which leads to loss of overall pavement performance) is most important in the management of roads surfaced with sprayed seals.

Sprayed seal performance can also deteriorate because of aggregate wear and polishing or aggregate embedment leading to loss of surface texture and reduced skid resistance, particularly in wet conditions. Deterioration may also occur due to loss of aggregate or through flushing of binder as a result of incorrect design of application rates or poor work practices.

1.1.2 Historical Context

Prior to the 1930s, bituminous surfacing of roads was completed using either mixtures of aggregate and binder or crude sealing techniques involving spraying liquid binder (road oil) and scattering graded aggregate to soak up the oil and create a marginally bound layer. The concept of a thin layer of hot bitumen and a clean single-sized aggregate (that was not submerged in the binder) was developed around the 1930s.

One of the first to articulate a design procedure for this technique was F. M. Hanson of New Zealand (Hanson 1935). His concept involved calculating voids between the aggregates as a function of aggregate size (average least dimension (ALD)) and filling a proportion of those voids with an amount of binder related to traffic volume. This remains the basis of sprayed seals design to this day, although with significant adjustment for changes in traffic loads, and improved understanding of other factors influencing sprayed seal behaviour.

Sprayed sealing techniques were quickly implemented by Australian road authorities. Some equipment was imported from the USA and other countries, but there was also substantial local innovation to meet the requirements developed by the authorities. This included the design and building of equipment such as simple robust bitumen sprayers, heating and storage units, aggregate spreaders and the unique Australian aggregate loaders that screened and precoated aggregates while loading trucks.

Understanding the importance of aggregate characteristics, the use of clean, dust-free, good quality, single-sized aggregates, the drive for innovative low-cost techniques and attention to detail were key factors in the development of sprayed seals that performed well. Apart from improvements in mechanical equipment, the basic techniques developed in the 1930s remain the same today.

Prior to World War II, the only sealed roads in Australia were in urban areas and on some of the more important highways near major centres of population. In the 1950s and 1960s sprayed seals played an important part in creating a network of safe, all-weather, low-maintenance, surfaced roads connecting all significant population centres and a substantial portion of the rural arterial road network (Figure 1.4).

Figure 1.4: Applying sprayed seal binder circa 1960s

Source: ARRB.

Prior to the 1950s, most bitumen was imported in drums. Drums were stacked at site dumps ready for the arrival of the spraying gang. When required for use, the drums were split and heated in open kettles. The sprayer gangs generally camped in tents and would complete work within approximately a 40 or 50 km radius, before moving on to the next dump site.

The construction of oil refineries in Australia in the 1950s saw the introduction of hot bulk bitumen being transported directly from refineries in rail cars and road tankers. With increased mobility of sprayer crews, most sprayed work is now performed by crews operating from fixed depots or modern accommodation in remote areas.

Initially, most sprayed work, particularly state highway and main road networks, was done by direct labour units operated by the state road authorities. Most of this work is now done by private sector contractors. The road agencies, and state and local government remain the major customers so that most work is performed to public authority specifications.

1.1.3 Development of Guides to Sprayed Sealing Practice

Expertise in sprayed sealing work largely developed within individual road agencies in Australia and New Zealand, leading to the production of comprehensive manuals articulating the practice in those particular organisations (e.g. Roads and Traffic Authority NSW (1997); Transit New Zealand, Road Controlling Authorities and Roading New Zealand (2005); VicRoads and Geopave (2004)).

The first attempt to produce a national guide was made with the publication of the *Principles and Practice of Bituminous Surfacing – Part 1: Sprayed Work* by the National Association of Australian State Road Authorities (NAASRA) in 1965. A companion volume referred to *Plant Mix Work*.

The 1965 guide was a simple overview of the selection, design and conduct of sprayed sealing work. Although rather basic, it was a popular publication, with a second edition in 1975 and reprints in 1980 and 1984. A third edition appeared in January 1989 as a technical report under the title of *Bituminous Surfacing Sprayed Work* (Figure 1.5).

Figure 1.5: Previous guides to sprayed sealing practice

Source: ARRB.

During the 1990s, it became apparent the published procedures for selection and design of sprayed seals were not keeping pace with increases in traffic (particularly heavy vehicles), and improvements in materials and equipment.

Changes in materials included introduction of crumb rubber and other polymer modified binders, commonly referred to as PMBs. Crumb rubber was one of the early polymers introduced in the early 1970s, based on a concept developed in the USA to utilise fine granulated scrap rubber from vehicle tyres. Other types of polymers have been introduced since. The use of PMBs enables a thicker bituminous membrane to be applied to resist reflection cracking in aged and/or cracked pavements.

Changes in road use arise particularly from increased wheel loads, tyre pressures and configuration of heavy vehicles as well as an overall increase in volume and speed of all vehicles. Increased demands on sprayed seals also arose from a desire to continue their use as a relatively economical treatment on a wide variety of road classes, and not just lightly trafficked rural roads.

A national working group was established to review sprayed seal design and performance. The initial outcome was a state-of-the-art review, published as *Review of Sprayed Seal Design* (NAASRA 1988). The working group commenced a long-term review of sprayed seal design and published, in brief format as an interim measure, the *Design of Sprayed Seals* in 1990. That design method was based on the best information available and retained the Hanson principles of aggregate voids related to traffic volume and aggregate ALD, but with more detailed advice on adjustments for different traffic effects, surface texture, embedment, absorption and aggregate characteristics.

National trials commenced in 1991 to evaluate a number of design criteria with the aim of further improving the reliability of sprayed seal design. The comprehensive review and trials of design factors related to sprayed seal performance took some time to complete. The performance of sprayed seals is sensitive to variations in traffic (particularly heavy traffic), aggregate characteristics (size, shape and wear characteristics), and to surface conditions relating to texture and embedment. It is also influenced by climate and binder properties. Some of these effects are only apparent after a long period of service. Hence, detailed observation of a large number of field trials over a lengthy period was required in order to enable sufficient data for valid statistical analysis. Development of suitable test procedures for design parameters and measurement of performance were an important part of the project.

The outcomes were initially published as the Austroads Provisional Sprayed Seal Design Method – Revision 2000 followed by Update of the Austroads Sprayed Seal Design Method in 2006, and Update of the Double/Double Design for Austroads Sprayed Seal Method in 2013.

1.2 Use of this Guide

Specifications for sprayed sealing work describe what must be achieved, but they give little guidance on selection of treatments or how to achieve the desired outcome. The aims of this Guide are therefore to:

- assist asset managers in the selection of the most effective use of sprayed seals; in this respect, it is complementary to the *Guide to Pavement Technology Part 3: Pavement Surfacings* (Austroads 2009a) and various Austroads/Australian Asphalt Pavement Association (APAA) Pavement Work Tips
- provide a guide to complementary sources of information on conducting sprayed sealing work, understanding and interpretation of specifications and the conduct of contract audit and surveillance activity
- provide a guide to the design of sprayed seals.

The Guide also provides a reference to students and others seeking an overview and general understanding of sprayed seal work.

2. Operating Environment

2.1 General

Sprayed seals, as for all road surfacings, need to contribute to smooth, safe and consistent conditions for road users, at a cost that minimises user and road agency long-term costs and with surface characteristics that are appropriate to the location.

The operating environment comprises a number of elements, including systems used for the management of road assets and the physical environment in which sprayed seals are required to perform.

The managerial environment has undergone significant change in the past 20 years. Policy and management issues have had a significant effect on the way that road surfacing treatments are evaluated and used, and the manner in which work is undertaken. Changes include:

- the introduction of electronic asset management systems for road networks that include the use of pavement management systems, maintenance management systems and whole-of-life costing assessments
- increasing focus on road user and community needs in terms of road safety, surface noise, ride quality and environmental impact
- improvements in workplace health and safety
- introduction of quality management systems at all levels of service delivery, with particular application to contract specifications
- a general trend in road agencies towards contract delivery of services in place of direct labour
- increasing use of performance-specified contracts.

At the same time the demands on pavements have increased due to greater volumes of road freight traffic, increased vehicle mass limits, larger vehicles and much higher tyre pressures.

2.2 The Managerial Environment

2.2.1 Pavement Management Systems (PMS)

A pavement management system (PMS) is a tool that provides a systematic method of road condition data collection, storage, analysis and modelling for decision-making associated with optimising resources across a pavement network.

Usual components of a PMS are:

- evaluation of optimal pavement performance
- evaluation of the most efficient allocation of resources given budget constraints
- analysis of data and resources
- database management.

At a network level, a PMS facilitates decision-making for long-term ‘needs based’ budgeting to address the overall condition of the network. At a project level, a PMS addresses the most cost-effective maintenance and rehabilitation means for each road segment. Achieving the desired performance outcomes has a significant impact on both the timing and type of treatment chosen.

2.2.2 Maintenance Management Systems (MMS)

While PMS focuses on the facility, i.e. the pavement, a maintenance management system (MMS) focuses on the function and effectiveness of maintenance. It is aimed at improving quality, productivity and work outputs.

An MMS is used to estimate and cost the amount of work to be performed, and monitor the effectiveness and results achieved. A condition-based needs assessment and budgeting procedure will provide for a uniformly defined maintenance planning process, as well as be a tool for checking the levels of maintenance service throughout the network.

2.2.3 Whole-of-life Costing

Whole-of-life costing recognises all user costs and road construction and maintenance costs that are expected in the long term and is used to evaluate alternative treatments that have different construction and maintenance cash-flow streams.

Cost elements should include construction and future maintenance and rehabilitation, as well as user costs. User costs can include increased vehicle operating costs due to deteriorated pavement roughness and delay expected during maintenance and rehabilitation activities.

2.2.4 User and Community Needs

User needs include safety, smooth ride quality, minimal road noise and aesthetics. Wider community concerns also apply to air quality, general traffic noise, conservation of resources, and health, safety and environmental impact of any works undertaken or proposed.

Road agencies have been encouraged to implement performance indicators relating to the efficiency with which roads are built and managed, their condition, and economic, social and environmental outcomes. Austroads has established a system of National Performance Indicators to monitor such performance which may be accessed through the Austroads web site.

The National Performance Indicator for smooth travel exposure is measured in terms of a target roughness level. Sprayed seals do not have direct impact on road roughness but can be important in preserving a road pavement to prevent deterioration in roughness due to entry of moisture, surface ravelling, cracking or ongoing maintenance patching. Sprayed seals can also be used in combination with an asphalt surfacing or microsurfacing and other shape-correction treatments to achieve the desired combination of improved ride quality, shape correction and waterproofing as a thin, cost-effective treatment.

Road safety effectiveness is measured in terms of road crashes. Although not directly measured as a National Performance Indicator, many road agencies monitor skid resistance and/or surface texture to identify risks associated with skidding crashes. Sprayed seals are an important tool in achieving desired texture and skid resistance levels.

2.2.5 Workplace Health and Safety

Sprayed sealing work is carried out in a potentially hazardous environment. Site safety is important to protect the travelling public during the progress of work and immediately following work due to the presence of loose aggregate or the absence of road markings. Site conditions for workers that need to be considered include hazards associated with traffic moving through or close to the site, hot and/or flammable materials, moving equipment and extensive outdoor exposure.

Various codes of practice have been developed to cover most of these hazardous situations as well as the need to comply with legislative requirements. Recommendations for handling bituminous materials are described in the *Bituminous Materials Safety Guide* (Austroads 2015).

2.2.6 Contract Delivery and Contract Specifications

Sprayed sealing work in Australia evolved largely as a matter of policy using direct labour activity in state road agencies and larger local government organisations. High standards of supervision and training, as well as pride in innovation and overall outcomes were significant influencing factors in the standards of direct labour work. The control of the quality of materials and construction procedures was found to be crucial in producing quality sprayed seal work. Most work is now done under some form of contract.

Early contracts for sprayed sealing work tended to rely on the level of supervision by the principal, including matters such as design of application rates, supply of materials, approval of surface preparation, site conditions and general oversight of work practices. Specifications are evolving that describe more of what must be achieved rather than how it is to be achieved. This will shift the responsibility for decision making and outcomes from the principal to the contractor.

A major change in contract specifications came with the introduction of quality systems, which was given impetus by the decision of the federal government, in 1988, to make the adoption of quality systems a condition of federal funding. Many of the operational and procedural aspects of specifications were removed on the basis that these would form part of the contractor’s work procedures and quality plan.

The selection and design of sprayed sealing treatments, and the work procedures that are used to deliver the completed product, are extremely important to the successful use of sprayed seals, regardless of which party takes the responsibility for performance outcomes.

2.3 The Physical Environment

2.3.1 Traffic

Traffic conditions vary greatly from very heavily trafficked urban and rural arterial roads (Figure 2.1) to roads with small amounts of traffic in isolated rural areas (Figure 2.2). The continuing increases in traffic volumes, vehicle mass, axle loads and tyre pressures mean that the selection, design and application of the correct surfacing type is more crucial than ever before.

The volume and composition of traffic are important considerations in the selection of treatment type, materials and design of sprayed seals. Increased traffic volumes, vehicle mass, axle loads and tyre pressures have significantly increased the demands on sprayed seals in terms of:

- dislodgment of aggregate due to braking, accelerating and turning traffic
- aggregate embedment into substrate materials
- aggregate wear and breakdown
- aggregate polishing
- cracking of binder due to increased deflection of substrate under loading.

Figure 2.1: High-volume traffic on a sprayed seal pavement

Source: ARRB.

Figure 2.2: Low-volume traffic on a sprayed seal pavement

Source: ARRB.

In high-stress areas, additional performance may be obtained with the use of PMBs and/or multiple applications of binder and aggregate. Particular attention must be given to the conditions under which treatments are applied in high-stress areas, with work ideally being performed in warm and dry conditions. It may also be necessary to put in place additional measures to care for the completed seal (after-care) before allowing unrestricted traffic use.

It is also necessary to recognise the limitations of sprayed seals and the need to consider alternative treatments, such as asphalt or concrete surfacing, for example at intersections and roundabouts.

2.3.2 Existing Pavement Condition

The condition of the pavement substrate plays an important role in the performance of sprayed seals. Particular concerns include embedment of the aggregate into softer materials, cracking, non-uniform surface texture and permeability of the pavement surface.

Aggregate embedment can occur in poor quality or wet granular materials. Compaction and the uniform surface finish of granular materials are critical elements in the successful use of sprayed seals as initial treatments on granular pavements. Aggregate embedment can also be an issue when designing a reseal for flushed or bleeding bituminous surfaces, or over fresh asphalt or microsurfacing.

Pavement cracking can allow moisture into underlying materials causing loss of pavement strength, increased roughness and increased levels of patching and routine maintenance. Timely retreatment of sprayed seals on granular pavements, before extensive cracking and pavement deformation develops, is desirable and cost-effective in terms of maintaining most rural road pavements. Even relatively poor quality granular materials can perform satisfactorily as road pavements if the moisture regime is well-controlled.

2.3.3 Climate and Weather

There are major climatic variations throughout Australasia from alpine conditions in the Australian and New Zealand Alps to the extreme temperature conditions found in the desert regions of central Australia (Figure 2.3). Rainfall patterns range from the high rainfall experienced in the north of Australia (Figure 2.4) and the west coast of New Zealand to the extremely low rainfall experienced in the arid regions of Australia.

Figure 2.3: Sprayed seal pavement in a dry, hot environment

Source: ARRB.

Figure 2.4: Sprayed seal pavement in a damp, cool environment

Source: ARRB.

The life of sprayed seals is influenced by climate including such effects as seasonal temperature variation, moisture change in pavement materials and binder oxidation at high temperatures. These factors will influence both the type of treatment and frequency of retreatment. Rainfall may also influence the choice of treatment to achieve particular texture levels without compromising waterproofing.

Australia's climate has warmed, and the duration, frequency and intensity of extreme heat events have increased across large parts of Australia (Bureau of Meteorology 2016). As a result, bituminous binders typically used in the past may not function as optimally as they have previously.

Development of adhesion between binder and aggregate is substantially reduced in cool or damp conditions, which can lead to early aggregate loss and seal failure. Weather conditions at the time of undertaking work are therefore extremely important. Weather conditions also influence the amount of care required in preparing and precoating of aggregates, use of cutter oils and adhesion agents, effect of modified binders and after-care of the completed work.

To reduce the risks of failure associated with sealing in cool weather, works should be programmed to be undertaken only in warm, dry condition, particularly for roads with high traffic volumes, single/single seals, PMBs and geotextile reinforced seals.

3. Types of Sprayed Seal Treatments

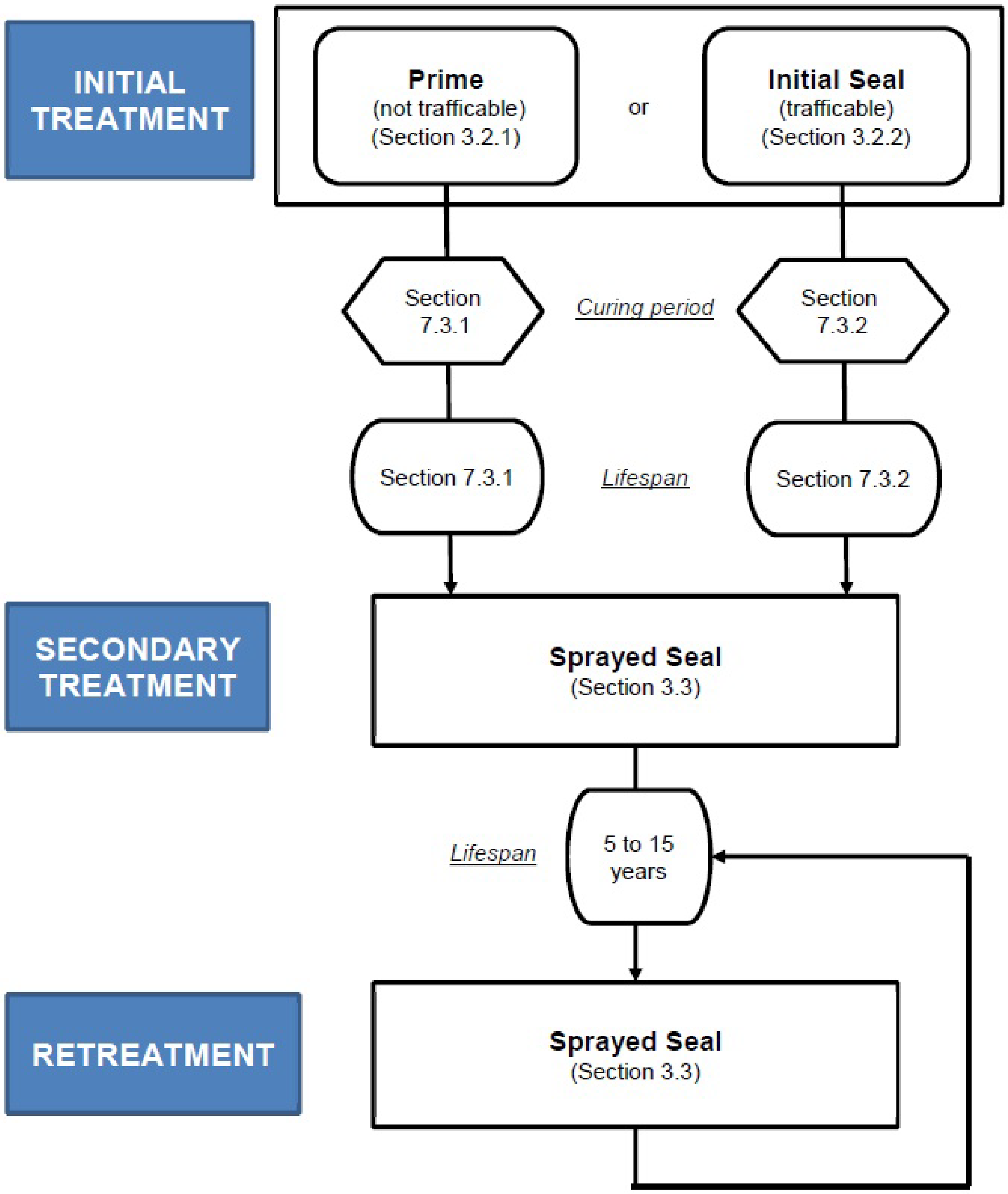
3.1 Categories of Sealing Treatments

All sealing works are defined as one of three broad categories:

1. initial treatment (an application of a prime or initial seal to a prepared basecourse)
2. secondary treatment (an application of a sprayed bituminous treatment on an initial treatment)
3. retreatment (an application of a sprayed bituminous treatment on an existing bituminous surfacing).

The typical life cycle and usage of these sprayed seal categories is demonstrated in the flow chart in Figure 3.1.

Figure 3.1: Sprayed seal life-cycle flow chart



3.2 Initial Treatments

An overarching term 'initial treatment' is used to describe spayed seal treatments applied directly onto newly constructed and prepared pavements.

Using an initial treatment usually results in a choice between applying a prime (Section 3.2.1) followed by a seal or by applying an initial seal (Section 3.2.2) followed by a seal within one to two years. Table 3.1 provides a summary of the advantages and disadvantages of both options.

Table 3.1: Advantages and disadvantages of initial seals, and prime and seals

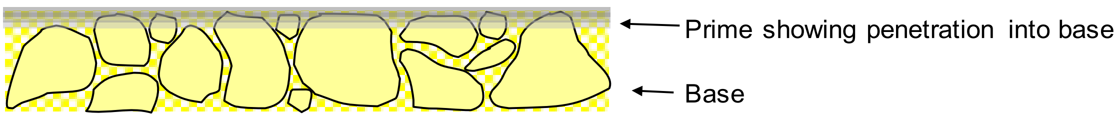
Initial treatment type	Advantages	Disadvantages
Prime and seal	1. Generally more economic in overall cost. 2. Reduced absorption of seal coat binder into the pavement. 3. Thicker waterproof layer. 4. Strong bond to the pavement. 5. May be used to protect pavement prior to sealing. 6. Easier to cope with non-uniform pavement condition and texture.	1. The pavement surface must be dry. 2. Best results are obtained in dry/warm conditions. 3. Two-stage process. 4. The primer must be dry and cure before sealing. A prime requires at least 3 days to cure without trafficking. 5. Use of pavement by traffic is restricted. 6. Rain may cause uncured primer to be washed off the pavement with loss of primer and risk of environmental damage.
Initial seals	1. Can be placed on a damp pavement. 2. One-step process that can be opened to controlled traffic once completed. 3. Allows repair of pavement deficiencies prior to final seal.	1. Relatively short-term treatment and should be followed by a secondary seal to complete the treatment within 1 to 2 years. 2. Cutback bitumen initial seals require 3 to 12 months for cutter to dissipate. 3. Rain soon after pavement construction can lead to problems such as aggregate embedment, binder emulsification, stripping of aggregates and binder pick-up by vehicles.

3.2.1 Prime

A prime is an initial treatment, being an application of a primer to a prepared granular base (Figure 3.2). It usually consists of a bitumen and cutter oil or specially formulated bitumen emulsion primer and is placed without a cover aggregate. Penetration of the prime into the base varies, but for granular base materials it is typically 5 to 10 mm, depending on the type and grade of prime.

As it has no aggregate, it should not be trafficked until the prime has dried and is no longer tacky. Public traffic should only be permitted once a more substantial surfacing treatment (secondary treatment) has been applied after the prime has cured. Curing times will vary depending on the weather conditions and nature of the base, but generally a minimum 3-day curing period is required for cutback primes, and a minimum 1-day curing period is required for emulsion primes, depending on the prevailing weather.

Figure 3.2: Prime



A prime is used to:

- penetrate the surface of an unbound granular layer filling all surface pores
- provide a bond onto which a subsequent bituminous surfacing can adhere
- provide a surface which retards the absorption of the bitumen, from a subsequent bituminous surfacing, into the pavement
- assist in waterproofing and protecting the pavement
- assist with the curing of stabilised pavements
- provide a temporary surface for traffic (though it should be noted that the life of the primed surface exposed to traffic is brief).

A prime is always recommended over granular pavements that are to be surfaced with a sprayed seal, or to be surfaced with asphalt where the depth of surfacing is less than 100 mm. A prime is also recommended for bonding of sprayed seals or asphalt to timber or concrete surfaces.

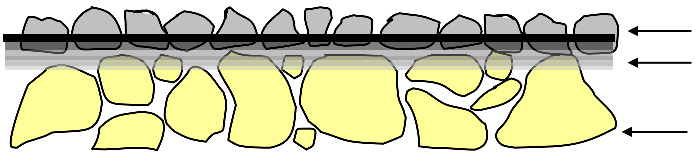
3.2.2 Initial Seal

An initial seal is an initial treatment, being an application of a sprayed seal to a prepared basecourse, which has not been primed. These are termed 'first coat seals' in New Zealand. It is intended that the seal adheres to the base, whilst providing a wearing course for traffic (Figure 3.3). It allows both immediate trafficking and permits a delay in placing of the final surfacing.

The success of initial seals relies on:

- selection of an appropriate initial sealing treatment
- appropriate binder application and aggregate spread rates
- preparation and condition of base materials
- application procedures (workmanship)
- careful control of traffic speed (e.g. speed reductions) in the first few days after application.

Figure 3.3: Initial seal



When considering the suggested initial seal treatments, it is vital to select a treatment that matches the purpose and requirements of the road, and the subsequent construction and maintenance schedule.

Short-term treatments, typically consisting of a single/single seal with small aggregate size, can be employed to provide a trafficable surface in conditions where priming is not practicable. A secondary treatment, providing an ongoing wearing course will be required after a short period (Section 7.3.2). Particular care must be taken in these situations to provide adequate curing time between treatments, while respecting the limited life expectancy of the initial seal.

Utilising larger aggregate sizes, double/double seals, and lower cutter oil contents, may be used as more robust treatments that provide longer-term wearing courses, particularly for low traffic volumes.

Longer-term treatments that provide an ongoing wearing course are available, utilising larger aggregate sizes, double/double seals, and lower cutter oil contents. However, it must be recognised that a direct application of an initial seal to a basecourse presents a higher risk of failure, and shorter potential life span than what can be expected from a prime and seal approach.

Initial sealing is most effectively applied during warm and dry conditions. Care should be exercised when undertaking initial sealing during cooler and damp conditions. Low temperatures may extend curing time due to a slow cutter evaporation rate and can increase difficulties of achieving successful adhesion of the aggregate to the binder, which typically leads to higher cutter contents being required to counteract poor adhesion.

The choice of binder is mainly influenced by the prevailing weather conditions, as well as the desired life of the treatment, and timing and type of final treatment.

The requirements for AMC cutback bitumen grades are provided in AS 2157. Equivalent field-blended grades may also be used.

Bitumen emulsions may be considered when a subsequent surfacing is to be applied before adequate curing of a cutback bitumen binder can occur. The requirements for bitumen emulsion grades are provided in AS 1160. Proprietary emulsion binders are also available.

Where a pavement stabilised with cementitious or chemical binder is to be initial sealed using a bitumen emulsion, a check on the compatibility of the emulsion with the stabilised material should be undertaken. Emulsions will always be compatible with bitumen-stabilised pavements.

Binders for very heavy traffic and/or very warm to hot conditions include proprietary grades of polymer modified binder, polymer modified emulsion, cutback bitumen manufactured with Class 320 base bitumen in place of Class 170 and cutback bitumen with low proportions of cutter oil. These binders provide for more rapid curing and reduced risk of bleeding in more demanding performance applications.

Whether a cutback or emulsion binder is used for an initial seal, the pavement surface should be lightly dampened (not wet) immediately prior to binder application to assist in the ‘wetting’ process.

3.3 Sprayed Seal (Secondary and Retreatments)

A sprayed seal is formed by the spraying of binder and covering it with a layer of aggregate. It may contain more than one application of binder and/or aggregate.

In New Zealand, the term ‘chipseal’ is used. ‘Chip’ refers to the description of the aggregate particles used in sealing work.

Depending on the application and type of seal, a sprayed seal may be used as an initial seal, secondary treatment, or retreatment, as defined in Section 3.1.

A ‘reseal’ is the term used to describe the application of a sprayed seal over an existing bituminous surface (e.g. a seal, asphalt or slurry surface).

Multiple application seals are generally described in a sequence of the application of binder and aggregate, for example:

- double/double = two applications of binder and two applications of aggregate
- single/double = a single application of binder and two applications of aggregate.

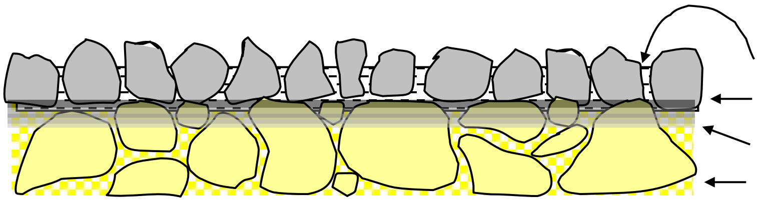
Special-purpose treatments are also used to meet specific circumstances and include single/single seal with scatter coat, dry matting, inverted seal, high-stress seal, strain alleviating membrane, strain alleviating membrane interlayer, fibre reinforced seal, geotextile reinforced seal and cape seal. Salt-affected pavements also require special consideration.

3.3.1 Single/single Seal

A single/single sprayed seal is so named to demonstrate it consists of a single layer of binder, covered by a single layer of aggregate (Figure 3.4). This naming convention provides the basis for all other sprayed seal type designations.

This is a common form of sprayed seal and is typically used for low-traffic and/or low-stress environments.

Figure 3.4: Single/single seal



3.3.2 Multiple-layer Applications

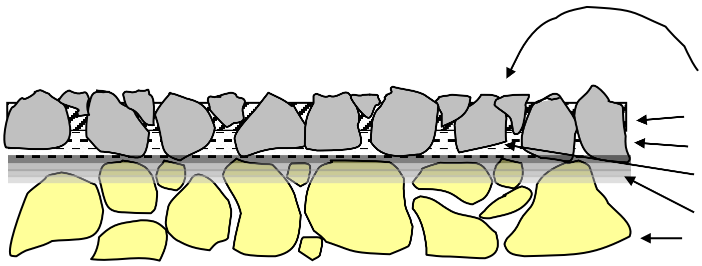
Sprayed seals may consist of multiple-layer applications of binder and/or aggregate. Some of the most common multiple layer application sprayed seals are described below. Other combinations not described are possible and may be explored by innovative practitioners.

Multiple-application seals provide a robust, heavy-duty surfacing. Examples include haul roads, roads subject to snow clearing operations, and ford crossings of creeks.

Double/double seal

A double/double seal is applied by spraying a layer of binder, spreading the large-sized aggregate and, after suitable rolling and sweeping, spraying another lower application of binder followed by the spreading of a layer of smaller aggregate. The smaller aggregate fits into the spaces between the larger aggregate and locks it into place (Figure 3.5). Double/double seals are commonly described by their aggregate sizes, for example a ‘14/7 double/double’ indicates a 14 mm bottom layer, covered by a 7 mm top layer.

Figure 3.5: Double/double seal



Single/double seal

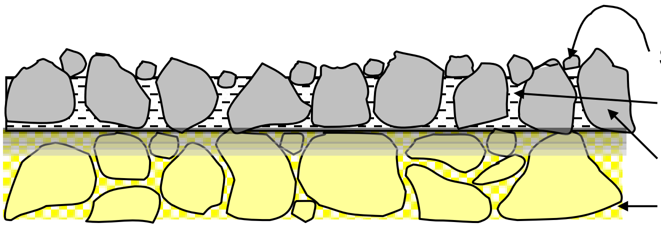
A single/double is a variation of the double/double seal (Figure 3.5). It is constructed by spraying a single layer of bitumen, spreading the large-sized aggregate at a more open spread rate than for a single/single seal and, before rolling is complete, spreading another layer of smaller aggregate. The smaller aggregate fits into the spaces between the larger aggregate and is locked into place by a small amount of bitumen (from the first spray). In a single/double seal, the second aggregate application is a permanent and integral part of the seal.

In New Zealand this type of treatment is also referred to as a ‘racked-in’ chip seal.

Scatter coat

A scatter coat is used in a similar manner to a single/double seal, the difference being that the first application of aggregate is spread at the normal rate for a single/single seal and the second aggregate application, or scatter coat, is used to provide a temporary mechanical interlock between the larger particles. This prevents traffic overturning and dislodging the coarse aggregate particles during the initial curing and compaction of the seal (Figure 3.6).

Figure 3.6: Single/single seal with a scatter coat



A scatter coat is particularly applicable when using emulsions.

A scatter coat differs from a single/double or racked-in seal in that the second aggregate is not applied until after rolling of the first application of aggregate is complete to avoid the small aggregate lodging below, and affecting adhesion of, the larger aggregate. As there is very little binder contact with the second aggregate, it is expected that a significant proportion of the smaller aggregate will be lost during the early service life of the seal as part of the process of further re-orientation of the principal aggregate under the action of traffic.

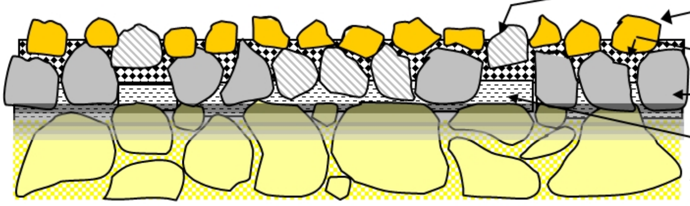
A scatter coat is similar to the ‘dry lock’ process used in New Zealand although, when used there, it is expected that a significant proportion of the second aggregate will remain wedged between the larger particles, resulting in a different appearance and reduced texture depth compared to a single/single seal.

Dry matting

Dry matting (also referred to as a ‘sandwich seal’ in New Zealand) is a technique involving the use of two applications of aggregate sandwiched around a single application of binder.

A particular use of dry matting is as a corrective treatment on stripped or partially stripped seals, or flushed bituminous surfaces. The process involves the spreading of a single layer of aggregate over the existing surface (or infill of the stripped areas of a partially stripped seal (Figure 3.7)) followed by a single application of binder and a further application of aggregate, generally a small-sized aggregate to lock the first aggregate application in place.

Figure 3.7: Dry matting

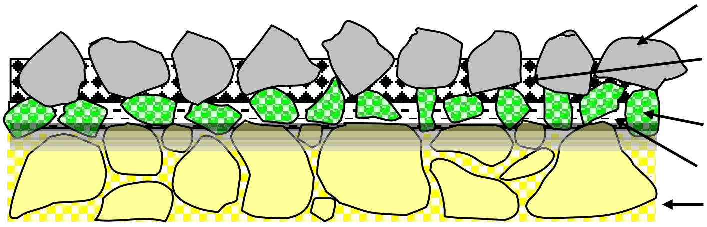


Inverted seal

An inverted seal (Figure 3.8) is a double/double seal that is 'inverted' from the normal double/double seal, such that the smaller-size aggregate is on the bottom coat and the larger-size aggregate is on the top coat. For example, it is a 7/14 rather than a 14/7 seal. Both applications are normally placed on the same day.

An inverted seal can be used to treat surfaces with large variation in transverse surface texture. It may also be used to reduce risk of embedment of the larger aggregate into soft pavement materials.

Figure 3.8: Inverted seal



3.3.3 Aggregate Retention Seal

An aggregate retention seal uses a lightly modified PMB to provide an improvement in adhesion performance, compared to a conventional bitumen. It reduces the risk of aggregate loss by early sweeping or trafficking, particularly in warm/hot conditions, or where binder application rates are considered to be low. It is to be used where the conditions do not demand the level of performance provided by use of HSS, XSS, or SAM treatments (the full terms are provided below).

3.3.4 High Stress Seals (HSS1 and HSS2)

High stress seals (HSS1 and HSS2) are bituminous seal or reseal treatments which are used in applications with moderate traffic loadings or where traffic is braking, accelerating or turning. Light-to-medium-modified PMBs are utilised to cope with these traffic stresses, and aid aggregate retention.

A HSS1 is a single/single seal with PMB.

A HSS2 is a double/double seal with PMB in both applications.

3.3.5 Extreme Stress Seal (XSS)

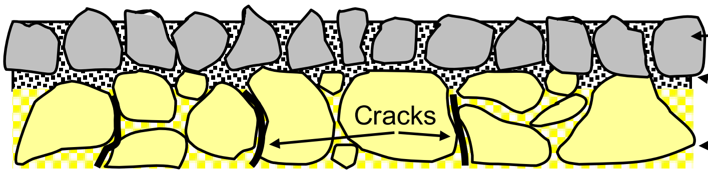
An extreme stress seal (XSS) is used to accommodate extreme stresses imposed by heavy traffic volumes and high proportions of heavy vehicles, or difficult service conditions such as long climbing lanes or tight radius curves. An XSS is a double/double seal where the bituminous binder is a medium to heavily modified PMB.

3.3.6 Strain Alleviating Membrane (SAM)

A strain alleviating membrane (SAM) is a sprayed seal consisting of a binder containing a heavily modified PMB (Figure 3.9). SAMs are used to treat cracked pavements by alleviating the effects of mechanical strains that occur in a road pavement, and thereby reduce the risk of reflection cracking at the surface.

The concept of a SAM seal is to provide a relatively thick membrane of a robust binder that absorbs movement from a weak or cracked underlying layer. SAMs are generally not effective if used with smaller aggregates as the binder layer is too thin to effectively absorb the strain. The use of larger aggregates of 10 mm or larger is recommended.

Figure 3.9: Strain alleviating membrane

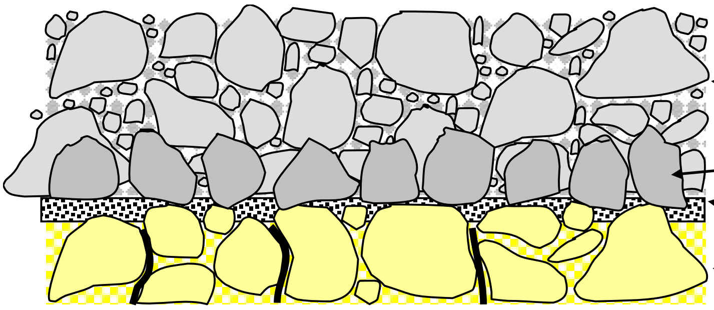


3.3.7 Strain Alleviating Membrane Interlayer (SAMI)

A strain alleviating membrane interlayer (SAMI), as with a SAM, alleviates mechanical strains that occur in a road pavement; however, SAMIs are placed as an interlayer beneath asphalt layers (Figure 3.10). They are not intended to be used as a permanent wearing course, and should be covered by asphalt within a few days.

SAMIs should only use aggregates of size 10 mm or larger, applied at a light spread rate that is sufficient to carry construction vehicles to place the asphalt layer. The binder in a SAMI is usually heavier in application rate and more heavily modified than a SAM binder.

Figure 3.10: Strain alleviating membrane interlayer



Care must be exercised if allowing traffic onto a SAMI in extremes of hot or cold weather.

In hot weather, the heavy binder application in a SAMI can lead to rapid flushing. This can also occur during the delivery of asphalt if trucks are channelised into the same path during the asphalt laying process.

In cold weather adhesion between the heavily modified binder and aggregate is difficult to achieve which can lead to widespread aggregate loss. In cold weather the laying of hot asphalt over the SAMI will reactivate the binder in the SAMI.

3.3.8 Fibre Reinforced Seal (FRS)

A fibre reinforced seal (FRS) uses an emulsion PMB and chopped glass fibre as reinforcement. The process uses a purpose-built sprayer or sprayer attachment (Figure 3.11) that, in a single pass:

- sprays binder onto the pavement
- cuts the required amount of fibreglass to length, generally 60 mm, and blows this onto the first layer of binder
- sprays a second layer of binder over the cut fibres.

The bitumen and fibre layers are immediately covered with an aggregate which is locked into place using an aggregate scatter coat.

FRS can be used as a SAM or a SAMI treatment, and can be expected to have enhanced performance compared to those treatments used with a PMB alone.

Figure 3.11: Application of binder and fibre for fibre reinforced seal

Source: Fulton Hogan (2016).

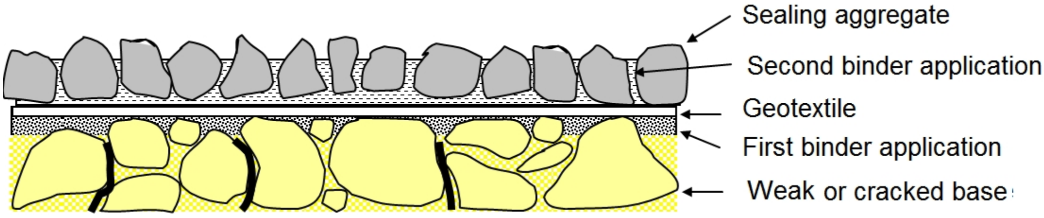
3.3.9 Geotextile Reinforced Seal (GRS)

Geotextile reinforced seals (GRSs) are produced by spraying a layer of bitumen onto a pavement (bond coat), then covering this bitumen with a layer of geotextile and lightly rolling.

GRS can be used to provide more robust waterproofing, and as a SAM or a SAMI treatment, and may be considered the most effective technique when treating badly cracked and distressed bound and unbound pavements. A double/double seal is typically applied over the geotextile (Figure 3.12) if it is intended to be a SAM wearing course, with single/single generally only used for SAMI applications.

Geotextile seals are more sensitive to weather conditions during and several weeks after construction, and as such they should be programmed to allow trafficking in warm weather.

Figure 3.12: Geotextile reinforced seal

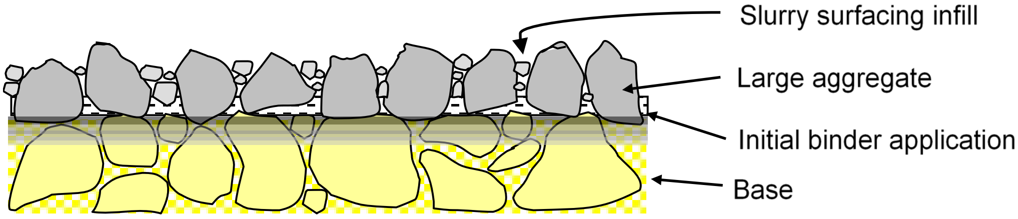


3.3.10 Cape Seal

Cape seals were developed and first used in the Cape Province of South Africa. They are constructed by applying a single/single seal to the pavement (usually using a size 14 or 20 mm aggregate) followed by a slurry (or microsurfacing) that can either partially fill the void space between the bitumen and the top of the aggregate (Figure 3.13), or completely cover the top of the aggregate. This is achieved by either a single or double application of slurry.

This type of treatment provides a very robust surfacing and the surface characteristics are substantially those of slurry. It has been used in rural areas to provide a surfacing with high shear resistance, comparable to that of asphalt, but in areas where asphalt is not economically viable.

Figure 3.13: Cape seal



3.4 Other Treatments

3.4.1 Variable Rate Spraying

Sealing with a variable rate spray bar is the process of spraying different binder application rates across the width of a spray run.

This process facilitates the optimisation of the seal design to address the most common types of defects in sprayed seal surfacings, which are:

- flushing/bleeding in the wheelpaths
- stripping in non-wheelpath areas (i.e. around the centreline, between wheelpaths and on shoulders).

Existing surface texture has an important influence on the amount of binder required to produce an effective sprayed seal. It is difficult to design a suitable single binder application rate when there is variable texture across a pavement, for instance when wheelpaths are flushed, yet the non-trafficked areas between wheelpaths and down the centreline are highly textured.

Variable binder application rates may be achieved by methods including pre-spraying (described in Austroads 2003), and utilising specialised equipment that sprays variable rates in a single pass.

Texture variation across and along the pavement may mean that an effective corrective treatment, or effective reseal, cannot be achieved and an alternative surfacing such as hot mix asphalt or microsurfacing needs to be considered. In some instances, it may be more effective and economic to remove the existing surfacing entirely and re-prepare the pavement for an initial treatment.

3.4.2 Salt-affected Pavements

Some pavement materials, particularly rubbles, may contain an appreciable quantity of salt. In addition, water used in compaction may also be saline. Where one or both of these conditions is encountered, it is possible that eruptions of small blisters may occur, with the surface of the pavement immediately beneath the primer being in a loose condition with saline fines.

Generally, the most effective treatment is to apply the initial treatment as an emulsion followed by the secondary treatment within a short space of time to provide a thick impermeable system as soon as possible. Light treatments, including primes and initial seals, are particularly vulnerable to salt damage.

If a prime or initial seal is affected by salt, all loose material, including any visible salt from the exposed base, should be swept off. An effective treatment is to re-prime with an emulsion followed immediately by a light seal using Class 170 bitumen. A further double/double seal should then be applied as soon as possible. Care must be taken when sweeping to avoid roughening the surface and rendering it unfit for sealing.

If a seal shows signs of light damage due to salt, blisters may be flattened by rolling and the surface resealed, if necessary. For severe damage to a seal, the surfacing and any visible salt should be removed. Potholes and severely affected pavement areas should be boxed out to the full depth of powdering, and patched before resealing the full road width. In extreme cases, resealing with PMBs may be required to provide an adequate treatment.

Guidelines for preliminary treatment techniques developed by Januszke and Booth (1992) are presented in Table 3.2. These guidelines are based on adjustment of treatment type depending on the salinity of the pavement expressed as salt content of the fines passing the 2 mm sieve.

Table 3.2: Initial treatments for salt- affected granular pavements

Salt content of fines	Initial treatment
0–1.5%	Treat as for a normal pavement.
1.6–2.5%	Initial seal followed as quickly as possible by the final seal.
2.6–3.0%	A sacrificial prime plus initial seal, followed as quickly as possible by the final seal may be satisfactory. If in doubt, treat as for > 3.0% salt content.
> 3.0%	Special investigations will be required and suitable procedures developed.

3.4.3 Surface Enrichment and Rejuvenation Treatments

Surface enrichment of a sprayed seal surface involves the spraying of a light application of a low viscosity grade of bituminous material (cutback or bitumen emulsion) or foamed bitumen onto the surface so that it runs into the voids of the existing surfacing. This treatment increases the amount of binder in the layer, but care must be taken to ensure that adequate surface texture remains. This treatment extends the life of the surfacing by ensuring the retention of the existing cover aggregate. Surface enrichment is generally applicable to low traffic sites such as shoulders and rest areas, and may also assist in waterproofing the surface.

A rejuvenating treatment is the application of a proprietary rejuvenating agent, usually in the form of an emulsion. Rejuvenation is used to replace the lost oils and resins in oxidised bitumen. Rejuvenation materials have a lower viscosity than the bitumen materials used in surface enrichment. They are particularly applicable to asphalt pavements for reducing permeability and delaying the onset of ravelling through ageing and oxidation of bitumen binders.

Enrichment and rejuvenation treatments are normally only used on roads in essentially good condition apart from aged binder where there is a risk of aggregate loss. They are generally only practical where traffic volumes are low and traffic can be diverted onto another lane or road, or the road shoulders. Traffic should not be allowed onto the treated surface until the binder has cured sufficiently to avoid pick-up. In some cases, a light coating of sand or grit can be used to reduce the time before trafficking.

Surface enrichment and rejuvenation can result in reduced skid resistance through a residue of surface binder. Traffic speed restrictions should remain in place until this residue has worn off and the skid resistance levels rise to acceptable levels.

3.4.4 High-friction Surface Treatment

For specialty sealing applications, thermosetting resin binders, including epoxy and polyurethane modified binders and other forms of polyester and resin esters can be used. These binders have been developed, in association with the appropriate aggregate, to provide good skid resistance in high-risk areas such as sharp curves and approaches to pedestrian crossings or signalised intersections (Figure 3.14).

Specialty binder seals can be used in combination with calcined bauxite, aluminium oxide, slag or natural aggregates of suitable hardness and resistance to traffic polishing. Aggregate sizes are 1–3 mm, although larger sizes can be used. Their relatively higher cost compared to conventional binders confines their use to specialised applications.

Figure 3.14: High-friction surface treatment

Source: Roadcor.

Careful preparation of existing surfaces is necessary prior to applying specialty binders. Any failures in the existing pavement need to be rectified to provide a uniform, sound base for the seal. Best results are generally obtained on asphalt surfaces that are in good condition. New asphalt surfaces may need to be trafficked for several weeks to allow the binder film on the aggregate surface to be worn off, but this can also be achieved with a high-pressure water treatment. Concrete surfaces must be cured, structurally sound, and mechanically abraded before treatment. The treatment can also be applied over timber and steel bridge decks subject to adequate surface preparation. Any oil or detritus from the pavement surface should be removed by cleaning with detergent and allowed to dry. It is important that there is no water on the surface, as this will prevent bonding.

High-friction surface treatments are proprietary products, and design, surface preparation and application guidance should be sought from the manufacturer. The sprayed seal design methods outlined in this Guide do not apply to high-friction surface treatments. Epoxy binder is generally applied at a rate of 1 to 1.5 L/m^2 using a mechanical spreader, squeegees or brooms. Higher application rates may be required on coarse textured or porous surfaces.

The 5 mm nominal sized calcined bauxite aggregate is usually spread at a rate of 100–125 m^2/m^3 (6–8 kg/m^2), immediately after the binder has been applied. It is not necessary to roll the aggregate as the random aggregate orientation and shape of the aggregate particles provides the desired texture.

Curing times depend on binder type, ambient temperature, and pavement temperature. Curing of polyurethane binders is further influenced by moisture and humidity.

3.4.5 Acrylic Oil Resistant Seal

Acrylic seals may be used as oil resistant treatments for known problem areas, such as bus stops, bus bays, bus parking areas and traffic lights, where the repeated deposition of oil and diesel spillage causes ravelling of the asphalt.

The acrylic binders are available commercially as two (or three) part acrylic resin systems. The aggregate should be fine, washed sand.

The same careful preparation of pavements for application of acrylic seals is required as that described for high-friction surface treatments.

Acrylic seal treatments are proprietary products, and design and application guidance should be sought from the manufacturer. The sprayed seal design methods outlined in this Guide do not apply to acrylic seal treatments.

An acrylic seal treatment consists of the application of acrylic binder using either an airless spray gun, paint roller, squeegees or brooms followed immediately by fine aggregate. The aggregate is not rolled as the random orientation and shape of the aggregate particles provides the desired texture.

Where the binder is applied in two coats, each application should be made at right angles to the previous layer. Curing time may take up to six hours before the pavement is suitable for trafficking. The curing time of the resin depends on road temperature and weather conditions.

3.4.6 Coloured Surface Treatment

Coloured surface treatments are used for delineation (Figure 3.15) and are applied either as a slurry of binder and fine aggregate, or by squeegeeing of specialty binders and application of synthetic aggregates using similar techniques to that described for high-friction surface treatments.

Coloured surface coatings are proprietary products, and design and application guidance should be sought from the manufacturer. The sprayed seal design methods outlined in this Guide do not apply to coloured surface coatings.

Figure 3.15: Coloured surface treatment incorporating epoxy resin binder and synthetic aggregate

Source: Roadcor.

The highest levels of colour intensity, surface friction and durability are generally obtained by the use of synthetic aggregates and epoxy resin, methylmethacrylate or polyurethane modified binders. While similar in appearance to high-friction surface treatments, it may not have the same skid resistance performance capabilities.

3.4.7 Dust Laying

Dust is a nuisance and can cause safety problems due to restricted vision and settling on road signs. The choice of treatment for dust laying on unsealed granular pavements to reduce dust nuisance, maintenance costs and loss of pavement material will depend upon the magnitude of the problem, but common treatments include:

- frequent application of water (Figure 3.16)
- treating the surface with diluted bitumen emulsion (Figure 3.17)
- spraying propriety dust suppressant.

Diluted emulsion is applied at 1 L/m^2 and care should be exercised to ensure that the material does not run off the pavement surface. Bitumen emulsion should be diluted with four parts water to one part emulsion for hard surfaces and 12 parts water to one part emulsion for soft surfaces (by volume). The mixture should be thoroughly mixed and used immediately.

Figure 3.16: Dampening down dusty surface

Figure 3.17: Dust laying techniques for other engineering works

The life expectancy of dilute emulsion treatments is between two or three days, but if repeated applications are applied the treated surface can last up to one month.

Manufacturer's instructions should be followed for proprietary products.

4. Selection of Treatments

4.1 Overview

The most common form of sprayed seal is a single/single seal consisting of one layer of conventional bitumen binder covered with a single layer of aggregate. Design of single/single seals forms the basis of the procedures described in this Guide. Choices available to the designer include sizes and combinations of aggregate together with a range of binder options to improve performance through improved temperature susceptibility, enhanced resistance to the stresses from traffic or improved waterproofing of cracked or weak pavements.

There are no quantitative measures available to define the limits of performance of different sizes and types of sprayed seals, or where no sprayed seal can be expected to provide a reasonable level of service and a different type of surfacing is required. This section provides a summary of the selection of surfacing type for a range of traffic, pavement strength and climatic conditions. Additional guidance on selecting pavement surfacings is provided in the *Guide to Pavement Technology Part 3: Pavement Surfacings* (Austroads 2009a).

The choices involve different costs and risks in performance outcomes. Designers should apply life-cycle cost analysis, where appropriate, to the selection of surfacing type and use their own experience and judgment in the selection and detailed design of the surfacing. Where that experience is insufficient, designers should seek specialist advice.

4.2 Purpose of Sprayed Seals

Sprayed seals aim to:

- provide a durable, safe and dust-free surface
- minimise the rate of pavement wear and whole-of-life maintenance costs
- protect the base from the effects of traffic and the environment by preventing moisture ingress into the pavement structure
- provide adequate skid resistance over the life of the surfacing.

A pavement is resealed when the condition of the existing surface requires the application of new binder and aggregate to restore one or more of the functions of the original seal. This provides a new surfacing and also re-waterproofs the pavement. It is usually conducted as part of a periodic maintenance program.

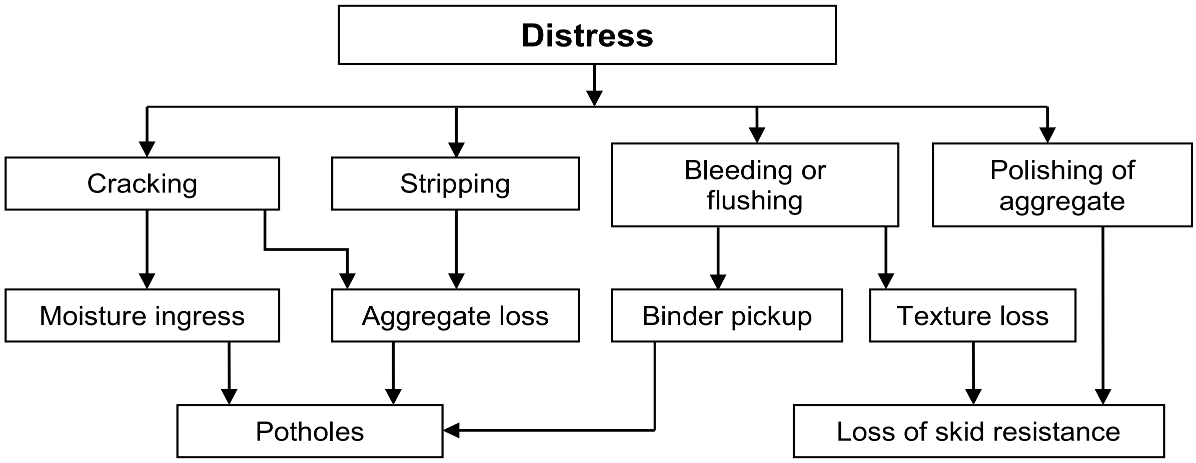
4.3 Distress Modes

Sprayed seals are subject to a number of distress modes, which may operate independently or interact. The primary mechanisms are illustrated in Figure 4.1. The potential distress modes must be addressed when looking at the selection, design and whole-of-life cost analyses of surfacing treatments.

A further distress mode is that of shearing where surface stresses from turning or braking exceed the cohesive strength of the binder or the adhesive bond of the binder/aggregate or the seal/base (i.e. in extreme cases, sections of the seal may be peeled off). High shearing forces typically occur where there are significant volumes of turning vehicles such as at roundabouts, turning lanes or intersections. Seals using conventional bitumen do not have a high resistance to shearing forces and alternative seal treatments or asphalt may need to be considered where the circumstances apply.

Distress in sprayed seals may also occur because of deficiencies in underlying base materials.

Figure 4.1: Distress modes for sprayed seals



4.4 Selection Process

4.4.1 Stakeholder Needs

The selection of a treatment type will depend on a number of site-specific parameters relating to the job, and also the need to balance the requirements of all relevant stakeholders. The stakeholders can be broadly divided into three categories:

- road asset managers
- road users
- the community.

The needs of these groups are summarised in Table 4.1.

Table 4.1: Summary of the needs of the principal stakeholder groups in surfacing selection

Considerations	Stakeholders		
	Road asset managers	**Road users**	**The community**
Practicality	• Existing shape and texture • Climate: temperature and rainfall • Treatment availability	• Maintaining access during construction	
Cost	• Initial costs including traffic management • Maintenance under traffic • Replacement costs of markings and delineation	• Delays to road users during construction, maintenance and rehabilitation • Fuel consumption: – rolling resistance • Vehicle depreciation: – wear and tear – windscreen damage	• Minimising damage to goods • Reducing haulage costs

Considerations	Stakeholders		
	Road asset managers	**Road users**	**The community**
Longevity	• Treating existing pavement issues: – surface cracking – texture loss – aggregate polishing – maintain waterproofing • Resist traffic stresses from: – volume, composition & speed – turning/stopping – stresses from vertical and horizontal geometry • Performance of surfacing: – fatigue resistance – resistance to flushing – skid resistance	• Maximising network access • Minimising delays	• Reduce frequency of intervention
Safety associated with construction, maintenance and use	• Accident history and statistics • Site vulnerability for accidents – speed environment – traffic density – site geometry – delineation effectiveness • Skid resistance requirements	• Skid resistance • Visibility: – glare and reflection – conspicuity of delineation – spray generation • Windscreen damage • Traffic management during operations • Drop-off at pavement edges • Pedestrians/cyclists: – conspicuity – surface texture	• Construction workers and adjacent residents: – fumes and dust – traffic management during operations
Environmental	• Legislative responsibility • Recycling potential • Pollution, air, noise and water	• Noise and dust • Aesthetics: – uniformity and colour • Pick-up of bitumen by vehicles or pedestrians	• Adjacent residents: – noise and dust – vibrations • Fumes during construction and use

Source: Austroads (2009a).

4.4.2 Performance Requirements

There are several parameters that require careful assessment in order to be able to select the most suitable seal treatment for a particular situation. These include:

- traffic volume, composition, speed, mass and turning/acceleration/deceleration movements
- existing surface condition (cracking type and severity, texture depth variation)
- performance requirements
  - skid resistance
  - surface texture
  - noise
  - water spray characteristics
  - conspicuity of pavement markings
  - appearance (aesthetics)
- availability of equipment, materials and expertise.

Austroads (2009a) provides advice on the effects of all of these parameters as well as a methodology for assessing sprayed seal, asphalt and concrete surfacings for a particular set of needs. Table 4.2 (from Austroads 2009a) provides an indication of the likely effects of resurfacing existing surfaces using different seal types. It gives a generic description of the effect of surfacing treatments.

The properties referred to in Table 4.2 are for newly placed surfacings after a settling-in period. For example:

- Skid resistance of new surfacings will increase after application when the precoating material has worn or been washed off the aggregate.
- New seals may be tender until they are bedded down, some of the cutter oils evaporated or, for emulsions, until the emulsion has cured.
- Asphalt surfaces may be tender until cooled sufficiently or tightened by the action of traffic.

Table 4.2: Effectiveness of sprayed seal, microsurfacing and combined resurfacing treatments on existing surfacing characteristics

Property requiring improvement	Sprayed seal treatments				Microsurfacing	Combined treatments	
	Surface enrichment	Single application sprayed seal (single/single)	Multiple application sprayed seal	Geotextile reinforced sprayed seal		Correction or regulation course plus SAM	Correction or regulation course plus SAMI with asphalt surface
Bitumen ageing/ oxidation	Delays further oxidation						
Roughness	No effect				Suitable for an uneven surface but has little impact on loss of longitudinal shape	Good	Very good
Waterproofing properties	Minimal	Good	Very good	Excellent	Minor improvement	Excellent	
Skid resistance	Possible short-term reduction	Excellent			Good at low speeds but may reduce at high speeds due to fine texture	Excellent	As for asphalt
Structural strength	No effect					Minimal but depends on thickness of asphalt layers	
Robustness (relating to sharp turning traffic)	No effect	Poor, but improved with modified binders	Some improvement over single coat seals due to interlocking of aggregate		Moderate	More robust if double application used	As for asphalt
Water spray reduction	No effect	May achieve some improvement depending on aggregate size			Minimal effect	Good	As for asphalt
Permeability of surface	Some reduction	Low			Moderate to high	Low	
Flexibility	Very good	Very good			Poor	Good	As for asphalt

Property requiring improvement	**Sprayed seal treatments**				**Microsurfacing**	**Combined treatments**	
	Surface enrichment	**Single application sprayed seal (single/single)**	**Multiple application sprayed seal**	**Geotextile reinforced sprayed seal**		**Correction or regulation course plus SAM**	**Correction or regulation course plus SAMI with asphalt surface**
Shape correction ability	No effect				Suitable for correcting shallow wheelpath ruts with single or multiple layers	Good	Very good
Surface reflection cracking	Little effect	Good[2]		Excellent	Poor	Excellent	
Likely life of treatment[1]	2 to 5 years	5 to 15 years	8 to 15 years	8 to 15 years	5 to 10 years	5 to 10 years	5 to 12 years

1 *Depends on the condition of the existing surface and the structural condition of the pavement.*

2 *The performance of a single/single seal will depend upon the width of the cracks and their extent. Where wide cracks are in the surface then the performance of a single/single seal may be between good and poor.*

Source: Austroads (2009a).

4.4.3 Whole-of-life Costs

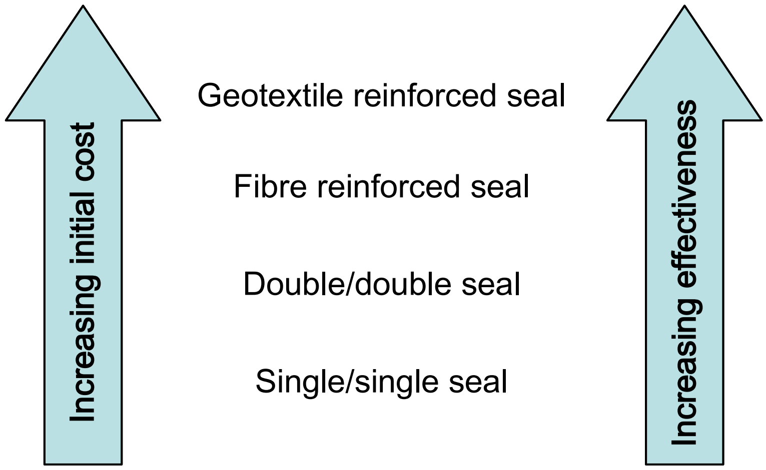
The selection of the best sprayed seal alternative is also influenced by the availability of equipment, materials and expertise as well as the whole-of-life costs.

Whole-of-life-cycle cost analysis (Austroads 2009c) is an economic procedure used by asset managers to compare competing investment options over a certain analysis period and to identify the option that results in the minimum total life-cycle cost (i.e. the optimal option).

To undertake a whole-of-life comparison it is necessary to have an understanding of the performance of the various treatments, their expected lifespan and the intended next treatment. With this information, it will be possible to evaluate the initial construction cost in the context of which treatment will provide the best value for the road agency. This approach must of course be balanced with the need to minimise disruption to road users and provide amenity to adjacent properties.

Figure 4.2 illustrates the general relationship between initial costs and effectiveness for alternative sprayed seal treatments.

Figure 4.2: General relationship between initial costs and effectiveness for alternative sprayed seal treatments



The use of a specialised binder (e.g. PMB, multigrade) will increase the price, which must be considered in relation to its effectiveness in the particular application.

4.5 Selection of Aggregate

Aggregate is the load bearing and wearing component of most sprayed seals. The functions of an aggregate are to:

- spread the wheel loads to the underlying pavement
- improve skid resistance of a road surface
- provide surface drainage during wet weather
- provide a durable abrasion resistant surface that will withstand traffic and weathering
- interlock and impart stability to the treatment
- bond to the bituminous binder.

To fulfil these functions aggregate must be derived from selected sources and have properties as described in AS 2758.2.

4.5.1 Aggregate Properties

The properties required of aggregate may be varied according to the intended type of treatment and traffic conditions. In general, higher quality aggregate is required for heavy traffic conditions (e.g. areas of high stress) and in treatments expected to have a long service life.

The suitability of aggregates may be evaluated by a series of Australian Standard tests (AS 1141: *Methods for Sampling and Testing Aggregates*) or in road agency test methods. Typical limits for these tests for sprayed seals are given in AS 2758.2 and road agency specifications. Information on the use of slag materials is given in Roads and Traffic Authority (1993). Other manufactured materials such as calcined bauxite are often supplied as proprietary materials for specific purposes and specifications vary. Expert advice should be sought on these materials.

4.5.2 Aggregate Size

Nominal aggregate sizes ranging from sand up to 20 mm are used in sprayed seals.

Aggregate sizes up to 14 mm are common in single/single seals; 10 mm and 14 mm aggregate are usually used where there is sufficient traffic volume to warrant the use of large sized aggregates. For lower traffic volume roads and low speed environments, the use of 7 mm aggregate is often sufficient.

Large aggregates such as 16 mm and 20 mm are occasionally used in single/single seals and will feature high binder application rates. They have the following disadvantages:

- high tyre/road noise
- increased risk of damage to vehicles from large, loose aggregate particles on new work
- increased cost.

The primary use of 16 mm and 20 mm aggregates is in combination with a smaller sized aggregate in double/double or single/double seals. It is desirable for aggregate in the second application to be approximately half the average least dimension (ALD) of the aggregate in the first application. Common combinations of aggregate in double/double and single/double seals are:

- 10 mm with a 5 or 7 mm aggregate
- 14 mm with a 5 or 7 mm aggregate
- 16 or 20 mm with a 7 or 10 mm aggregate.

Smaller aggregate sizes such as 5 mm and 7 mm may be used:

- as a second application of a double/double or single/double seal
- as a surfacing treatment for very lightly trafficked pavements, or for pavements where a fine surface texture is required
- as part of a temporary treatment to waterproof and cure the pavement after construction before trafficking, e.g. new construction which will not be opened to traffic for some time
- as part of a scatter coat or racked-in treatment
- for corrective treatments prior to resurfacing.

A guide to the most commonly used sizes is shown in Table 4.3.

Table 4.3: Generally recommended aggregate sizes for sprayed seal treatments

Treatment	Conditions	Common sizes	Comment
Initial seal	To be resealed before opening to traffic	5 or 7 mm	A small-sized aggregate will carry construction traffic at lowest cost and avoid presenting a very coarse texture that may require additional binder when applying the final seal.
	Under traffic	7 mm for firm pavements and low traffic 10 mm, 10/5, 10/7 or 14/7 in other cases	
Prime and sprayed seal	To be resealed before opening to traffic	5 or 7 mm	For low-traffic roads, 7 and 10 mm sprayed seals can provide adequate service at lowest initial cost; 14 mm sizes are initially more expensive but can be cost-effective in some light traffic applications where surface enrichment is used to extend the life of the seal (surface enrichment may be undertaken a number of times).
	Under traffic	10 or 14 mm for low stress environments 14/7 or 20/7 for heavy traffic and high stresses	

<table>
<tr><th>Treatment</th><th>Conditions</th><th>Common sizes</th><th>Comment</th></tr>
<tr><td rowspan="3">Reseal</td><td>Existing seal 7 mm, or asphalt surface</td><td>Generally 7 or 10 mm for low traffic, and 14 mm for high traffic (but reduce to 10 mm if noise is an issue)</td><td rowspan="3">If the existing surface texture is very high or uneven, it may be very difficult to successfully reseal. In such cases a corrective treatment using 5 or 7 mm aggregate, or microsurfacing may provide a more even surface texture which can subsequently be resealed with a larger aggregate size.</td></tr>
<tr><td>Existing seal 10 mm</td><td>7 mm for low traffic or 14 mm for high traffic (see comment)</td></tr>
<tr><td>Existing seal 14 or 16 mm</td><td>7 mm for low traffic or 10 mm for high traffic (see comment)</td></tr>
<tr><td rowspan="3">SAM</td><td>Existing seal 7 mm or an asphalt surface</td><td>Generally 10 mm for low traffic and 14 mm for high traffic (but reduce to 10 mm or use double/double seal if noise is an issue)</td><td rowspan="3">If the existing surface texture is very high or uneven, it may be very difficult to successfully reseal. In such cases a corrective treatment using 5 or 7 mm aggregate, or microsurfacing may provide a more even surface texture which can subsequently be resealed with a larger aggregate size.
Generally, a SAM seal requires 1.5 L/m^2 of PMB to resist reflection cracking. The aggregate size may need to be selected to accommodate this rate or accept that a reduced life may result if a lower rate is used.</td></tr>
<tr><td>Existing seal 10 mm</td><td>10 mm for low traffic or 14 mm for high traffic (see comment)</td></tr>
<tr><td>Existing seal 14 mm</td><td>10 mm for low traffic or 14 mm for high traffic (see comment)</td></tr>
<tr><td>SAMI</td><td>Interlayer beneath asphalt</td><td>Generally 10 mm</td><td>Generally, a SAMI seal requires 1.8 to 2.2 L/m^2 of PMB to resist reflection cracking. Risk of flushing of a 10 mm seal at such application rates is minimal where the seal is only trafficked for a short period before applying asphalt.</td></tr>
<tr><td rowspan="2">GRS</td><td>To remain as a sprayed seal surface</td><td>Generally 14/7 mm</td><td rowspan="2">Double application geotextile reinforced sprayed seals using PMB or Class 170 binder are preferred for most GRS applications.
If the existing surface on which a single application geotextile sprayed seal is placed is coarse (e.g. surface texture higher than 1.5 mm), a 7 mm sprayed seal may first be used to lower the texture and reduce the risk of premature stripping.</td></tr>
<tr><td>To be surfaced with asphalt</td><td>Generally 10 mm</td></tr>
<tr><td rowspan="4">Special seals</td><td>Floodways/areas subject to inundation</td><td colspan="2">A heavy robust surfacing is required. Generally this involves a double application seal using combinations of 20 mm or 16 mm with 10 or 7 mm aggregate, or 14 mm with 7 mm aggregate.</td></tr>
<tr><td>Flushed areas</td><td colspan="2">If single application seals or corrective treatments are considered unsuitable, then an effective alternative can be a double application seal using 20 mm with 10 or 7 mm aggregate or an inverted seal.</td></tr>
<tr><td>Shoulders on highways and freeways</td><td colspan="2">Whilst small size aggregate seals can be used, generally the greatest durability is obtained with double/double seals using a combination of 14 mm with 7 mm (or 20 mm with 10 mm aggregate where a heavier treatment is required).</td></tr>
<tr><td>Arid country</td><td colspan="2">Consider a double application seal where the role of the top seal coat is to protect the binder in the bottom coat from deterioration/contamination from dust.
Consider a single/single seal with an aggregate spread rate 5% less than the design spread rate to provide coverage of binder with aggregate.</td></tr>
</table>

4.6 Binders

Binder types used in sprayed seals include:

- conventional bitumen
- multigrade bitumen
- cutback bitumen
- bitumen emulsion
- foamed bitumen
- polymer modified binders
  - elastomeric polymer types
  - crumb rubber
- specialty binders (e.g. bitumen extended epoxy, polyurethane, acrylic).

A detailed guide to binder materials is provided in the *Guide to Pavement Technology Part 4F: Bituminous Binders* (Austroads 2017).

4.6.1 Conventional Bitumen

Bitumen is a viscous product obtained from the refining of crude oil. Bitumen is temperature sensitive, i.e. the material is fluid when heated allowing it to be pumped and sprayed. When cold, it is a plastic solid providing sufficient stiffness to retain aggregate and resist the forces of traffic. Flow or deformation properties are important when considering selection and application.

Other key characteristics of bitumen include:

- adheres strongly to most materials
- water resistant
- flexible and ductile
- durable
- low toxicity
- low cost.

This combination of properties makes bitumen an effective binder for sprayed seals.

Bitumen is generally supplied and applied at elevated temperatures, as this is usually the most economic form of binder delivery system. The technology involved is well developed, widely understood and supported by industry investment in equipment and other resources. Bitumen can also be applied as a bitumen emulsion or foamed bitumen, and these delivery systems have certain advantages and disadvantages compared to conventional bitumen delivery systems at more elevated temperatures.

Classification and properties of bitumen

The properties of bitumen for roadmaking are specified in AS 2008: *Residual Bitumen for Pavements*. This Australian Standard classifies and specifies the properties of conventional pavement-grade bitumens most widely used in Australia.

The following classes are most commonly used in sprayed sealing works in Australia:

- Class 170: the most commonly used class for sprayed sealing
- Class 240: higher viscosity binder (compared to C170) used by some road agencies in warm climates
- Class 320: higher viscosity binder (compared to C170 and C240) sometimes used for sprayed sealing in areas where pavement temperatures or traffic stresses were high, but has been largely superseded by PMBs and multigrade bitumen.

In New Zealand, the sealing grade bitumens are characterised by penetration grade and consist of:

- 180/200 penetration: generally used in sprayed seal work (the approximate equivalent of Class 50 bitumen which was a softer class of bitumen than Class 170 used in Australia in the past)
- 130/150 penetration: a slightly harder grade used as an alternative to 180/200 (approximate viscosity between that of Class 50 and Class 170 bitumen)
- 80/100 penetration: generally only used in sprayed seals in hotter areas or when resealing fatty or bleeding seals (the approximate equivalent of Class 170 bitumen).

4.6.2 Multigrade Bitumen

Multigrade bitumen is manufactured from the same sources as conventional bitumen but requires processing to reduce temperature susceptibility. This provides some of the advantages of increased binder stiffness at higher temperatures while retaining satisfactory low-temperature characteristics. Although initially introduced for use in asphalt, a multigrade binder has been developed for sprayed seal work (designated as M500) to provide an improvement in aggregate retention at higher pavement temperatures. The properties of multigrade bitumen are specified in AS 2008.

Multigrade bitumen is treated as a conventional bitumen (Class 170 or Class 320) in the design procedures.

Multigrade may be used for high-stress seals and in place of conventional bitumens in high-temperature areas.

4.6.3 Polymer Modified Binder (PMB)

PMB consists of bitumen blended with a synthetic polymer or crumb rubber. PMBs are used to enhance the performance of binders on heavily trafficked or distressed pavement surfaces, often in adverse climatic conditions. Property improvements include reduced temperature susceptibility, increased elasticity or resilience, increased cohesion and improved tenacity once a bond has been established. In terms of sprayed sealing, performance improvements include lower risk of bleeding, improved crack resistance, better aggregate retention and less deformation at high temperatures. These improvements are the basis of the use of PMBs in strain alleviating membranes (SAMs), strain alleviating membrane interlayers (SAMIs) and high-stress seals (HSSs).

Polymer groups are coded as follows:

- **E** for elastomeric polymers including styrene-butadiene-styrene (SBS), styrene-butadiene rubber (SBR) and polybutadiene (PBD). Binders modified with elastomeric polymer have improved resilience or elasticity, are less temperature susceptible, and are widely used as HSSs, SAMs and SAMIs.
- **P** for plastomeric polymers including ethylene vinyl acetate (EVA), ethylene methacrylate (EMA), atactic polypropylene (APP), and polypropylene (PE). Binders modified with plastomeric polymer have increased stiffness and are may be used in HSSs.
- **R** for crumb rubber materials. Crumb rubber is generally obtained from shredding and grinding of scrap rubber from vehicle tyres. When blended with bitumen the rubber behaves as a form of elastomer and is used in HSSs, SAMs and SAMIs.

More information on various types of PMBs is provided in the *Guide to Pavement Technology Part 4F: Bituminous Binders* (Austroads 2017). The properties of PMBs are specified in Austroads (2014c).

4.6.4 Bitumen Emulsion

Bitumen emulsions are usually two-phase systems consisting of two immiscible liquids, bitumen and water. The bitumen phase can be dispersed in the aqueous phase by mechanically shearing it in a colloid mill. The dispersion of bitumen particles is held in suspension in water by a chemical emulsifier which usually imparts an electrical charge so that the resulting electrostatic forces prevent the globules from readily coalescing. That is, like charges on each dispersed bitumen particle repel and prevent the particles from coalescing and settling from the suspension.

Emulsions can be used for almost any purpose for which conventional bitumens, polymer modified binders and cutback bitumens are used, and are suited to a number of other applications where the use of cutbacks is not appropriate.

The types and grades of bitumen emulsions are given in AS 1160. Proprietary emulsion binders with improved properties are also available. Several factors will influence the selection of the type and grade of emulsion as described in Austroads (2017).

4.6.5 Effect of Spraying Conditions and Delivery System on Binder Selection

Bitumen is normally a plastic solid at ambient temperatures. To enable application as a sprayed seal it is liquefied by heating, cutting back or emulsification. The viscosity of the binder varies with the binder type, delivery system and ambient conditions. Two of the parameters to be considered in choosing a binder delivery system are the likely pavement temperature at the time of spraying and the maximum gradient of the surface being sealed. Guidance on practical limits for these variables is provided in Table 4.4 and Table 4.5.

The minimum temperatures in Table 4.4 do not apply to SAMI seals, as is it recommended that little to no cutter is used even at low temperatures due to the potential to detrimentally effect to the properties of the overlaying asphalt. Cold weather trafficking of the SAMI seal should be avoided, due to the risk of stripping from poor adhesion between the heavily modified binder and aggregate. Once overlying asphalt is laid, heat from the mix will activate the SAMI allowing the binder and aggregate to bond.

Table 4.4: Recommended pavement temperatures for various binders

Binder type	Minimum pavement temperature (°C)	
	with cutter oil	without cutter oil
Hot bitumen	15	35
Polymer modified binder(1)	20	45(2)
Crumb rubber bitumen	20	45(2)
Bitumen emulsion	–	5

1 *Does not apply to SAMI seals.*

2 *This will vary by binder type and could be as high as 65 °C in some cases.*

Table 4.5: Recommended maximum permissible gradients for various binders

Binder type	Maximum gradient (%)[1]
Hot bitumen	12
Hot cutback bitumen	10
Polymer modified binder	> 12[2]
Bitumen emulsion	8[3]
Multigrade (M500)	12

1 *The gradient will also depend to some extent on the existing surface texture and surface temperatures.*

2 *Depends on the PMB type and concentration.*

3 *Depends on the percentage of residual bitumen content, with higher residual bitumen content or polymer modified emulsions preferred for steeper grades.*

4.7 Selecting a Prime

The application of a prime and secondary treatment is the preferred option for sealing a basecourse, presenting lower risk and longer potential life span than the direct application of an initial seal.

It is typical practice to prime all newly constructed granular and stabilised/modified pavements prepared for sprayed seal or asphalt surfacings. For asphalt pavements, although desirable, a prime is not always necessary where the total thickness of asphalt is in excess of 100 mm.

It is not always possible (due to traffic management constraints) to divert traffic around the area of pavement under construction while the prime cures. In such instances an initial seal may be used as the initial treatment instead of a prime. Where an initial seal is being considered in place of a prime and secondary treatment, the risks and consequences of a failure should be taken into account particularly on roads with high volumes of traffic.

Concrete pavements and timber surfaces such as bridge decks should also be primed to assist and provide an adequate bond between the pavement surface and sprayed seal or asphalt treatment. This applies in particular to conditions where a strain alleviating membrane interlayer (SAMI) is to be applied over a concrete or stabilised surfacing prior to placing an asphalt overlay.

Priming is most effective during warm and dry conditions. Care should be exercised when undertaking priming during cooler and damp conditions. Low temperatures may extend curing time while damp conditions can prevent penetration of the primer into the base and increase potential for run-off of the uncured primer. Primer washed off the pavement during this curing stage can cause pollution of waterways and environmental hazards (EPA Victoria 2002).

4.8 Selecting an Initial Seal

Table 4.6 is a preliminary guide to selecting initial seals, based on traffic, equivalent heavy vehicles (EHV(%)), and climatic conditions. Specialist advice should be sought to manage variations based on local experience.

Further guidance for the selection of an appropriate binder and aggregate size is provided in Section 4.8.1 and Section 4.8.2 respectively.

Consideration should be given to the average seasonal temperature that the pavement will be subjected to during the day of sealing, and the following weeks.

Table 4.6: Preliminary guide to the selection of initial seals

EHV(%)	Average seasonal temperature	Low traffic (<-200 v/l/d)[3]	Medium traffic (200–2000 v/l/d)[3]	High traffic (> 2000 v/l/d)
		Typical binder[5] and seal type		
Low (< 25%)	Cool[4]	AMC4 (S/S) CRS67 (S/S) CRS60 (D/D)	AMC5 (S/S) CRS67 (D/D)	AMC6 (S/S, D/D) CRS67 (D/D) Modified emulsion (D/D)
	Warm	AMC5 (S/S) CRS67 (S/S)	AMC6 (S/S) CRS67 (D/D)	AMC7 (S/S, D/D) CRS67 (D/D) Modified Emulsion (D/D) PMB[1][2] (S/S, D/D)
	Hot	AMC6 (S/S)	AMC7 (S/S)	AMC7 (S/S) PMB[1][2] (S/S, D/D)
High (≥ 25%)	Cool[4]	AMC5 (S/S) CRS67 (S/S, D/D)	AMC6 (S/S) PMB[1][2] (S/S, D/D) CRS67 (D/D)	CRS67 (D/D) Modified emulsion (D/D)
	Warm	AMC6 (S/S) CRS67 (S/S)	AMC7 (S/S) PMB[1][2] (S/S, D/D) Modified Emulsion (D/D)	AMC7 (S/S) PMB[1][2] (D/D) Modified emulsion (D/D)
	Hot	AMC7 (S/S)	AMC7 (S/S) PMB[1][2] (S/S, D/D)	AMC7 (S/S) PMB[1][2] (D/D)

1 *Guidance to field application of PMBs for sprayed seals (including cutting practice) is provided in Appendix E.*

2 *Care must be taken when using PMBs (especially SBS) because it is difficult to achieve sufficient adhesion to the base and aggregate wetting. To date successful trials have been undertaken only with crumb rubber binders (Austroads 2014a), and as yet other binders are unproven in this application, pending further trials.*

3 *When low or medium traffic is coupled with high-stress situations such as intersections, turning lanes, and grades, consider following guidance for the 'high traffic' category instead.*

4 *As sealing in cool and damp conditions increases the risk of seal failure, consideration should be given to postponing works if possible until weather conditions have improved.*

5 *Cutback bitumen grades nominated in the table are based on typical pavement materials used in Australia. Adjustment to the proportion of cutter oil content may be required for very porous (less cutter oil) or tightly bonded (more cutter oil) pavement surfaces. For tightly bonded surfaces (including stabilised pavements), pavement surface preparation is essential to achieving an adequate bond, particularly when emulsions, low cutter content cutback bitumen and PMB grades are used.*

4.8.1 Binder Type

The binder types listed in Table 4.6 can be considered as typical for those applications, however other binder types can be used.

The choice of binder is mainly influenced by the prevailing weather conditions, as well as the desired life of the treatment, and timing and type of final treatment.

The requirements for AMC cutback bitumen grades are provided in AS 2157. Equivalent field-blended grades may also be used.

Bitumen emulsions may be considered when a secondary surfacing is to be applied before adequate curing of a cutback bitumen binder can occur. The requirements for bitumen emulsion grades are provided in AS 1160.

Where a pavement stabilised with cementitious or chemical binder is to be initial sealed using a bitumen emulsion, a check on the compatibility of the emulsion with the stabilised material should be undertaken. Emulsions will always be compatible with bitumen stabilised pavements.

Binders for very heavy traffic and/or warm to hot conditions include proprietary grades of polymer modified binder, polymer modified emulsion, cutback bitumen manufactured with Class 320 base bitumen in place of Class 170, and cutback bitumen with low proportions of cutter oil. These binders provide for more rapid curing and reduced risk of bleeding in more demanding performance applications.

4.8.2 Aggregate Size

The choice of aggregate size depends on traffic, life expectancy and climatic conditions.

For single/single initial seals, 7 and 10 mm aggregates are appropriate for low-traffic applications, and can be used successfully for higher-traffic applications in the absence of conditions such as high-stress traffic movements, extreme heat, or predominantly wet conditions.

The 14 mm aggregates are not recommended for single/single initial seals. There is an increased risk of unsatisfactory performance with this type of treatment, and it should only be used when there are special requirements that demand it. It is not recommended for high-traffic applications. A binder with adequately high viscosity will be necessary to allow the binder to successfully retain the aggregate, but it is unlikely to have adequate bonding with the base.

Double/double initial seals, or single/single initial seals incorporating a scatter coat, are useful for high-traffic, high-stress sites. Various aggregate sizes can be used for double/double seals, with 10/5, 10/7 and 14/7 mm combinations being common choices.

4.9 Selecting Speciality Treatments

4.9.1 Variable Binder Spray Rates

Sealing with a variable rate spray bar could be considered in the following situations:

- where there is a significantly different surface texture across the lane (e.g. where the difference in texture allowance is ≥ 0.3 L/m² between the wheelpath and non-wheelpath areas), and/or
- where there is a high percentage of equivalent heavy vehicles (EHV(%)) and/or a high annual average daily traffic (AADT)
  - This can sometimes result in a uniform spray rate across the road which is too low to avert stripping in untrafficked areas (i.e. around the centreline, between wheelpaths and on shoulders) and yet too high to avert flushing in the wheelpaths.

The underlying principle of variable rate seal design is to:

- design for the wheel paths
- increase the spray rate for the non-wheelpath areas to account for the higher risk of stripping in these areas.

When determining the spray rates to be adopted, the limitations of the variable rate sprayer to be used must be considered.

Due to the reduced binder application rate in low-spray areas, sufficient time under traffic at higher temperatures is required to ensure adhesion of the aggregate before the onset of cold weather. Therefore, it is highly desirable for any variable-rate seal to be subjected to at least one month of hot/warm weather under traffic. Variable-rate seals are not typically used when the expected daily minimum air temperatures are less than 10 °C within one month after completion of the works.

4.9.2 Geotextiles

Geotextiles may be used to reinforce sprayed seals for improved waterproofing over cracked or weak pavements. *Geotextiles Reinforced Seals* (Austroads 2005b) contains detailed information on these and other uses of geotextiles and the range of materials available.

The material preferred for reinforcement of sprayed seals is a non-woven needle punched polyester geotextile. The standard geotextile grade has a mass of 130–140 g/m^2 with a heavier grade (175–200 g/m^2) material adopted for severely cracked, heavily trafficked pavements where additional waterproofing is needed.

This type of material has been used in sprayed seals over cracked bituminous wearing courses, cement stabilised bases with shrinkage cracks, and on lightly trafficked roads with basecourses made of heavy clays with plasticity indices of 30 to 35. Table 6.6 presents the properties required of a geotextile for use in sprayed sealing.

4.10 Selecting a Sprayed Seal

Table 4.7 is a preliminary guide to select an appropriate seal, and specialist advice should be sought to manage variations based on local experience.

Table 4.7: Preliminary guide to seal selection

<table>
<tr><th></th><th>Design traffic (v/l/d)</th><th colspan="4">≤ 200</th><th colspan="4">201–750</th><th colspan="4">751–2000</th><th colspan="4">2001–5000</th><th colspan="4">> 5000</th></tr>
<tr><th></th><th>Equivalent heavy vehicles (%)</th><th>< 15</th><th>15–26</th><th>26–45</th><th>> 45</th><th>< 15</th><th>15–26</th><th>26–45</th><th>> 45</th><th>< 15</th><th>15–26</th><th>26–45</th><th>> 45</th><th>< 15</th><th>15–26</th><th>26–45</th><th>> 45</th><th>< 15</th><th>15–26</th><th>26–45</th><th>> 45</th></tr>
<tr><td rowspan="3">Rural: roads, highways and freeways – no high stress areas</td><td>Temperature* – High</td><td colspan="3">S/S</td><td>D/D
HSS1</td><td colspan="2">S/S</td><td colspan="4">D/D
HSS1</td><td colspan="5">HSS2</td><td colspan="4">XSS</td><td>XSS^</td></tr>
<tr><td>Medium</td><td colspan="3">S/S</td><td>D/D
HSS1</td><td colspan="3">S/S</td><td>D/D
HSS1</td><td>S/S</td><td colspan="2">D/D
HSS1</td><td colspan="6">HSS2</td><td colspan="3">XSS</td></tr>
<tr><td>Low</td><td colspan="10">S/S</td><td colspan="4">D/D
HSS1</td><td colspan="5">HSS2</td><td>XSS</td></tr>
<tr><td rowspan="3">High stress locations</td><td>Small radius curves, roundabouts, driveways, turning lanes, intersections</td><td colspan="3">D/D</td><td>HSS2</td><td colspan="2">D/D</td><td>HSS2</td><td>XSS</td><td colspan="3">HSS2</td><td colspan="3">XSS</td><td colspan="6">NO SEAL SUITABLE^</td></tr>
<tr><td>Grades# > 5%</td><td colspan="2">S/S</td><td colspan="5">D/D
HSS1</td><td colspan="4">HSS2</td><td colspan="8">XSS</td><td>XSS^</td></tr>
<tr><td>Cracked pavements</td><td colspan="20">• SAM – preferred SAM is an S/S (14 or 10 mm) but a D/D may be required where there are also high-stress conditions. Slow rate of movement cracking – environmental (S10E, S15E, S35E, S45R, S15RF). Rapid rate of movement – traffic induced (S15E, S20E, S45R, S15RF).
• Minimum binder rate for SAM application is 1.5 L/m².
• GRS – C170 with D/D is the preferred type of GRS (14/7 mm).</td></tr>
</table>

S/S	Single/single with C170 or C240. C320 or M500 binder may be appropriate for hot climates.
D/D	Double/double with C170 or C240. C320 or M500 binder may be appropriate for hot climates.
HSS1	Single/single seal with PMB for moderately severe sites (S10E, S35E, S45R or S15RF) and severe sites (S15E, S20E, S45R or S15RF)
HSS2	Double/double seal with PMB in first or both applications for medium traffic loading (S10E, S35E, S45R or S15RF) and heavy traffic loading (S15E, S20E, S45R or S15RF)
XSS	Double/double seal with PMB in both applications (S20E, S45R or S15RF) for high-stress areas. Seal performance may be inadequate under these conditions and may require alternative treatments
	Generally dense graded asphalt size 10 or 14 mm, where an XSS sprayed seal cannot be expected to cope

** Temperature categories are determined as per Appendix D.*

^ Seal performance may be inadequate under these conditions and may require alternative treatments.

 # Considerably steeper grades or combinations of extreme events may lead to unsatisfactory performance and may require alternative treatments.

5. Design Method

5.1 Principles

The design philosophy adopted applies principally to the design of single/single sprayed seal using conventional bitumen as the binder. Designs of other seal types are based on the design procedure for single/single seals, with appropriate amendments in the procedure, and additional information as required.

Assumptions used in the design of single/single seals are:

- aggregate is single-sized and of appropriate quality
- average least dimension (ALD) of the aggregate is an important input into the design method and must be representative of the aggregate being used
- design traffic volume is expressed in vehicles/lane/day (v/l/d) and based on average annual daily traffic (AADT)
- aggregate is spread in a uniform layer of one stone thickness, with particles in continuous, partly interlocked contact and the least dimension near vertical
- there is no separate allowance to be made for whip-off in the design aggregate spread rate
- aggregate spread rate determines the inter-aggregate void space in the seal layer, and hence the amount of binder required; failure to achieve, within practical limits, the design aggregate spread rate will result in the design binder application rate being incorrect
- a single layer of aggregate particles settles with, typically, 40–60% voids after orientation and packing of the aggregate by rolling and trafficking
- binder rise should be a minimum of about 35–40% up the height of the aggregate particle after initial rolling and trafficking, increasing to between 50–65% (i.e., 1/2–2/3) about two years after construction
- aggregate particles may penetrate (embed) into the base
- reseals interlock with the existing surfacing
- binder may be absorbed into the base and, sometimes, by the aggregate
- the proportion of voids to be filled with binder may be varied to optimise requirements such as surface texture, maximum seal life, and for specific applications such as non-traffic areas; a minimum texture is generally required for skid resistance
- preliminary treatments such as primes and initial seals have been correctly designed and applied; if this has not been achieved, remedial work should be undertaken prior to, and well in advance of, the commencement of sealing
- all application rates determined by this method are expressed in L/m^2 of residual binder at the standard reference temperature of 15 °C.

Sprayed seals are a system and sealing trials and subsequent work have shown that the design of the rates of application of binder and aggregate spread rates are both of major importance in achieving a satisfactory performance for the service conditions.

5.2 Design Traffic

The traffic volume and type have a major impact on the outcome of a seal design, and therefore appropriate and accurate traffic volumes are an essential requirement for the determination of the rates of application of binder.

For seal design, a best estimate of the traffic using each lane is required. A separate sprayed seal design is required for each lane of traffic having either a different traffic volume (v/l/d) and/or different proportion of heavy vehicles. The traffic determined for the lane to be sealed is termed the design traffic.

Design traffic, when determined from AADT, must take into account the following:

- the number of carriageways (generally single or dual)
- the direction of traffic (one-way or two-way)
- number of lanes
- percentage of the total traffic travelling in each lane
- the number of heavy vehicles travelling in each lane.

The design traffic includes all light and heavy vehicles that travel in that lane, as per Equation 1:

$$\text{Design traffic} = \text{Light vehicles} + SHV + LHV \qquad (1)$$

where

Light vehicles	=	number of light vehicles in the traffic mix (i.e. Austroads vehicle Classes 1 and 2)
SHV	=	number of standard heavy vehicles in the traffic mix (i.e. Austroads vehicle Classes 3 to 9)
LHV	=	number of large heavy vehicles in the traffic mix (i.e. Austroads vehicle Classes 10 and above)

For the purpose of this design method, where general references are made to typical traffic volumes, the following descriptions apply:

- very low: ≤ 200 v/l/d
- low: 201–750 v/l/d
- medium: 751–2000 v/l/d
- high: > 2000 v/l/d.

5.2.1 Traffic Data

Traffic data is generally provided as the total traffic volume on the road in both directions, and not for individual lanes, shoulders etc. Traffic volume may be given as:

- AADT, which is the most common method used by road agencies, being the total volume of traffic passing a roadside observation point over the period of a calendar year, divided by the number of days in that year (365 or 366 days). The percentage of commercial vehicles within the total volume of traffic is also reported, and can be further broken down into different heavy vehicle types as per the Austroads vehicle classification system.
- a 12-hour or 24-hour count at a particular date or time. Road agencies can generally provide factors to convert the 12 and 24-hour counts to AADT. For example, on medium to low traffic roads, a factor of the order of 1.25 to 1.30 is typically used to convert 12-hour counts to AADT. For a freeway or other very busy urban road, with a large percentage of traffic travelling at night, the factor is generally 1.45 to 1.50, and can be as high as 2.0 in some instances.
- v/l/d, generally on multiple-lane urban and rural roads where the traffic count is taken for individual lanes.

As this sprayed seal design method uses v/l/d as its basis, traffic data provided in other formats should be converted to this.

5.2.2 Accuracy of Data

The traffic data used for sprayed seal designs should be as current as possible.

It is important to use a traffic count taken as close as possible to the location of the proposed sealing work. This particularly applies to rural roads connecting townships where the traffic counts are often taken at or near the town limits where the traffic volume is higher than elsewhere on the road. If traffic volumes provided are considered not representative, a traffic count should be determined for the site using automatic or manual traffic counts.

When the total count is considered representative, but the traffic distribution is uncertain, a site investigation should be conducted to provide a reliable estimate of traffic distribution for each lane. For example, this may be the case where heavy traffic does not travel predominantly in the left-hand lane as commonly accepted/observed due to interference from turning traffic, stop/start traffic, parking lanes etc., such as on roads through urban areas, rural towns and tourist areas.

5.2.3 Distribution of Traffic

Multi-lane roads

On multi-lane roads, the distribution of vehicles over the available lanes must be determined. Procedures for this are described in Section 5.2.4.

Heavy vehicles

The traffic volumes used throughout the seal design procedures are based on the general mix of light and heavy vehicles, with the heavy vehicle proportion assumed to be between 5 and 10% of the total. It is important to determine the actual percentage of heavy vehicles.

In some locations, the proportion of heavy vehicles in each lane may not be uniform or may not be equal in both directions because of restrictions, specified routes, specified lanes such as bus lanes, overtaking/climbing lanes, or roads with a third lane in the centre used as passing lanes by traffic in both directions.

On multi-lane roads, the percentage of heavy vehicles should be calculated separately for each lane, based on the mix of light and heavy vehicles estimated to use each lane. Worked examples have been included in Appendix C. Adopting an overall or average heavy vehicle percentage across all lanes given as part of AADT (e.g. 28%) will often result in an incorrect design traffic and/or traffic adjustment being applied.

Design consideration should be given to whether the heavy vehicles are evenly loaded/unloaded in both directions, or predominantly travel loaded/empty in one direction only. This is particularly important where for example the road may be an access to an industrial estate, a quarry access road, or a road connecting major industrial centres. Specialist advice should be sought for these situations.

5.2.4 Procedure for Determining Design Traffic

Single carriageway – two-way traffic

A single carriageway is the most common sealed road pavement in rural areas and traffic needs only to be apportioned to each lane. The width of sealed pavement influences the traffic pattern. Assuming that traffic is equal in both directions, Table 5.1 provides a guide to estimating the design traffic.

Table 5.1: Estimation of design traffic from AADT for single carriageways

Width of seal	Estimated design traffic (v/l/d)	Comment	
3.7–5.6 m	AADT	Seal width is considered too narrow for 2 lanes	
> 5.6 m	½ × AADT	Traffic is considered to predominantly travel in distinct lanes on seals of this width, especially if the centre line and/or lanes are line marked	
Sealed shoulders, parking lanes, identified by edge line marking to be separate from the traffic lanes	Adopt < 100 (minimum voids factor)	If not line marked, or on winding alignments, some of the traffic may wander onto the shoulder and < 100 v/l/d may not be appropriate. If in doubt, a traffic count should be conducted, or adopt the design traffic volume from the adjacent lane	
Overtaking lanes (in one direction)	60–80% of ½ × AADT	Determine % HV for each lane as a proportion of the total traffic volume in that lane	If in doubt, arrange a traffic count for each lane
Left-hand lane (3.7 m)			
Right-hand lane (3.7 m)	20–40% of ½ × AADT		
Single lane in opposite direction	½ × AADT	%HV same as in AADT	
On and off ramps on freeways or urban road systems	Traffic volumes (AADT) before and past the ramp may provide a good indication of AADT on the ramp. Otherwise, arrange a traffic count. Traffic volume on the road connected to the ramp may also provide additional useful information to determine AADT on the ramp		
Service roads to major roads	For one-way traffic, the design traffic is equal to the AADT For two-way traffic, use ½ AADT	AADT refers to traffic using the service road only. If not available, arrange a traffic count	

Dual carriageway – one-way traffic

AADT is usually defined as the total traffic carried by both carriageways, but this should be confirmed. Where this is the case, the first step is to determine the traffic on each carriageway, and this is generally assumed to be ½ AADT.

For heavily trafficked roads, with more than two lanes in each direction, an actual traffic count may be available for each lane and this should be the traffic volume used in the design.

For rural freeways and highways, or duplicated roads into rural townships (classed as urban-type locations) with medium to high traffic volumes, Table 5.2 provides a guide to estimating the design traffic from AADT.

Generally, the heavy vehicles travel in the left-hand lanes on multi-lane carriageways, occasionally using the climbing/passing lanes provided that the additional lane is of sufficient length to allow the heavy vehicles to change lanes without undue interference.

Table 5.2: Estimation of design traffic from AADT for dual carriageways

Lane (assumed 3.7 m wide)	Estimated design traffic (v/l/d)	Comments	
Multi-lane, heavily trafficked	½ AADT divided by the number of lanes in the carriageway or ½ AADT x % traffic in each lane	These roads are usually in urban areas or linking major centres. Traffic volume is often > 2000 v/l/d in all lanes but the % heavy vehicles may vary between lanes	
Two- lane carriageway:			Each carriageway = ½ AADT
left-hand (outer) lane	60 to 80% of ½ AADT	Generally 60% for urban/80% for rural	
right-hand (inner) lane	40 to 20% of ½ AADT	Generally 40% for urban/ 20% for rural	

Lane (assumed 3.7 m wide)	Estimated design traffic (v/l/d)	Comments
Sealed shoulders, parking lanes identified by edge line marking to be separate from the traffic lanes	Adopt < 100	On some busy roads, trucks may tend to travel partially on the shoulder, and this must be taken into account. A traffic count should be conducted, and/or traffic pattern determined
Where two lanes merge into one (at end of a duplicated section)	½ AADT	Merged traffic is ½ AADT, but design of binder application rates and layout of sprayer runs within the merge area require particular care
Overtaking lanes		
Off and on ramps	% of ½ x AADT	If actual traffic counts are not available for ramps, traffic on the side road, before and past the ramp, may provide an indication of the traffic volume using the ramp

5.2.5 Equivalent Heavy Vehicle (EHV(%))

The EHV(%) concept was developed to cater for the effects on sprayed seals of new types of heavy vehicles introduced in the last decade.

Heavy vehicles have a significant effect on aggregate packing and the performance of sprayed seals. The effect is exacerbated for very large heavy vehicles (LHV), i.e. Class 10 onwards which includes B-doubles, double and triple road trains (Holtrop 2008). EHV(%) accounts for the large influence of the LHV portion of the traffic account on the performance of sprayed seals.

The EHV(%) is calculated in the seal design method using Equation 2. Austroads vehicle classes are provided in Appendix B:

$$EHV(\%) = SHV(\%) + (LHV(\%) \times 3) \tag{2}$$

where

SHV(%) = percentage of standard heavy vehicles in the traffic mix (i.e. Austroads vehicle Classes 3 to 9)

LHV(%) = percentage of large heavy vehicles in the traffic mix (i.e. Austroads vehicle Classes 10 and above)

The value of EHV(%) calculated by this procedure is used solely for the determination of adjustments to the basic voids factor for the effects of traffic (Table 6.2) and does not alter the design traffic volume.

Designers must apply caution when designing binder application rates for seals used by these large heavy vehicles. They should monitor and compare their design against actual seal performance to provide additional information in order to be able to make appropriate additional amendments for traffic adjustments in future designs. Refer to Appendix C for some worked examples on converting heavy vehicle traffic counts to EHV(%).

5.2.6 Short-term Traffic Variations

Short-term traffic variations may occur as a result of a range of factors including:

- seasonal variation on roads in tourist areas
- school holidays

- grain harvests
- events (e.g. local show days, race days)
- staging of construction or rehabilitation work.

Designers need to be aware of the impact of undertaking sprayed seal work at a time when the traffic conditions vary from that applicable to normal use. Where possible, the impact of short-term variation should be minimised by avoiding undertaking work during, or shortly before, abnormal events. Generally, the traffic volume used in seal design should be that estimated to apply at the time, or within the first few months, of sealing. The influence of anticipated weather conditions coinciding with the expected higher traffic volumes should also be considered in determining design application rates.

It is suggested that a design is carried out for both traffic conditions (normal and short term), and final design rates of application determined taking into account risk factors such as potential loss of aggregate (low binder rates) and potential flushing (high binder rates).

5.2.7 Access Roads to Sites such as Quarries and Mining Locations

Traffic in these locations often consists predominantly of SHV and LHV with only a few light vehicles and cars. In such circumstances, the determination of an appropriate traffic volume for selection of the basic voids factor at the start of the design process can be difficult.

Adjustments to binder application design rates for proportions of equivalent heavy vehicles greater than 15% and up to 65% of total traffic are provided in Table 6.2 for single/single seals. Where the proportion of equivalent heavy vehicles is greater than 65%, the following procedure may be used for selection of an alternative basic voids factor.

The procedure is based on the assumption that the basic voids factors shown in Figure 6.1 and Figure 6.2 have been developed around a mixture of light and heavy vehicles, where the proportion of heavy vehicles (including SHV and LHV) is typically around 10% of the total. In order to use the same procedure when EHV(%) exceeds 65%, it is appropriate to determine a nominal design traffic volume that adequately accounts for the influence of the high proportion of heavy vehicles.

The nominal design traffic for access roads is determined by Equation 3:

$$\text{Nominal design traffic volume for access roads} = (\text{SHV} + \text{LHV} \times 3) \times 10 + \text{volume of light vehicles} \qquad 3$$

where

SHV	=	number of standard heavy vehicles in the traffic mix (i.e. Austroads vehicle Classes 3 to 9)
LHV	=	number of large heavy vehicles in the traffic mix (i.e. Austroads vehicle Classes 10 and above)
Volume of light vehicles	=	number of light vehicles in the traffic mix (i.e. Austroads vehicle Classes 1 and 2)

The procedure is as follows:

1. Determine number of SHV, LHV and light vehicles.
2. Calculate Equation 3 to determine a nominal design traffic volume.
3. Select a basic voids factor based on this nominal traffic volume.

When using this procedure, adjustment to the basic voids factor from traffic effects should be applied using the 0 to 15 EHV(%) category of Table 6.2, which accounts for channelised traffic and slow-moving vehicles.

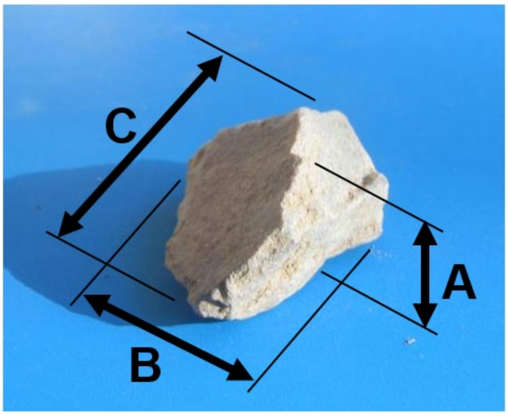
5.3 Aggregate Size and Shape

5.3.1 Average Least Dimension (ALD)

The concept of an aggregate particle tending to lie with its least dimension vertical is central to the volumetric design of a sprayed seal.

The least dimension is defined as the smallest dimension of a particle when placed on a horizontal surface (Figure 5.1). The shape is most stable when lying with its least dimension (A) vertical. If placed with the width (B) or the depth (C) of the shape vertical, it would require less energy to knock the aggregate particle over so that the least dimension (A) was again vertical, particularly if the particle is other than cubic. Thus, in a seal, the final orientation of most particles is such that the least dimension is near vertical, providing that there is sufficient room for the particles to re-align.

Figure 5.1: Three-dimensional shape of a sealing aggregate particle



The least dimension may be only marginally smaller than the other two dimensions, as in the case of almost cubical aggregates, or can be much less in the case of flaky aggregates.

ALD can be determined by:

- direct measurement (AS 1141.20.1 for 10 mm or larger nominal size or AS 1141.20.2 for 5 mm and 7 mm nominal sizes)
- AS 1141.20.3 involving calculating (or using a nomograph) the ALD from the grading, median size, and flakiness index
- NZS 4407 using Test Method 3.13: The Size and Shape of Aggregate Particles.

ALD is the critical parameter in the Austroads sprayed seal design procedures. It is used to calculate both the aggregate spread rate and the design binder application rate. The design procedures assume that, for 10 mm and larger, only a single layer of aggregate particles adheres to the binder film, but for 7 mm and smaller aggregates, the aggregate layer can often be two (or more) aggregate particles in thickness.

The importance of using a representative ALD cannot be overemphasised. Poor sampling techniques and/or inaccurate testing procedures to determine ALD will result in incorrect aggregate design spread rates and inaccurate design binder application rates.

It is poor practice to use assigned or nominal values of ALD for a particular nominal size of aggregate. ALD of individual aggregate samples can vary by up to 17% within normally specified ranges of grading and flakiness index, resulting in an equivalent variation in the design rates of basic binder application and aggregate spread rate. It is thus important to separate aggregate at stockpiles with significantly different ALDs (> 1.0 mm) and monitor the ALD of aggregate stockpiles regularly within a sufficiently comprehensive sampling scheme to progressively evaluate whether seal design changes are warranted.

5.3.2 Flakiness Index

Flaky aggregate is defined as an aggregate particle with a least dimension (thickness) less than 0.6 of the mean of the smallest sieve size through which the particle passes and the largest sieve size on which the particle is retained.

The flakiness index is defined as the percentage (by mass) of stones in an aggregate having an ALD of less than 0.6 times their average dimension.

Flaky aggregates tend to produce seals with less voids due to their tendency to pack more tightly than cubical aggregates, consequently flaky particles require less binder.

Flakiness index may be determined by AS 1141.15.

5.4 Surface Texture

The existing texture of the surface to be sealed is an important consideration in sprayed seal design.

An allowance (Section 6.2.2) is added or subtracted to the binder application rate based on the measurement of the surface texture by the sand patch method, using Austroads (2008).

Surface texture data is also commonly collected on network-level surveys with laser profilometers, as described in Austroads (2016), however the surface texture reported by these methods may not be equivalent to the sand patch results, and should only be used for seal design purposes where a correlation exists between the sand patch and the particular measurement device is provided.

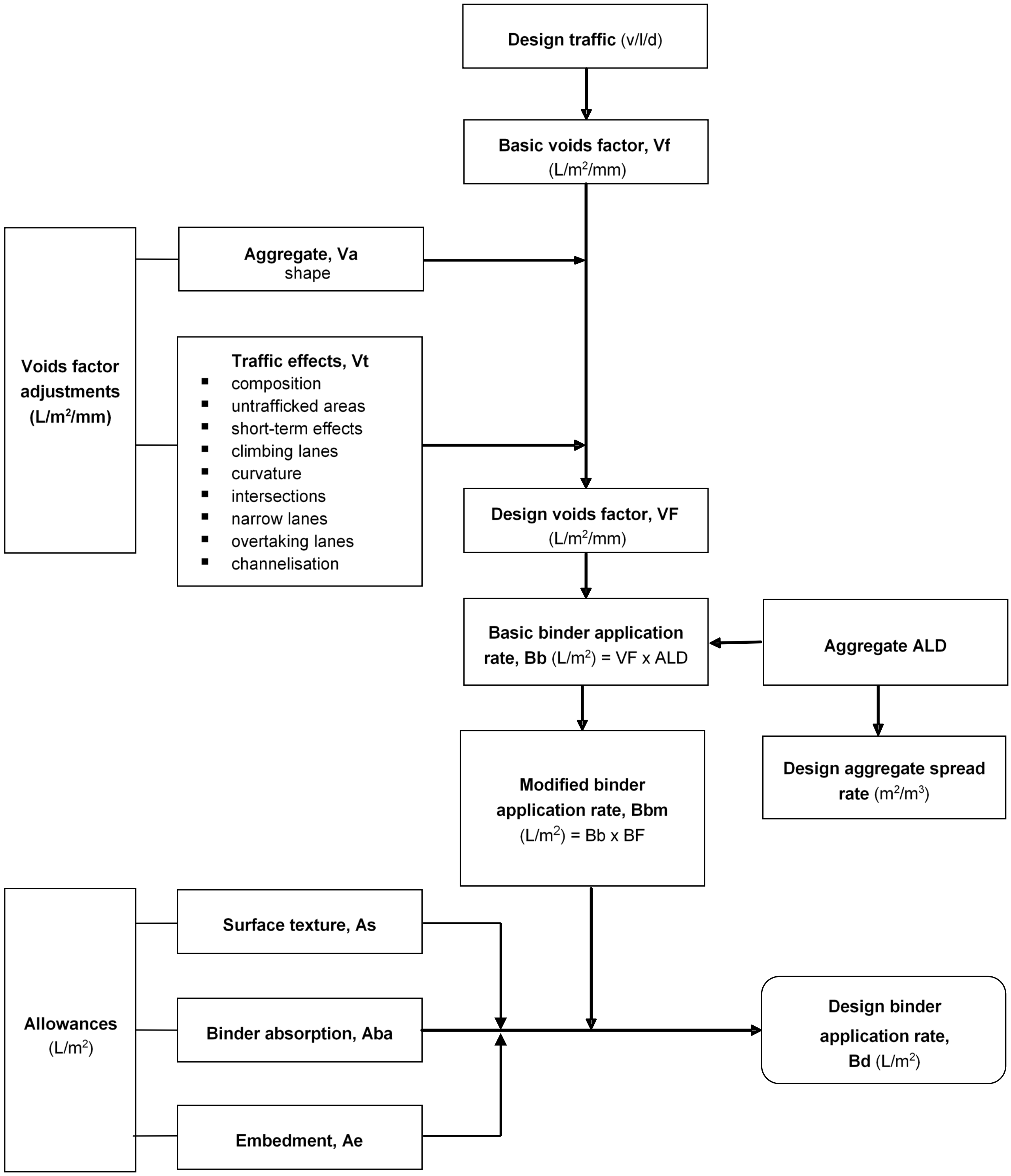
The existing surface texture, and the size of the aggregate on an existing surface contribute to selecting the size of an aggregate to be used in sprayed sealing. Guidance for selecting appropriate aggregate sizes is provided in Table 4.3.

5.5 Design Process

5.5.1 Single/single Sprayed Seal

A general schematic of the process for determination of binder and aggregate application rates for single/single seals is shown in Figure 5.2.

Figure 5.2: Flow chart for design of a single/single seal



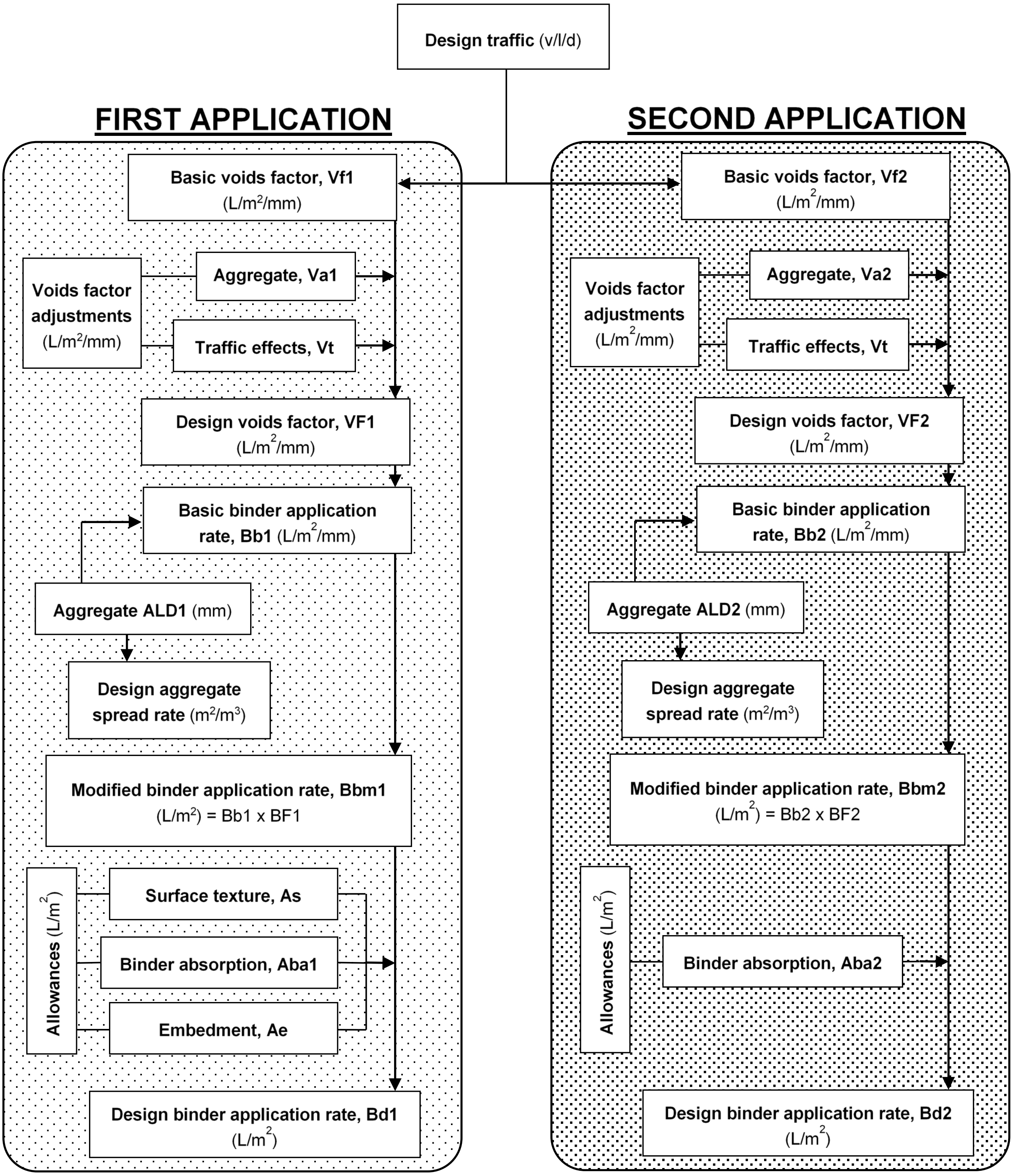
The design procedure is as follows:

1. Determine design traffic (Section 5.2).
2. Determine basic voids factor, Vf (Figure 6.1 or Figure 6.2).
3. Apply voids factor adjustments (Section 6.1.2)
    a. Aggregate, Va
    b. Traffic effects, Vt.
4. Calculate design voids factor, VF (Section 6.1.3).
5. Determine basic binder application rate, Bb (Section 6.2.1).
6. Determine modified binder application rate, Bbm (Section 6.3.1).
7. Apply allowances
    a. Surface texture, As (Table 6.3)
    b. Binder absorption, Aba (Section 6.2.4)
    c. Embedment, Ae (Section 6.2.3).
8. Calculate design binder application rate, Bd (Section 6.4).
9. Determine design aggregate spread rate (Section 6.7.3).

5.5.2 Double/double Sprayed Seal

A general schematic of the process for determination of binder and aggregate application rates for double/double seals is shown in Figure 5.3.

Figure 5.3: Flow chart for design of a double/double seal



First application

The voids relationship in the first application seal of a double/double seal is affected by the use of the smaller aggregate in the second application, which partially fills and therefore reduces the air voids. The reduction in air voids varies from about 10% at high traffic to 30% at very low traffic volumes. This is compensated for by reducing the basic voids factor compared to a single/single seal. These plots only apply to double/double seals constructed on the same day or both seals applied consecutively with minimal trafficking of the first application seal.

The first application seal is designed using the same procedure as for a single/single seal, but taking into account the fact that the voids in this layer will be reduced by the smaller aggregate in the second application seal.

The design process is as follows:

1. Determine design traffic (Section 5.2).
2. Determine basic voids factor, Vf1 (Figure 6.3 or Figure 6.4).
3. Apply voids factor adjustments (Section 6.1.2)
    a. Aggregate, Va1
    b. Traffic effects, Vt.
4. Calculate design voids factor, VF1 (Section 6.1.3).
5. Determine basic binder application rate, Bb1 (Section 6.2.1).
6. Determine modified binder application rate, Bbm1 (Section 6.3.2).
7. Apply allowances
    a. Surface texture, As (Table 6.3)
    b. Binder absorption, Aba1 (Section 6.2.4)
    c. Embedment, Ae (Section 6.2.3).
8. Calculate design binder application rate, Bd1 (Section 6.4).
9. Determine design aggregate spread rate (Section 6.7.4).

Second application

Where, as recommended, the second application is to be applied immediately after the first with little or no trafficking between applications, the following design procedure is used. Guidance for delaying the second application is provided next.

The design traffic is the same for both layers but for the design of the second application seal there is nil reduction in the air voids.

The design process is as follows:

1. Use the same design traffic as determined for the first application.
2. Determine basic voids factor, Vf2 (Figure 6.3 or Figure 6.4).
3. Apply voids factor adjustments (Section 6.1.2)
    a. Aggregate, Va2
    b. Traffic effects as applied in the first application, Vt.
4. Calculate design voids factor, VF2 (Section 6.1.3).
5. Determine basic binder application rate, Bb2 (Section 6.2.1).

6. Determine modified binder application rate, Bbm2 (Section 6.3.2).
7. Apply allowances, which are generally nil for the second application; the only allowance that could be considered is binder absorption into the aggregate, but this is unlikely for normal aggregates
   a. Binder absorption, Aba2 (Section 6.2.4).
8. Calculate design binder application rate, Bd2 (Section 6.4).
9. Determine design aggregate spread rate (Section 6.7.4).

Second application delayed

For double/double seals, it is recommended that the second application is to be applied immediately after the first with little or no trafficking between applications. If this is not possible, the double/double should be considered as two single/single seal layers, with some modification to the design process as outlined below.

If the second application is delayed, and the seal will be trafficked during this period, the outcomes become more difficult to predict. Designers must modify binder application rate allowances for surface texture, as well as aggregate spread rates, depending on the extent of trafficking of the first application.

If unsure, it is recommended that the second application be delayed for 12 months, or longer if practical, to allow the first application to settle down and provide a reasonable indication of final orientation of the aggregate and surface texture of the mosaic.

The design procedure is as follows:

1. First application – design the first application as a single/single seal (Section 5.5.1).
2. Second application – design the second application as another single/single seal (Section 5.5.1). In this design, measure the surface texture of the first application and determine an appropriate allowance from Table 6.3. The texture allowance values in this table are an indicative guide only. If the time delay is less than 12 months between applications, include only part of the surface texture allowance as shown in Table 5.3.

Table 5.3: Double/double seal design surface texture allowance and time between seals

Time between seal applications	Surface texture allowance – as a percentage of the standard allowance (Table 6.3)
Less than 3 months	30%
Between 3 and 6 months	30 to 50%
Between 6 and 12 months	50 to 75%
12 months to 24 months	75 to 100%

The longer the delay, the more of the standard texture allowance is applied. After about 12 months, the full allowance is generally applicable. The texture must be measured each time the design is being considered, and the appropriate allowance determined.

Note: It is preferable to delay the second application up to 12 months to let the first application settle down, and this should provide a better indication of any texture allowance that should be applied. If the binder is still lively in the first application, the surface texture allowance should be reduced, possibly to about 75% of the value given in Table 6.3.

5.5.3 Initial Treatments

Primes

There is no formal design method for the selection and design for priming which is usually based on experience with the local pavement materials and prevailing weather conditions. A general guide to the selection of the grade of cutback bitumen primer and primer application rates is shown in Table 5.4.

Table 5.4: Guide to grades and application rates of primer

Pavement types	Grade (AS 2157)	Primer application rate (L/m^2)
Tightly bonded	AMC 00	0.6 to 1.1
Medium porosity	AMC 0	0.8 to 1.1
Porous	AMC 1	0.9 to 1.3
Very porous (limestone and sandstone)	AMC 1	2 application rates: 1st @ 0.7 to 0.9 2nd @ 0.5 to 0.7
Hill gravels, granitic sands	AMC 0	0.8 to 1.1
Stabilised	AMC 00(1)	0.5 to 0.8
Concrete	AMC 00(1)	0.2 to 0.4

1 *Can also consider using proprietary materials, or additional cutter in these cases.*

The most suitable grade and application rate of primer will depend on the surface finish of the basecourse. Small-scale trials can be conducted on pavement materials in situ to test and compare the appropriateness of the prime grade and application rate.

Standard grades of bitumen emulsion are not suitable for priming but proprietary grades have been developed that should be used in accordance with manufacturer's guidelines.

Where a pavement stabilised with cementitious or chemical binders is to be primed with a bitumen emulsion, a check on the compatibility of the emulsion with the stabilised material should be undertaken. Emulsions will always be compatible with bitumen stabilised pavements.

Initial seals

Binder application rates are calculated as per the typical Austroads seal design methods and are reported in terms of residual binder.

Rates will generally need to be adjusted in line with allowances for absorption and aggregate embedment.

For higher traffic loadings, design binder application rates may be undesirably low, in which case alternative treatments should be considered to provide a more robust and waterproof initial treatment. Design binder application rates may be checked for appropriateness by comparing to those of performing initial seals in similar conditions and traffic loadings, and by seeking specialist advice.

The design procedure is as follows:

1. Apply steps 1 to 6 of the design procedure for single/single (Section 5.5.1) or double/double (Section 5.5.2).

2. Apply allowances
   a. Surface texture, As

      Some pavement basecourses present a coarse-textured surface and it may be possible to measure surface texture. The allowances as suggested for texture measured on an existing 5 or 7 mm seal in Table 6.3 can be applied in this case.

      If surface texture cannot be measured, the texture allowance is generally in the order of 0.0 to +0.3 L/m^2.

      Practitioners should proceed with caution when applying texture allowances where large surface texture is to be matched with small aggregate particles, as the aggregate may sit inside the texture of the basecourse.
   b. Binder absorption, Aba

      Allowances for absorption are required for initial seals, except for unusually tight and hard surfaces, or impermeable pavement materials such as stabilised basecourses. Guidance for the absorption allowance is provided in Section 6.2.4.

      When pavements are stabilised with chemical binders, refer to the *Guide to Pavement Technology Part 4D: Stabilised Materials* (Austroads 2006).
   c. Embedment, Ae

      Embedment allowances can be applied as per the instructions in Section 6.2.3.

      For ball penetration values exceeding 3 mm, the reduction in binder application rate from the embedment allowance may lead to a situation where heavily trafficked sprayed seals have inadequate binder present to waterproof the pavement.

      Where ball embedment exceeds 4 mm, re-preparation of the pavement, including possibilities for improvement in quality of the pavement material, armour coating with a thin layer of good quality material, stabilisation and other treatments should be considered.
3. Calculate design binder application rate, Bd (Section 6.3).
4. Determine design aggregate spread rate for single/single (Section 6.7.3) or double/double (Section 6.7.4).

5.5.4 Other Seals

Strain alleviating membrane interlayer (SAMI)

SAMI treatments use highly modified binders and are applied at high rates of application. SAMI treatments are usually designed to be overlaid with asphalt within 1 day (2 days maximum) after construction. If they are left for a longer period under traffic, they should be designed as a SAM treatment to reduce the risk of flushing or bleeding.

As a SAMI is trafficked for only a short period, or not at all, the normal basic voids factors and adjustments do not apply. A design voids factor (VF) of between 0.16 and 0.18 is generally suitable, with VF = 0.17 appropriate for most designs. The lower or higher value may be adopted considering the volume and type of traffic the SAMI will be exposed to during its short life.

Design binder application rate is calculated by Equation 4:

$$\text{SAMI design binder application rate} = (0.17 \times ALD \times BF) + \text{allowances (rounded to nearest } 0.1\ L/m^2) \quad (4)$$

where

ALD = Average least dimension (Section 5.3)

BF = Binder factor (Section 6.3)

For a SAMI treatment to provide effective crack reflection performance, a minimum design binder application rate of 1.8 L/m² is recommended.

This minimum binder application rate can generally be achieved with a 10 mm single/single seal, but 14 mm aggregate may be used where higher binder application rates are required to control more severe cracking, or when being placed as a waterproofing layer under open graded asphalt.

Geotextile reinforced seals (GRS)

A minimum fabric mass of 130 g/m² is used for general sealing applications with 10 mm aggregate. Aggregates larger than 14 mm have an increased potential for puncturing the fabric, particularly when used as an initial treatment over a soft base, and heavier grades of fabric (175 to 200 g/m²) are preferred for such applications.

Geotextiles made from polyester are preferred when using hot bitumen as they have a higher melting point. Where polypropylene fabric is used, the binder temperature should not exceed 170 °C.

GRS (seals or reseals) are designed in accordance with conventional design procedures for the relevant seal type (single/single or double/double) and binder type. Allowances are then added for binder retention by fabric as follows:

1. Determine design binder application rate, Bd, for the relevant seal type overlying the geotextile (Section 5.5.1 or Section 5.5.2).
2. Determine binder geotextile fabric retention allowance (Section 6.5.1).
3. Calculate the design binder application rate for GRS, BdG (Bd + geotextile fabric retention allowance).
4. Apportion BdG between the bond coat allowance (Section 6.5.2) and seal coat binder.
5. Determine aggregate spread rate for GRS by design of the relevant seal type (Section 6.7) with no further allowances.

Fibre reinforced seals (FRS)

The design of FRS is based on conventional single/single design procedures, including allowances for polymer and bitumen emulsion, plus an appropriate allowance for the amount of binder required to coat the fibres. The procedure is as follows:

1. Determine design binder application rate, Bd, as for a single/single seal (Section 5.5.1).
2. Determine glass fibre binder allowance (Table 6.7).
3. Calculate the design binder application rate for FRS, BdF (Bd + glass fibre binder allowance).
4. Determine aggregate spread rate for FRS as for conventional single/single seal with bitumen emulsion binder (Section 6.7.3) with no further allowances.
5. A scatter coat of a small sized aggregate is generally applied to 10 mm and 14 mm aggregate FRS. The scatter coat is usually applied at a rate of 400 to 600 m²/m³ using 7 or 5 mm aggregate on 14 mm seals, and 5 mm aggregate on 10 mm seals.

6. Seal Design Input Parameters

6.1 Voids Factor

6.1.1 Basic Voids Factor

The basic voids factor, Vf (L/m²/mm), is related to traffic volume. It is critical that the traffic volume used in the design is representative of the actual traffic on the area being considered, as the volume and composition of traffic has a direct effect on the performance of a sprayed seal (Section 5.2).

For single/single seals, Vf is determined from Figure 6.1 or Figure 6.2 (depending on the traffic volume). The central target line is used to determine Vf in all cases. Figure 6.1 and Figure 6.2 also contain lower and upper limits that represent indicative confidence limits for the Design Voids Factor, VF, after applying aggregate and traffic adjustments to Vf.

For double/double seals, Vf is determined from Figure 6.3 or Figure 6.4 (depending on the traffic volume). The voids relationship in the first application/layer seal of a double/double seal is affected by the use of the smaller aggregate in the second application, which partially fills and therefore reduces the air voids. This is compensated for by using a reduced basic voids factor for this first application/layer.

In all cases, Vf should be read to the nearest 0.01 L/m²/mm.

Figure 6.1: Basic voids factor (Vf) for single/single seal – traffic volume 0 to 500 vehicles/lane/day

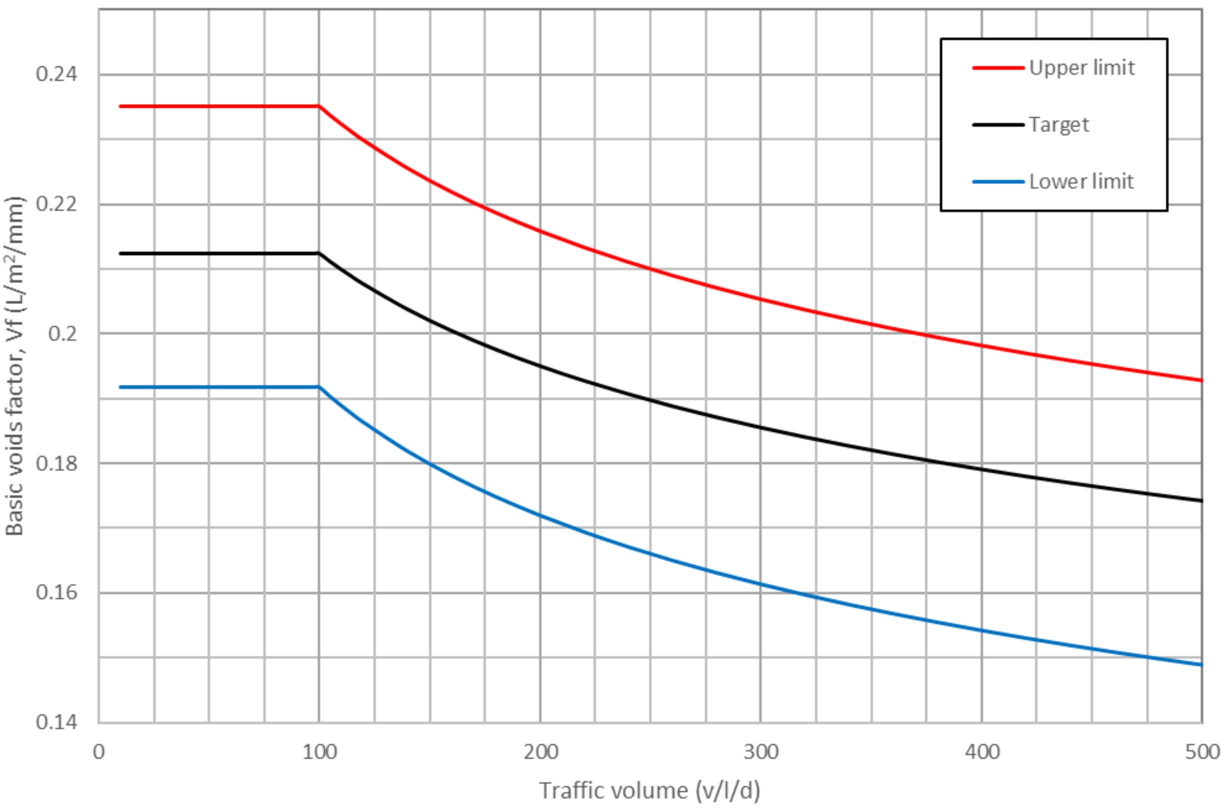


Figure 6.2: Basic voids factor (Vf) for single/single seal – traffic volume 500 to 10 000 vehicles/lane/day

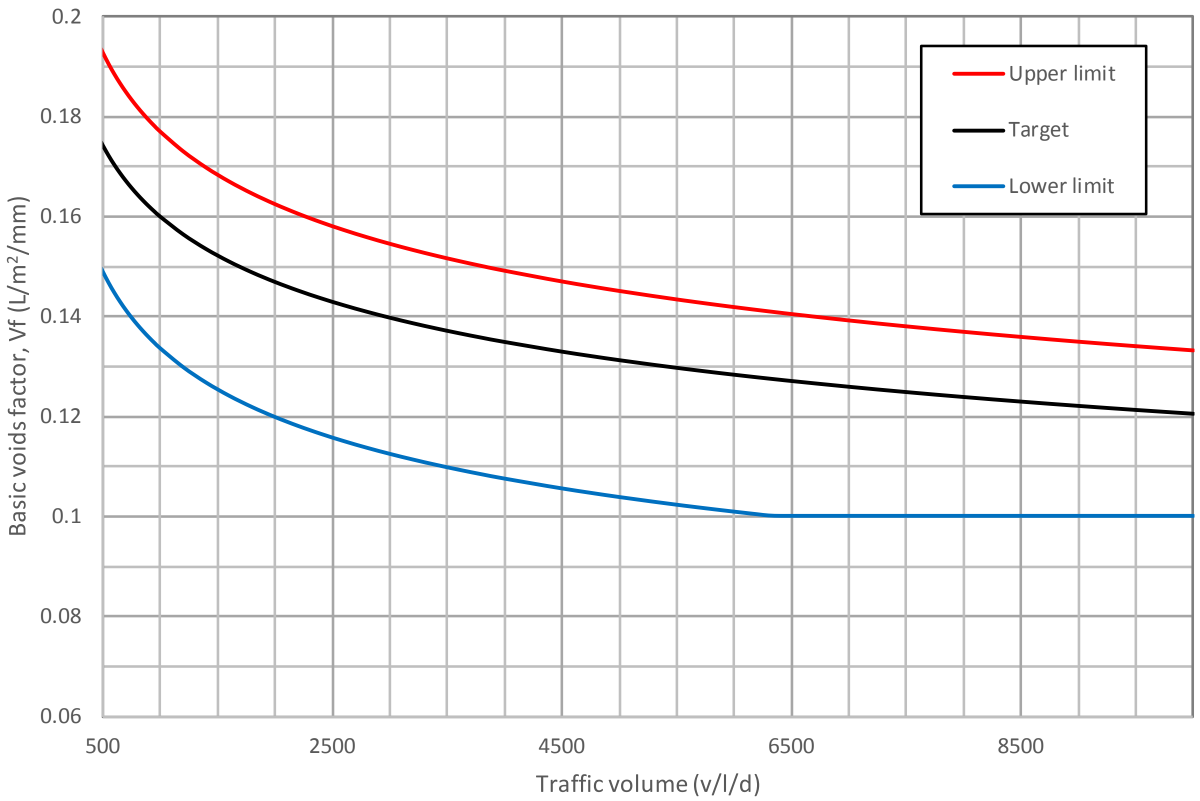


Figure 6.3: Basic voids factor (Vf) for double/double seal – traffic volume 0 to 500 vehicles/lane/day

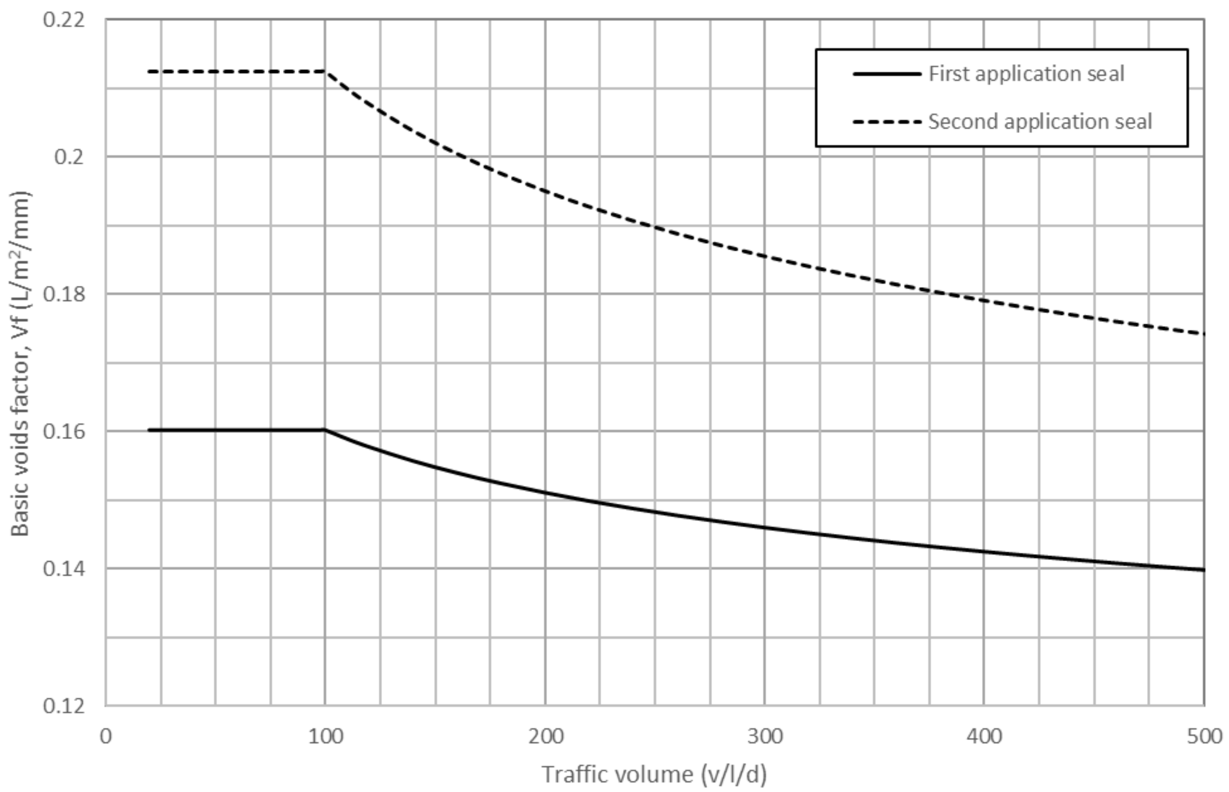
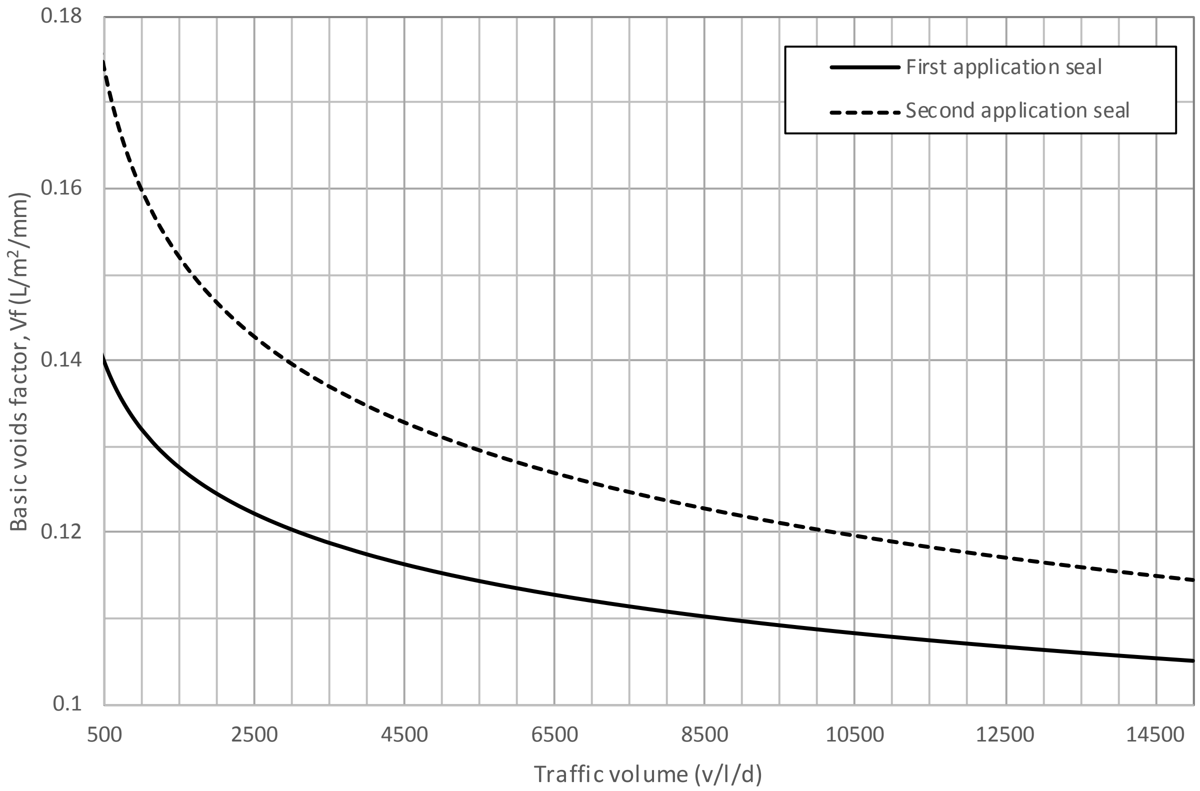


Figure 6.4: Basic voids factor (Vf) for double/double seal – traffic volume 500 to 15 000 vehicles/lane/day



6.1.2 Adjustments to the Basic Voids Factor

The design voids factor, VF (L/m^2/mm), is determined by adjusting the basic voids factor (Vf) to account for abnormal aggregate shape (Va) and the effect of traffic (Vt). These factors may be positive or negative and are cumulative.

Adjustment for aggregate shape (Va)

An adjustment, Va, is made to the basic voids factor (Vf) to account for variation in aggregate shape in accordance with Table 6.1. Flaky aggregates tend to produce seals with less voids due to their tendency to pack more tightly than cubical aggregates, consequently flaky particles require less binder.

Table 6.1: Adjustment to basic voids factor for aggregate shape (Va)

Aggregate type	Aggregate shape	Flakiness index (%)	Shape adjustment (Va) (L/m^2/mm)
Crushed or partly crushed	Very flaky	> 35	Considered too flaky and not recommended for sealing
	Flaky	26 to 35	–0.01
	Angular	16 to 25	Nil
	Cubic	10 to 15	+0.01
	Very cubic(1)	< 10	+0.02
	Rounded	n.a	+0.01
Not crushed	Rounded	n.a	+0.01

1 *Not recommended for bottom layer of D/D seal as insufficient angularity does not promote interlock with top layer.*

Adjustment for traffic effects (Vt)

The basic voids factors, Vf, described in Section 6.1.1, have been developed for an average mix of light and heavy vehicles in a free traffic flow situation. Where this assumption is not correct, an adjustment, Vt, needs to be made to compensate for variations in the traffic composition. This can include non-trafficked areas, lanes with few heavy vehicles or for large proportions of heavy vehicles, channelisation or concentration of traffic, and slow-moving heavy vehicles in climbing lanes or stop/start conditions (refer to Table 6.2).

Traffic normally wanders within traffic lanes resulting in wheelpath travel up to 1.2 m wide. Where traffic is constrained (channelled) from wandering such as on single-lane bridges, tight radius curves or narrow lane widths, an adjustment to the Vf must be made to reduce the risk of the seal bleeding. For example, a narrow single-lane bridge may increase the effective traffic loading in the wheelpath by as much as threefold when the cumulative effects of combining lane volumes and constraining traffic to a confined path are taken into account.

Table 6.2: Adjustment (Vt) to basic voids factor for traffic effects

Traffic	Adjustment to basic voids factor (L/m^2/mm)			
	Flat or downhill		Slow moving – climbing lanes	
	Normal	Channelised*	Normal	Channelised*
On overtaking lanes of multi-lane rural roads where traffic is mainly cars with ≤ 10% of HV	+0.01	0.00	n.a.	n.a.
Non-trafficked areas such as shoulders, medians, parking areas	+0.02	n.a.	n.a.	n.a.
0 to 15 EHV(%)	Nil	–0.01	–0.01	–0.02
16 to 25 EHV(%)	–0.01	–0.02	–0.02	–0.03
26 to 45 EHV(%)	–0.02	–0.03	–0.03	–0.04
46 to 65 EHV(%)	–0.03	–0.04	–0.04	–0.05
> 65 EHV(%)	Use the process described in Section 5.2.7 for access roads to quarries, mining locations, etc.			

n.a.: Not applicable.

EHV(%): Equivalent heavy vehicles, includes both standard heavy vehicles and large heavy vehicles (see Equation 2, Section 5.2.5).

* *Channelisation – a system of controlling traffic by the introduction of an island or islands, or markings on a carriageway to direct traffic into predetermined paths, usually at an intersection or junction. This also applies to approaches to bridges and narrow culverts.*

Possible short-term increases in traffic volumes such as during grain harvests and local field days may occur early in the life of the seal. Designers should consider this and may need to make some adjustment to the traffic volumes and design voids factor adopted in the design procedure.

Where a short-term traffic increase is only for a few days, it is preferable to defer the sealing work, for example to avoid a local annual field day or race meeting.

Seasonal variation, particularly an increase in large heavy vehicles such as large truck and trailer combinations, B-doubles or larger combinations during hot summer periods, can affect the performance of a seal for up to two summers after construction. This applies mostly to annual crops harvested during the hotter weather conditions, stock transport and similar situations.

Consideration should be given to changing the type of treatment and/or binder if the increase is relatively large compared to the average annual daily traffic.

If unsure, design the rates of application for the normal and worst traffic cases before deciding on deferral of work, selection of an alternative treatment or selection of a final design.

6.1.3 Design Voids Factor

The design voids factor,VF, is now calculated by Equation 5:

$$\text{Design voids factor, } VF = Vf + Va + Vt \quad (5)$$

where

Vf = basic voids factor

Va = adjustment for aggregate shape

Vt = adjustment for traffic effects

If adjustments for aggregate shape and traffic effects result in a reduction in the basic voids factor of 0.04 L/m^2/mm or more, special consideration should be given to the suitability of the treatment and possible selection of alternative treatments.

Selection of an alternative type of treatment should be considered where the design voids factor is at, or close to, the minimum recommended value of 0.10 L/m^2/mm. For example, use of a PMB to aid aggregate retention or a double/double seal to provide a more robust treatment.

6.2 Binder Application Rate

6.2.1 Basic Binder Application Rate (Bb)

The procedure for the determination of the basic binder application rate, Bb (L/m^2), for the proposed seal is as follows:

- Determine the design voids factor, VF as described above.
- Determine the basic binder application rate, Bb, to the nearest 0.01 L/m^2 by multiplying the VF by the ALD, as shown in Equation 6:

$$Bb = VF \times ALD \ (L/m^2) \quad (6)$$

where

VF = design voids factor

ALD = average least dimension of aggregate

For example: VF = 0.16 L/m^2/mm and ALD = 5.8 mm

Bb = 0.16 x 5.8 = 0.928 = 0.93 L/m^2.

6.2.2 Allowances Applied to the Basic Binder Application Rate

The following allowances need to be considered to complete the design. Allowances are determined to the nearest 0.1 L/m^2 and are cumulative. They must be added to or subtracted from the basic binder application rate, Bb (L/m^2), to determine the design binder application rate, Bd (L/m^2).

Allowances in L/m^2 are made for the following:

- surface texture of existing surface
- potential aggregate embedment into the existing surface

- potential binder absorption into the existing pavement
- potential binder absorption into the sealing aggregate.

Surface texture allowance (As)

Measurement of surface texture

Surface texture allowance is based on measurement of the existing surface texture using the sand patch method provided in Austroads (2008) or in Transit New Zealand (1981).

Texture measurements should be taken at least every 400 to 500 m or where there is a visual change in texture, such as a change to a seal of different aggregate size. For shorter sites, measure at a minimum of two locations.

It is recommended that the texture depth be measured in the wheelpaths, between wheelpaths, and outside of the wheelpaths. This will assist in deciding if separate design rates of binder need to be considered across the lane. If the difference in texture allowance is 0.3 L/m² or greater, one of the following alternatives may assist in achieving optimal performance across the full width of the seal:

- Regulate the surface with a 5 or 7 mm seal.
- Pre-spray the coarse-textured areas using the techniques described in Austroads (2003).
- Use a bitumen sprayer with a variable rate spray bar.

Surface texture allowance for existing seals

Table 6.3 provides a guide to binder application rate allowances for different sizes of aggregate for a seal over various existing seal sizes and textures. The allowances are based on an assumption of satisfactory interlock between aggregates. Aggregates that have unusual (atypical) shape or size may require minor variations from the tabulated values.

Some aggregate sizes will not be readily compatible with existing seal sizes and texture depths. For example, small-sized reseals will generally not give good results over flushed large-sized seals, and 10 mm reseals may sometimes not interlock well with existing hungry coarse textured 16, 14 and 10 mm seals.

Allowances to be applied for existing surface texture may be substantial and require a degree of judgement by the designer.

Consideration should be given to changing the size of aggregate and/or the treatment if surface texture allowances required become excessive, say exceeding 0.5 L/m².

On surfaces with low texture depths (e.g. < 0.5 mm), it may not be possible to measure the texture adequately, and a visual assessment may be necessary. This may particularly apply to asphalt, slurry, concrete, timber and primed surfaces (see notes below).

Table 6.3: Surface texture allowance for existing surfacing, As (L/m²)

Existing surface	Aggregate size of proposed seal (Note 4)	Measured texture depth (mm)	Surface texture allowance (L/m²)
14, 16 or 20 mm seal	5 or 7 mm	0 to 0.3	**Note 1**
		0.4 to 0.6	**Note 2**
		0.7 to 0.9	+0.1
		1.0 to 1.3	+0.2
		1.4 to 1.9	+0.3
		2.0 to 2.9	+0.4
		> 2.9	+0.5
	10 mm	0 to 0.3	–0.1
		0.4 to 0.5	0
		0.6 to 0.7	+0.1
		0.8 to 0.9	+0.2
		1.0 to 1.3	+0.3
		1.4 to 1.8	+0.4
		> 1.8	**Note 3**
	14 mm	0 to 0.3	–0.1
		0.4 to 0.5	0
		0.5 to 0.6	+0.1
		0.6 to 0.7	+0.2
		0.8 to 0.9	+0.3
		1.0 to 1.3	+0.4
		1.4 to 1.8	+0.5
		> 1.8	**Note 3**
10 mm seal	5 or 7 mm	0 to 0.3	**Note 1**
		0.4 to 0.9	+0.1
		1.0 to 1.4	+0.2
		1.5 to 2.0	+0.3
		2.1 to 2.7	+0.4
		> 2.7	+0.5
	10 mm	0 to 0.3	**Note 1**
		0.4 to 0.7	+0.1
		0.8 to 1.1	+0.2
		1.2 to 1.7	+0.3
		> 1.7	**Note 3**
	14 mm	0 to 0.2	**Note 1**
		0.3 to 0.6	+0.1
		0.7 to 0.9	+0.2
		1.0 to 1.2	+0.3
		1.3 to 1.7	+0.4
		> 1.7	**Note 3**

Existing surface	Aggregate size of proposed seal (Note 4)	Measured texture depth (mm)	Surface texture allowance (L/m²)
5 or 7 mm seal	5 or 7 mm	0 to 0.3	**Note 1**
		0.4 to 0.9	+0.1
		1.0 to 1.5	+0.2
		1.6 to 2.2	+0.3
		2.3 to 3.2	+0.4
		> 3.2	+0.5
	10 mm	0 to 0.3	**Note 1**
		0.4 to 0.7	+0.1
		0.8 to 1.1	+0.2
		1.2 to 1.8	+0.3
		> 1.8	**Note 3**
	14 mm	0 to 0.2	**Note 1**
		0.3 to 0.6	+0.1
		0.7 to 0.9	+0.2
		1.0 to 1.4	+0.3
		1.5 to 2.0	+0.4
		> 2.0	+0.5
Asphalt/microsurfacing	All	0 to 0.1	0
		0.2 to 0.4	+0.1
		0.5 to 0.8	+0.2
		0.9 to 1.4	+0.3
		> 1.4	+0.4

Notes:

1 *Embedment considerations are dominant.*

2 *Specialised treatments are necessary.*

3 *This treatment might not be advisable depending on the shape and interlock of aggregates so alternative treatments (surface enrichment, small size seal or others) should be considered.*

4 *For application of aggregate sizes greater than 14 mm, adopt the allowances applicable to 14 mm aggregate.*

Texture allowance for asphalt

For an asphalt surface, the sand patch test may not be appropriate. Based on experience and depending on the type of mix, the texture allowance for hardened and aged asphalt surfaces is typically between +0.0 to +0.3 L/m². Embedment into freshly placed asphalt or asphalt that is slick with fatty patches, may also need to be considered (see Section 6.2.3).

Texture allowance for microsurfacing

For microsurfacing, the sand patch test is, again, usually not appropriate. Similar to asphalt, a typical allowance is between +0.0 to +0.3 L/m². Embedment into freshly placed microsurfacing may also need to be considered (see Section 6.2.3).

Texture allowance for concrete surfaces

The concrete must be primed and, in order to get a satisfactory seal over a well-primed concrete surface, the allowance should be +0.2 to +0.4 L/m^2, even on smooth surfaces, to compensate for the lack of aggregate embedment and interlock into the texture of the concrete surface. For broom-dragged or tyned surfaces, the allowance can be as high as +0.4 to +0.5 L/m^2.

Texture allowance for timber surfaces

Timber may be untreated, primed, coated or impregnated. Similar to concrete, and as a guide, an allowance of between +0.2 to +0.4 L/m^2 may be appropriate.

Texture allowance for pavement and primes

Some pavement materials and primes present a coarse-textured surface and it may be possible to measure surface texture. If not, and based on experience, the texture allowance is generally in the order of +0.0 to +0.3 L/m^2.

Texture allowance for initial seals

A texture allowance is determined as per existing sealed surfaces.

Texture allowance for regulation or patched areas

Shape correction of pavements and maintenance patching prior to sealing is often carried out using asphalt, microsurfacing or premix. Allowance may need to be made for patches that are much smoother in texture than the surrounding seal, particularly if the affected area is substantial.

In addition, if the regulation/patching has not had time to cure, there is an increased risk of aggregate embedment, with resulting flushing of the seal over those areas. The regulation/patching should be allowed to cure to minimise the risk of flushing/bleeding. Recommended minimum curing times are three months in hot weather and six months in cooler weather (see also Austroads (2010b)).

6.2.3 Embedment Allowance (Ae)

Embedment allowance compensates for loss of voids in the seal under traffic due to the aggregate being forced into of the substrate. This depth of embedment will depend on the volume and mass of traffic and the condition (hardness) of the surface being sealed.

Embedment problems can generally be recognised by the fact that the wheelpaths will become flush in a very short time period (within weeks), while the remainder of the seal remains coarser textured. Long-term, very slow reduction in texture is a separate issue and not part of this step in the design process.

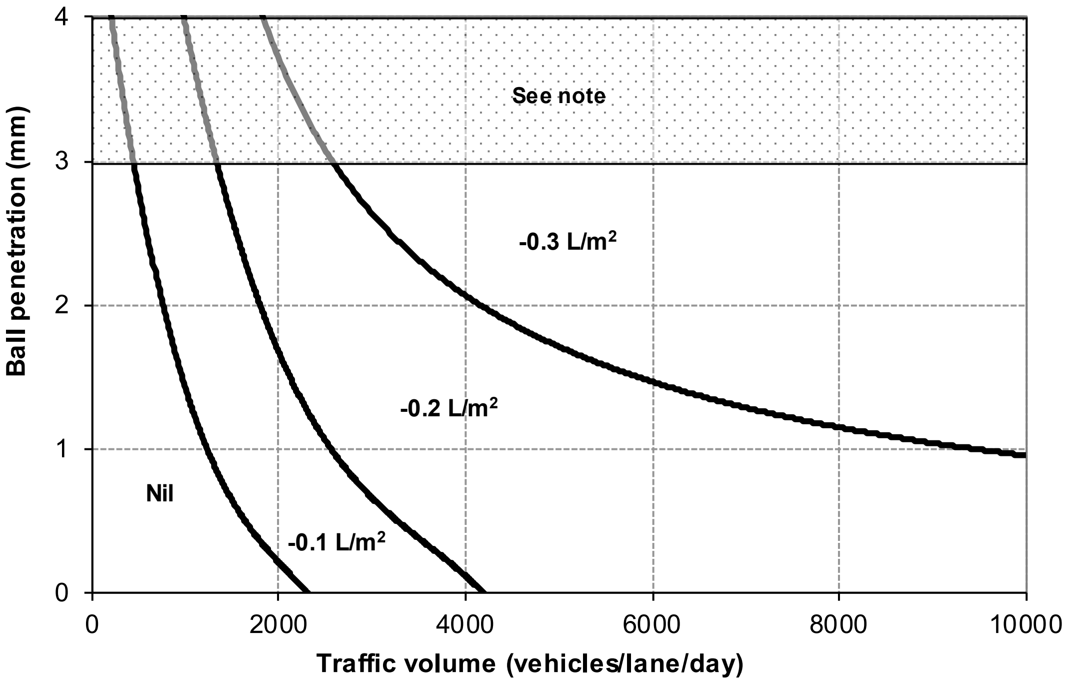
Embedment on pavement and primes

Embedment of aggregate may occur in initial treatments applied over:

- a soft base
- primed or initial sealed surfaces.

Typical embedment allowances (in L/m^2) are shown in Figure 6.5. Pavement surface hardness should be determined in accordance with Austroads (2010c).

Figure 6.5: Embedment allowance for initial treatments



Note: It is recommended that the following alternatives be considered where the ball embedment value exceeds 3 mm:

- *If due to moisture, defer sealing to allow the surface to harden as it dries back. The surface should be retested once it has dried sufficiently.*
- *Apply a small aggregate seal as the first seal to act as an armour-coat and minimise the amount of embedment of the larger aggregate applied at a later date, say after about 12 months. This is only recommended for roads with low traffic volumes with low percentages of heavy vehicles.*

To minimise potential risk of flushing/bleeding it is recommended that:

- When cutback bitumen is used, the secondary treatment should not be applied until a reasonable period of curing has elapsed, as residual cutter oil can soften subsequent bituminous surfacings. The curing rate depends on binder grade, application rate and climatic conditions during the curing period. A minimum of six months of warm or hot weather is recommended, although 12 months may be beneficial in colder weather. The minimum curing period may be reduced to three months for relatively low cutter content initial seal binders (such as AMC7) when used in warm or hot conditions.
- A surface primed with cutback bitumen should be allowed to cure for a minimum period of three days prior to sealing. Otherwise, the possibility of absorption of binder and the potential cutting back effect of the cutter in the primer must be taken into consideration. Bitumen emulsion primers (specialty grades) can often be sealed after one or two days curing depending on prevailing drying conditions.

Embedment on reseals

Embedment of aggregate may occur in reseals:

- if there is free binder on the surface being resealed
- when applying a reseal over fresh asphalt or microsurfacing
- when applying a reseal over fresh maintenance patching. Patches that are soft and/or porous can cause problems with embedment and/or binder absorption. Maintenance patches should be allowed to cure for a minimum of three to six months depending on type of patching material (Austroads 2010b).

Where the binder in the existing seal is relatively soft, some embedment may occur. The ball penetration test (Austroads 2010c) has been found to provide poor correlation with field performance for flushed bitumen surfaces and further research is required to determine appropriate allowances. In the meantime, designers must apply their own judgement in providing suitable allowances. Where surfaces are severely flushed, alternative treatments may need to be considered. Alternative treatments may include:

- specialty treatments (Section 4.9)
- surface treatments using solvent and aggregate (Austroads 2010a)
- removal of excess bitumen by high-pressure water blasting (Austroads 2004)
- selection of a surfacing type other than a sprayed seal.

6.2.4 Binder Absorption Allowance (Aba)

It will be necessary to increase the binder application rate to allow for any binder absorption by pavement and/or aggregate, Aba, but it is not possible to give a general allowance.

Binder absorption by pavement

Initial seals

It is strongly recommended that all new pavement surfaces should be primed. However, where an initial seal is applied directly to the prepared granular pavement, and binder from a sprayed seal may drain into voids in the surface of the basecourse. This is most likely to occur in sandy or silty rubble base materials (sandstone, limestone or silty gravels) in a hot dry climate.

The following binder absorption allowances provide a guide for use with various pavements:

- granular unbound pavements — allow +0.1 to +0.2 L/m^2
- pavements using cementitious binders — allow +0.0 to +0.1 L/m^2
- bitumen stabilised pavements — allow –0.1 to +0.1 L/m^2
- pavements using chemical binders — for the use of chemical binders, refer to Austroads (2006).

For highly absorptive pavement surfaces, particularly in hot climates, long-term absorption of the binder into the basecourse can occur. The allowance for this will generally be between +0.1 to +0.2 L/m^2. Where more than 0.2 L/m^2 is required, an alternative treatment should be considered.

Alternative treatments may comprise:

- use of a different class of binder, including PMB
- modification or stabilisation of the basecourse
- use of a 5 or 7 mm initial seal, followed by a larger aggregate seal one or two years later.

In extreme cases, binder absorption into base materials may lead to the need for surface enrichment or a small aggregate reseal being required within one or two years.

Reseals

Binder absorption into existing spray sealed surfaces will seldom be a problem unless the existing surface is visibly open and porous.

Binder absorption can occur when sealing over aged and brittle asphalt and microsufacing. In these cases, a binder absorption allowance of +0.1–0.2 L/m^2 may be appropriate.

Binder absorption by aggregate

Absorptive aggregates may fall into two general categories:

- porous, e.g. sandstone, rhyolite
- vesicular (full of cavities), e.g. scoria, slags.

In general, binder absorption into aggregate is not applicable, but if an allowance is required, it should not usually exceed 0.1 L/m^2.

6.3 Binder Factor

The type of binder used in a sprayed seal effects the required application rate. The design process achieves this by using 'binder factors' that are specific to the different treatments and type of binder.

All polymer modified binders are more viscous and elastic than conventional binder and may be used at higher rates of application for increased effectiveness.

High bitumen content emulsions reduce aggregate reorientation as a result of a rapid increase in binder stiffness after the initial breaking and curing of the emulsion, and may be used at higher rates of application to compensate for this.

Binder factors are applied to polymer modified binders for both hot applied, and emulsion delivery systems.

The binder factor is applied to the basic binder application rate, to create a modified basic binder application rate, Bbm, which is calculated using Equation 7:

$$\text{Modified basic binder application rate, Bbm} = \text{Bb} \times \text{BF (rounded to nearest 0.1 L/m}^2\text{)} \qquad 7$$

where

Bb = basic binder application rate

BF = binder factor

6.3.1 Single/single Seals

Binder factors are typically applied to single/single seals as shown in Table 6.4.

Table 6.4: Binder factors for single/single seals

Treatment type	Binder	Binder factor
Conventional seal	C170, C240, C320	1.0
	M500	1.1
Unmodified emulsion seal	Conventional emulsion (60%)	1.0
	High bitumen content emulsion (≥ 67%)	1.1
Modified emulsion seal	User binder factors below for the PMB that has been emulsified	
Aggregate retention (AR)	S35E	1.0
	S10E	1.1
High stress seal (HSS1)	S10E, S15E, S35E	1.0
	S20E, S45R, S15RF	1.1
Strain alleviating membrane (SAM)	S10E, S15E, S35E	1.2
	S20E, S45R, S15RF	1.3
Strain alleviating membrane interlayer (SAMI)	S25E, S18RF	1.6

6.3.2 Double/double Seals

Double/double seals are strong robust seals by virtue of the mechanical interlock of the large and smaller aggregates and are not as reliant on the binder as a single/single seal to cope with high traffic stress. Binder factors for double/double seals (Table 6.5) are thus reduced compared to those used for single/single seals.

Table 6.5: Binder factors for double/double seals

Treatment type	Binder	Binder factor(1)
Conventional seal	C170, C240, C320	1.0
	M500	1.1
Unmodified emulsion seal	Conventional emulsion (60%)	1.0
	High bitumen content emulsion (≥ 67%)	1.1
Modified emulsion seal	User binder factors below for the PMB that has been emulsified	
High stress seal (HSS2)	S10E, S15E, S35E	1.0
	S20E, S45R, S15RF	1.1
Extreme stress seal (XSS)	S20E	1.1
	S45R, S15RF	1.1
Strain alleviating membrane (SAM)	S10E, S15E, S35E, S20E	1.1
	S45R, S15RF	1.1

1 *Under very heavy traffic conditions with high percentages of heavy vehicles these factors may be reduced by 0.1 but should not reduce the binder factor to less than 1.0.*

6.4 Design Binder Application Rate (Bd)

The design binder application rate, Bd, is determined by Equation 8:

$$Bd = Bbm + \text{allowances} \ (L/m^2) \qquad 8$$

where

Bbm = modified basic binder application rate (rounded to the nearest 0.01 L/m^2)

Allowances = any applicable allowances as per Section 6.2.2

For example: Bbm = 0.97 L/m^2

Surface texture allowance = +0.3 L/m^2

Embedment allowance = –0.1 L/m^2

Bd = 0.97 + 0.3 – 0.1= 1.17 = 1.2 L/m^2 (rounded to nearest 0.1 L/m^2).

6.5 Geotextile Reinforced Seals (GRS)

6.5.1 Binder Fabric Retention Allowance

A binder fabric retention allowance is added to the preliminary design binder application rate for binder required to saturate the fabric. The extent of the binder retention allowance varies from 0.9 to 1.3 L/m^2 of residual binder, depending on the thickness and characteristics of the geotextile fabric and type of binder being used.

This allowance is apportioned between the bond coat and the first application of binder in the seal coat.

Where possible, the allowance for retention of the binder by fabric should be calculated using an appropriate test procedure (ASTM 2005) with the following modifications:

- C170 bitumen is used as the binder
- testing is undertaken at 160 °C.

This covers:

- material thickness (mm) under 2 kPa pressure (AS 3706.1)
- unit mass (g/m^2) of fabric (unprocessed material)
- unit mass (g/m^2) of fabric (processed material).

Typical allowances for binder retention are shown in Table 6.6.

Table 6.6: Typical binder retention allowance for geotextile reinforced seals

Geotextile grade	Retention allowance (L/m^2)
130 to 140 g/m^2	0.9 to 1.0
175 to 200 g/m^2	1.1 to 1.3

6.5.2 Bond Coat

The bond coat is applied to the existing surface and is a proportion of the binder fabric retention allowance. The balance of the fabric retention allowance is added to the seal coat on top of the fabric.

The bond coat must be sufficient to hold the fabric in place, without bleeding through the fabric and adhering to the tyres of the fabric spreading and rolling equipment.

Bond coat application rates typically vary between 0.4 and 0.8 L/m^2 depending on surface texture and weather conditions. In warm to hot conditions, the top end of this application rate may lead to excessive application rates and binder pickup.

6.6 Fibre Reinforced Seals (FRS)

The design binder application rate is determined using the procedures for conventional sprayed seals (Section 5).

Typical rates of application for the glass fibre, and binder allowance for coating of the glass fibres are shown in Table 6.7.

Table 6.7: Typical binder allowances for glass fibre

Seal type	Glass fibre (g/m^2)	Binder allowance
SAM	60	0.1 L/m^2 per 30 g/m^2 of fibre
SAMI	90	

6.7 Aggregate Spread Rate

6.7.1 Influence of ALD

The amount of aggregate required in single/single sprayed seals is based on the average least dimension (ALD) of the aggregate.

The spread rate is based on ALD and it is therefore important that the ALD used is representative of the aggregate supply to be used.

6.7.2 Influence of Traffic

Traffic will influence the packing of the aggregate and affect the void space to be filled with binder. Some adjustment in the spread rate is required for different design traffic volumes in order to achieve a satisfactory, tightly packed mosaic of aggregate after rolling and trafficking.

Aggregate rearranges during construction rolling into a more stable position with the least dimension tending towards vertical. This can only happen if there is sufficient space (provided by the aggregate spread rate) for the aggregate to move/rotate.

At the design spread rate, with an interlocked mosaic, particles provide mutual support and can thus provide greater resistance to the shearing and plucking action of traffic. If the spread rate is too heavy, the contact to contact mosaic may form in a more random orientation. The void volume in this random orientation is considerably higher (up to 25% more) than is the case where a large percentage of the particles lie with the least dimension vertical. If the aggregate spread rate is too light, the particles will not be able to form a fully interlocked mosaic resulting in a lower binder rise and likely reduced seal life.

Aggregates in a sprayed seal continue to reorientate under traffic. The rate of reorientation and amount of change in void volume is dependent on the traffic volume and, in particular, the number of heavy vehicles. This reorientation occurs mainly during the first one or two years of service. High traffic volumes result in the least dimension of nearly all particles being near vertical and interlocking with each other. The extent of reorientation is less at low traffic volumes resulting in greater random orientation of aggregate particles and greater void volume.

For the binder application rate to fill the voids within the aggregate mosaic to a depth of about two-thirds up the aggregate, it is essential that the aggregate is spread at the design rate.

The aggregate spread rate for very low-traffic roads (≤ 200 v/l/d) can be about 5% heavier than that for more heavily trafficked roads to achieve both a satisfactory aggregate mosaic and to avoid pick-up of binder by the aggregate spreader/trucks due to the relatively heavier rates of application of binder.

To achieve a satisfactory aggregate mosaic, the actual spread rates may have to be varied in practice by as much as ±10 m^2/m^3 from the design spread rate given below. It is not required to add an allowance for whip-off to the design aggregate spread rate.

When ordering aggregate for works, stockpile wastage should be considered by including an additional allowance. A typical allowance for stockpile wastage is an additional 5 to 10% of aggregate above the quantity (tonnes or m^3) required to cover the proposed works at the design spread rate.

6.7.3 Single/single Seals

The design aggregate spread rates for single/single seals to produce a satisfactory aggregate mosaic are shown in Table 6.8.

To achieve a satisfactory mosaic and to avoid binder pick-up using low viscosity binders and emulsion binders, the aggregate spread rate needs to be heavier than for other binders.

Table 6.8: Aggregate spread rates for single/single seals

Binder	Aggregate spread rate (m^2/m^3)
C170, C240, C320, multigrade bitumen, PMB	900/ALD
Emulsion, AMC4 & AMC5 cutback binders	800/ALD

Table 6.9 provides the aggregate spread rate for a scatter coat of small-sized aggregate. A scatter coat is sometimes used with single/single seals to reduce the risk of aggregates being dislodged by traffic during initial trafficking. It is particularly useful when using emulsion binders to overcome the low cohesion during the curing period.

Table 6.9: Aggregate spread rates for scatter coat

Application	Aggregate spread rate (m^2/m^3)
Scatter coat	400

For strain alleviating membrane interlayers (SAMI), the aggregate spread rate needs to be lighter than for conventional bitumen and multigrade binders to enable interlock between the seal and the overlying asphalt mix (Table 6.10).

Table 6.10: Aggregate spread rates for SAMI

Application	Aggregate spread rate (m^2/m^3)
SAMI	1000/ALD to 1100/ALD

6.7.4 Double/Double Seals

As for a single/single seal, the design aggregate spread rate is based on ALD, but the first layer of aggregate is reduced by about 10% to provide a slightly more open mosaic to allow the second application of aggregate to firmly interlock.

Design for little or no trafficking between applications

Aggregate spread rates for the first application of a double/double seal are shown in Table 6.11.

Table 6.11: Double/double seal design aggregate spread rates for the first application seal, with little or no trafficking between applications

Binder	Aggregate spread rate (m^2/m^3)
C170, C240, C320, multigrade bitumen, PMB	950/ALD
Emulsion, AMC4 & AMC5 cutback binders	850/ALD

The spread rate of both layers should be adjusted to achieve an interlocking aggregate mosaic with just enough small stone to fill the voids in the first application. Suggested aggregate spread rates for the second application are shown in Table 6.12 as a guide to design the appropriate aggregate spread rates.

Table 6.12: Double/double seal design aggregate spread rates for second application, little or no trafficking between applications

Binder	Aggregate size (mm)	Aggregate spread rate (m^2/m^3)
All binder types	10, 7	900/ALD
	5 (no ALD)	225

Note: For the second aggregate application, the design aggregate spread rate may be up to 20% less (i.e. 1100/ALD) than for a normal single/single seal design depending on the spread rate of the first aggregate application.

When specifying aggregate spread rates, values should be rounded to the nearest 5 m^2/m^3.

Design for second application delayed

A double/double seal with the second application delayed is to be considered as two separate single/single seals for design purposes.

For both applications, the aggregate spread rate is determined as appropriate for a single/single seal, based on the type of binder as per Table 6.8.

7. Construction

The construction of sprayed seals involves a number of phases, including:

- planning and programming
- scheduling and organising
- pavement/surface preparation
- sprayed sealing operations
- recording and monitoring of the completed works and payment.

These phases take place over a considerable period of time. Depending upon the scope of the work, the time between planning and finishing the job could be weeks or even months.

A brief outline of the principal activities involved in sprayed sealing operations is provided below. Details of the construction of sprayed seals are provided in the *Guide to Pavement Technology Part 8: Pavement Construction* (Austroads 2009b). Further useful information on the construction of sprayed seals is provided in manuals prepared by road agencies (Roads and Traffic Authority 1997; VicRoads and Geopave 2004; Transit New Zealand, Road Controlling Authorities & Roading New Zealand 2005) as well as Austroads/AAPA *Pavement Work Tips*. The work tips may be directly accessed from the Austroads website.

Workplace health and safety is an important requirement in all construction work. Requirements for sprayed sealing works include signing and provision for traffic, working with machinery and working with bituminous materials. Guidelines for safe handling of bituminous materials are provided in Austroads (2015).

7.1 Pavement/Surface Preparation

7.1.1 Primes

The performance of primes and subsequent seals applied to granular pavements is dependent on the adequacy of the underlying pavement in respect to surface condition, strength and stability. These issues are discussed in Austroads (2010b).

The prepared pavement surface should be swept, to remove surface dust and provide a surface that is free of foreign material, with the larger-sized stones at the surface of the pavement exposed but not loose or dislodged. Guidance on surface preparation (homogeneity, exposed aggregate, avoidance of laminating materials or a build-up of fines) is provided in the *Guide to Pavement Technology Part 8: Pavement Construction* (Austroads 2009b).

Pavements to be primed should be surface dry, and no more than damp to the required depth of primer penetration. Excess moisture will inhibit the penetration of the prime, as voids filled with moisture cannot be filled with primer (Austroads 2009b).

It is critical to attain a satisfactory level of dry-back or removal of moisture from the compacted and prepared basecourse pavement layers to present a suitably hard surface for priming. Guidance in controlling moisture in pavement construction and specifying and measuring dry-back is provided in Austroads Pavements Reference Group (2003).

Poor surface hardness can lead to excessive aggregate embedment and flushing. This can be due to a number of factors including excess moisture in the pavement or a layer of fines at the surface. The ball penetration test (Austroads 2010c) is a useful indicator of both the level of surface hardness and dry-back that has been achieved in the basecourse. It provides an input to the determination of the binder application rate in seal design, allowing for the potential embedment of the sealing aggregate into granular pavements.

Photographic examples of good, marginal and poor granular pavement preparation are provided in Appendix A.

7.1.2 Initial Seals

Preparation of the pavement basecourse is critically important to achieving a consistent high standard of initial seal.

The success of an initial seal relies on the binder adhering to the basecourse, and anything that impedes this process should be avoided. Sweeping is important to expose the stone mosaic of the larger aggregates within the basecourse material which facilitates bonding of a binder to the prepared basecourse, especially more viscous or emulsion binders. Guidance on surface preparation (homogeneity, exposed aggregate, avoidance of laminating materials or a build-up of fines) is provided in Austroads (2009b).

Surfaces to be initial sealed should be kept slightly damp, but not wet. A wet pavement may result in aggregate embedment and flushing in the wheelpaths. A dry surface may prevent the binder from properly ‘wetting’ and bonding to the pavement surface. Where the pavement surface is excessively dry a water tanker should be used to lightly dampen the surface.

7.1.3 Reseals

Surfaces are prepared by sweeping and by patching any defects. Patching of existing pavements should be done well in advance of sprayed sealing work and should attempt to match the surface texture of the surrounding seal. Where patching creates large variations in surface texture a small-sized correction or regulation seal or microsurfacing may be needed.

7.2 Sprayed Sealing Operations

The principal activities involved in sprayed sealing operations are:

- blending of binder and incorporation of additives
- aggregate loading and treatment
- spraying of binder
- aggregate spreading
- rolling
- sweeping
- opening to traffic.

7.2.1 Aggregate Loading and Treatment

Sufficient aggregate needs to be stockpiled in the vicinity of the job. If the aggregate has been stockpiled for a long period it may need to be screened to remove contaminants. Aggregate should be separated into lots at the stockpile site, so that application rates can be adjusted to cater for variations in ALD.

Precoating is advisable and this may be done at the quarry or a plant, which is the most efficient method. However, precoating can also be done in the field. Both screening and precoating can be carried out in a single operation at the stockpile site.

7.2.2 Spraying of Binder

Bitumen sprayers are designed to provide a constant rate of binder output across the width of the spray bar. The desired application rate is thus obtained by varying the forward speed of the sprayer and the bitumen pump speed. Accurate spraying to design rates of application requires precise control of both these functions, by means of routine calibration.

Binder application rates are usually checked at the end of each sprayer run against the design so that any adjustments to the sprayer can be made to maintain rates within a reasonable tolerance.

With the adaptation of microprocessor controls, bitumen sprayers are now being developed that can alter the width while spraying and, in some instances, provide for variable transverse rates such as different rates of application in wheelpath areas and outside wheelpaths.

7.2.3 Aggregate Spreading

Basic aggregate spreading is provided by a hopper mounted on the truck tailgate. The spread rate is controlled by the gate opening and truck speed. Greater control over the spread rate is obtained with metering rollers built into the spreader, or by using self-propelled spreaders that include a receiving hopper that transfers aggregate to the metered spreader.

Aggregate spreaders can be calibrated to determine the required settings to achieve the desired spread rate for a particular aggregate source. This is usually undertaken at the stockpile site prior to work commencing.

7.2.4 Rolling

Rolling is usually undertaken by a multi-tyred roller (Figure 7.1). This assists in embedment of aggregate into the binder and reorientation of aggregate for maximum surface contact and interlock. Rubber-coated vibrating drum rollers may also be used. Steel drum rollers should be avoided as excessive use may cause breakdown of aggregate.

Figure 7.1: Multi-tyred roller

Source: ARRB.

7.2.5 Sweeping

Sweeping of the seal is necessary to remove excess loose aggregate that could damage vehicles, and cause crushing of the aggregate in the seal. This is particularly important at the overlaps between aggregate spreader runs where multiple layers of aggregate can lead to stripping of the seal at these locations. Sweeping is normally undertaken using a rotary broom with suction sweepers being required in urban areas to remove aggregate from gutters.

7.2.6 Opening to Traffic

Traffic can be allowed on the seal almost as soon as the aggregate is spread and in fact can be beneficial to aid in quickly rolling the aggregate over to a stable position. Traffic speeds must be strictly controlled at this stage to avoid damage to the seal and risks associated with loose surface aggregate. All loose, surplus aggregate should be removed by sweeping before normal speed limits are restored.

7.3 Construction and Maintenance Scheduling

7.3.1 Primes

Curing time

Initially, the primer should be allowed to dry and cure, or thicken and increase in viscosity (by evaporation of cutter oil), or in the case of emulsions ‘break’ before any trafficking is allowed.

A surface primed with cutback bitumen should be allowed to cure for a minimum period of three days prior to sealing, depending on prevailing drying conditions. Cutter can be trapped in the prime if sealed over too early and will diffuse into the seal and soften it.

Bitumen emulsion and some proprietary primers (specialty grades) can often be sealed after one or two days curing, depending on prevailing drying conditions. Caution should be taken to verify this shorter curing period is adequate for the particular product and prevailing conditions before use.

Expected lifespan

A prime can be expected to have an untrafficked lifespan of several weeks, without further treatment other than normal maintenance, if an appropriate prime grade and application rate are used. Trafficking has the potential to reduce the lifespan of a prime and should be minimised.

7.3.2 Initial Seals

Curing time

Initially, the binder should be allowed to cure, or thicken and increase in viscosity, or in the case of emulsions ‘break’ before any trafficking of the initial seal is allowed.

When cutback bitumen is used, the secondary treatment should not be applied until a reasonable period of curing has elapsed, as residual cutter oil can soften subsequent bituminous surfacings. The curing rate depends on binder grade, application rate and climatic conditions during the curing period. A minimum of six months of warm or hot weather is recommended, although 12 months may be beneficial in colder weather. The minimum curing period may be reduced to three months for relatively low cutter content initial seal binders (such as AMC7) when used in warm or hot conditions.

Initial seals constructed with bitumen emulsions may be covered with asphalt after only two to three days, however a period of three months is recommended before covering with a spray seal.

Expected lifespan

An initial seal can be expected to last between 3 to 24 months, depending on traffic level, aggregate size, and choice of binder. Under light traffic conditions, there is potential for initial seal lives to exceed these approximations.

The use of larger aggregate sizes, multiple layer seals and PMBs may also contribute to achieving longer life spans.

7.3.3 Sprayed Seals

A sprayed seal can be expected to have a lifespan of between 5 to 15 years, depending on many factors such as seal type, traffic, climate and location.

Resealing an existing sprayed seal surface prematurely should be avoided where possible, as there is an increased risk that the binder in the underlying sprayed seal will still be soft and could be prone to embedment from the aggregate in the new seal. This could subsequently lead to the reseal flushing or bleeding.

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Appendix A Photographic Examples of Pavement Preparation

Figure A 1: Examples of well-prepared granular pavements

- Uniform texture and appearance.
- Tops of aggregate clearly visible.

- Hard, tight, dense surface.
- Tops of aggregate clearly visible.

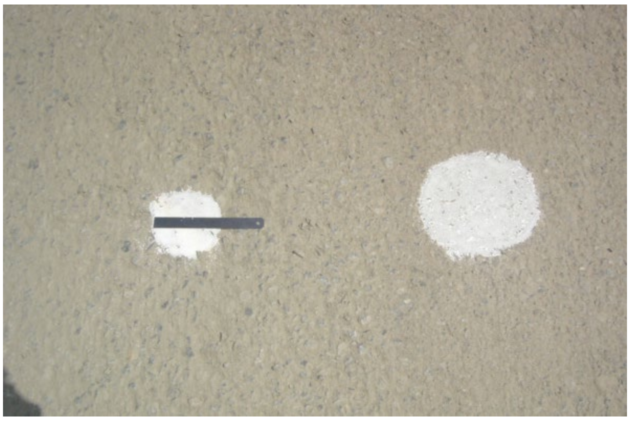
- Hard, tight, uniform surface.
- Tops of aggregate visible.

- Hard, dense surface.
- Uniform texture with aggregate visible.

Source: VicRoads (2014).

Figure A 2: Examples of marginal cases of prepared granular pavements

- Hard and dense surface.
- Some variability in surface texture/finish but mostly uniform.



- Hard, tight surface. Aggregate visible.
- Highly variable surface texture.

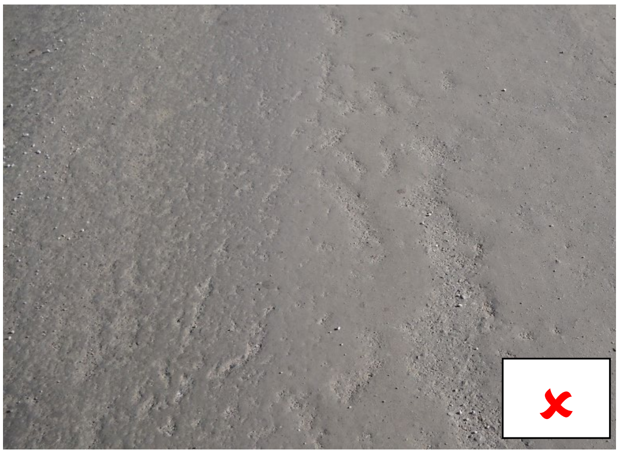
- Aggregate visible and mostly uniform.
- Windrow of excess fine particles swept from the surface resulting in bony and coarse surface finish.

- Isolated lamination (adjacent to pen) and pockets of tearing of the surface.
- Aggregate still visible with mostly uniform texture.

Source: VicRoads (2014).

Figure A 3: Examples of poorly prepared granular pavements

- Slurrying of fines on the surface.
- Non-uniform, soft uneven surface.
- Not level with adjacent kerb and channel.



- Scabbing and excess fines on the surface.
- Non-uniform texture.

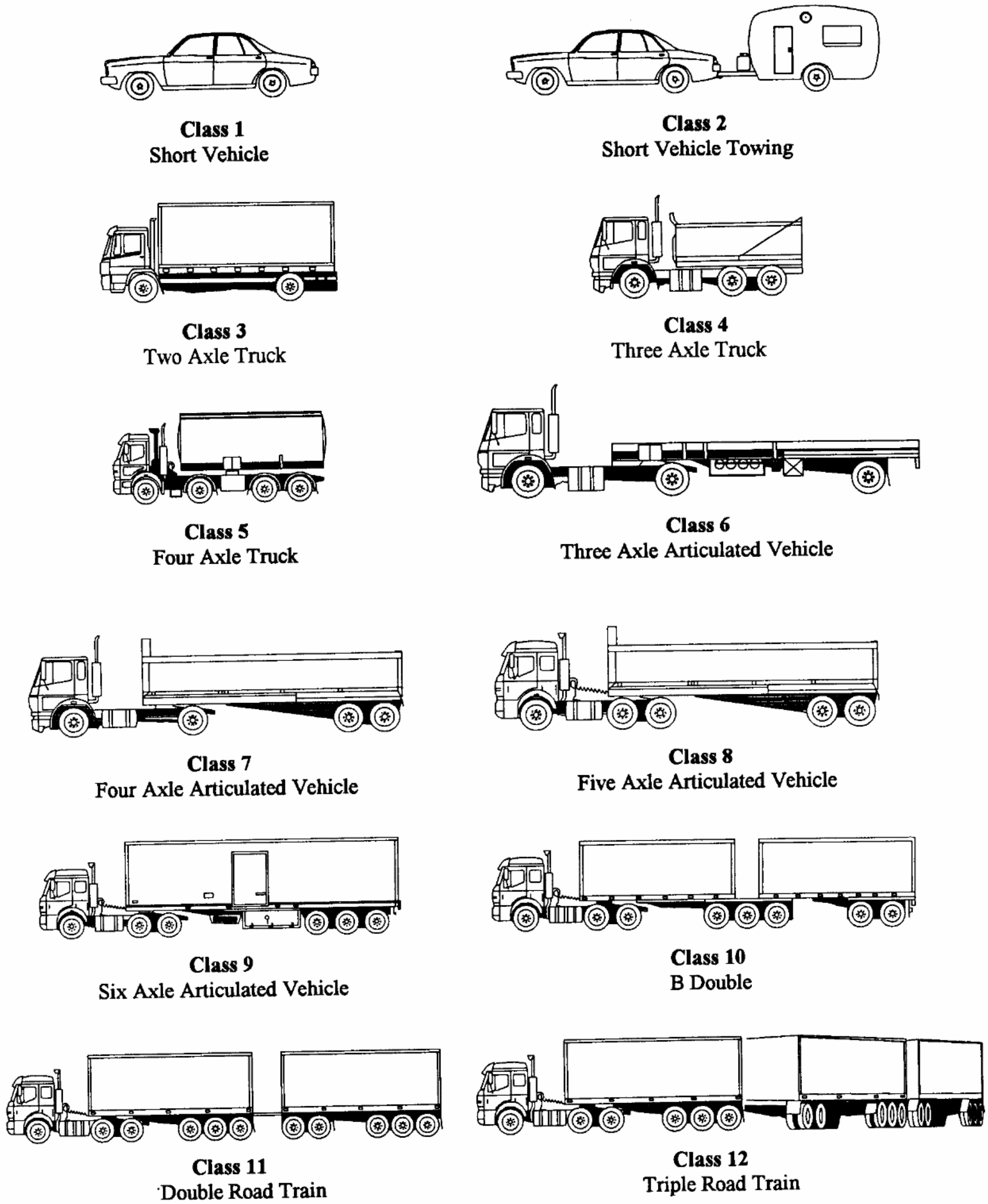
- Tearing and delamination of surface after sweeping.
- Non-uniform surface finish.

- Non-uniform surface finish/texture.
- Scabbing and tearing of the surface.
- Uneven drying indicates non-homogenous material.

Source: VicRoads (2014).

Appendix B Austroads Vehicle Classification

Figure B 1: Austroads vehicle classifications



Appendix C Worked Examples

Five design examples are described to show typical designs for determining rates of application of binder and aggregate spread rates. These examples cover:

- single/single reseal on a heavily trafficked rural highway
- double/double reseal carrying a high percentage of heavy vehicles
- single/single strain alleviating membrane (SAM) reseal
- geoxtextile reinforced seal (GRS)
- quarry access road.

These cover a range of traffic volumes and highlight the various adjustments and allowances that should be taken into consideration, as well as the calculations that must be carried out to determine the binder design application rate and aggregate spread rate.

Attention to detail is most important to ensure the design being prepared is appropriate to the job conditions. Some common errors observed in the design process, which directly affect the rates and therefore the outcome and performance of the sprayed seal are:

- insufficient attention being given to obtaining the latest traffic volumes required to determine the appropriate design traffic, particularly on the more complex and/or multi-lane situations
- not checking that the aggregate details provided by the supplier are relevant and apply to the aggregate being used on the job.

C.1 Single/single Reseal – 14 mm HSS1

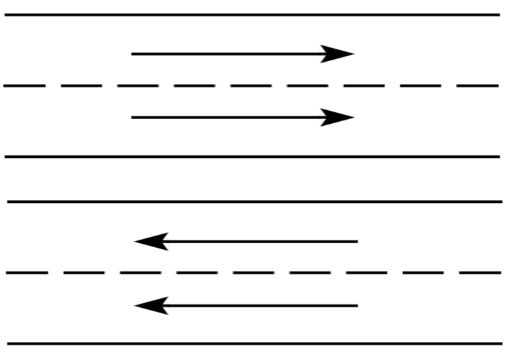
One carriageway of a duplicated highway is to be resealed to provide waterproofing and skid resistance for at least five years, at which time it is expected this section will be rehabilitated and upgraded by the addition of another lane.

The area to be resealed is on a long uphill (3% grade) section of the highway.

The climatic temperature conditions at the site are considered to be in the low category.

C.1.1 Job Details

Figure C 1: Carriageways of duplicated highway



The sealed pavement consists of 2 traffic lanes of 3.7 m width plus a sealed 2.0 m shoulder on the left-hand side.

The outside (left-hand) lane was rutted and also had some distressed areas. This has been patched and regulated with asphalt, about 12 months ago. The surface texture is uniform in appearance. It is too smooth for the sand patch test to determine a meaningful surface texture. A texture allowance, based on experience, of +0.1 L/m^2 is considered appropriate.

The right-hand (median) lane is a seal of size 10 mm basalt aggregate. It is reasonably uniform in appearance and texture, although along the edges and between the wheelpaths the texture is slightly coarser, but not enough to warrant a correction treatment. Sand patch test results for the wheelpaths give an average surface texture of 1.5 mm.

The shoulder is a seal of size 7 mm basalt applied at some stage to prevent further loss of the original size 10 mm aggregate. It is uniform in appearance but has a very coarse texture. The sand patch test results give an average surface texture of about 2.4 mm.

C.1.2 Traffic Data

Traffic – 6000 AADT, including 18% heavy vehicles, consisting of:

- standard heavy vehicles = 10% (SHV)
- large heavy vehicles = 8% (LHV).

Assume traffic is equal over the two carriageways, thus each carriageway carries 6000/2 = 3000 vehicles per day.

Determine the volume of each vehicle type in each carriageway:

- Volume of light vehicles = 82% of 3000 = 2460
- Volume of standard heavy vehicles = 10% of 3000 = 300
- Volume of large heavy vehicles = 8% of 3000 = 240.

An assumption on the proportion of traffic in each lane must be made (Section 5.2.4). It is assumed that the traffic is distributed in the proportions listed in Table C 1.

Table C 1: Distribution of traffic

Vehicle Type	Outside Lane (LH)	Median lane (RH)
Light vehicles	60%	40%
SHV	80%	20%
LHV	100%	0%

It is reasonable to assume that almost all of the SHV, and 100% of the LHV will travel in the outside lane.

The volume of each vehicle type, and the resultant percentage of equivalent heavy vehicles (Equation 2), must be calculated for each lane to make an appropriate adjustment to the basic voids factor.

The volumes of vehicles in each lane is calculated as per Table C 2.

Table C 2: Vehicle volume by lane

Vehicle Type	Outside Lane (LH)	Median lane (RH)
Light vehicles	60% of 2460 = 1476	40% of 2460 = 984
SHV	80% of 300 = 240	20% of 300 = 60
LHV	100% of 240 = 240	0% of 240 = 0
Total (v/l/d)	1956	1044

Therefore, using Equation 2 (Section 5.2.5), EHV(%) can be calculated:

Outside lane EHV (%) = SHV(%) + (LHV(%) x 3)

= (240/1956 x 100) + ((240/1956 x 3) x 100)

= 12.3 + 36.8 = 49.1% = Adopt 49%

Median lane EHV (%) = SHV(%) + (LHV(%) x 3)

= (60/1044 x 100) + 0

= 5.7% = Adopt 6%

An EHV(%) of 10% will be assumed for the shoulder.

Due to the uphill grade, traffic volume and high proportion of heavy vehicles in the outside line, a HSS1 seal has been selected for the reseal.

C.1.3 Aggregate

A HSS1 type seal has been selected for both lanes and the shoulder.

The aggregate properties are shown in Table C 3

Table C 3: Aggregate properties

Attribute	Property
Size/type	14 mm, basalt
Flakiness index	22%
ALD	8 mm

C.1.4 Binder

The high proportion of heavy vehicle traffic on an uphill grade can be considered as a moderately severe traffic loading, and thus suitable PMBs are S10E, S15E, S35E, S45R or S15RF (Table 4.7). The PMB selected is S15RF. The binder factor (BF) is 1.1 for this PMB (Table 6.4).

C.1.5 Seal Design

A summary of the seal design for both lanes and the shoulder is provided in Table C 4.

Table C 4: Design calculations

Attribute	Symbol	Units	Outside lane	Median lane	Shoulders
Traffic	–	AADT	6000	6000	See Table 5.2
Design traffic	–	v/l/d	1956	1044	Adopt ≤ 100
Basic voids factor	Vf	–	0.15 (Figure 6.2)	0.16 (Figure 6.2)	0.21 (Figure 6.1)
Adjustments: Aggregate shape Traffic effects Other	 Va Vt –	 L/m²/mm L/m²/mm L/m²/mm	 Nil (Table 6.1) –0.04 (Table 6.2) Nil	 Nil (Table 6.1) N/A (Table 6.2) Nil	 Nil (Table 6.1) N/A (Table 6.2) Nil
Design voids factor Vf + Va + Vt	VF	L/m²/mm	0.11 See Note 1	0.16	0.21
ALD of aggregate	ALD	mm	8.6	8.6	8.6
Basic binder rate VF × ALD	Bb	L/m²	0.11 × 8.6 = 0.95	0.16 × 8.6 = 1.38	0.21 × 8.6 = 1.81
Binder factor	BF	-	1.1 (Table 6.4)	1.1 (Table 6.4)	1.1 (Table 6.4)
Modified binder rate	Bbm	L/m²	0.95 × 1.1 = 1.04	1.38 × 1.1 = 1.51	1.81 × 1.1 = 1.99
Allowances: Surface texture Binder Abs. by Agg. Binder Abs. by Pav. Embedment	 Ast Aba Ap Ae	 L/m² L/m² L/m² L/m²	 + 0.1 (Table 6.3) Nil (Section 6.2.4) Nil (Section 6.2.4) Nil (Section 6.2.3)	 + 0.4 (Table 6.3) Nil (Section 6.2.4) Nil (Section 6.2.4) Nil (Section 6.2.3)	 + 0.5 (Table 6.3) Nil (Section 6.2.4) Nil (Section 6.2.4) Nil (Section 6.2.3)
Design binder rate Bbm + Ast + Aba + Ae	Bd	L/m²	1.04 + 0.1 = 1.14 adopt 1.1	1.51 + 0.4 = 1.91 adopt 1.9	1.99 + 0.5 = 2.49 adopt 2.5 See Note 1
Aggregate spread rate	–	m^2/m^3	900/ALD = 104.6 (Table 6.8) adopt 105	900/ALD = 104.6 (Table 6.8) adopt 105	900/ALD = 104.6 (Table 6.8) adopt 105

NOTES:

1 *Use of 2.5 L/m² for the shoulder is considered to be an expensive option for a reseal and has a high risk of binder drainage in hot weather. Alternatives that may be considered include enrichment, or a small sized aggregate seal as this will provide a more economical and fit for purpose treatment.*

C.2 Double/double Seal Carrying a High Percentage of Heavy Vehicles

An access road to an industrial subdivision has been initially sealed (7 mm) to cater for construction traffic. The final double/double seal is to be applied prior to opening to traffic, which is expected to include heavy vehicles delivering building and construction materials.

Both layers of the seal will be constructed on consecutive days prior to opening to traffic.

The climatic temperature conditions at the site are considered to be in the low category.

C.2.1 Job Details

The alignment is straight and level. An intersection near the end of the work, providing access into the subdivision, will be surfaced with dense graded asphalt.

Pavement is 7.6 m between kerbs.

Existing initial seal is a size 7 mm, with a uniform surface texture, with an average of 1 mm as measured with the sand patch test.

The initial seal is over 12 months old and has a very tight mosaic. Aggregate embedment of the final seal is considered to be nil.

Traffic is estimated to be about 1800 AADT, with 35% heavy vehicles which will mainly be large trucks and semi-trailers with few very large vehicles.

C.2.2 Traffic Data

Traffic – 1800 AADT, including 35% heavy vehicles consisting of:

- standard heavy vehicles = 35% (HV)
- large heavy vehicles = 0% (LHV).

The road section is two-lane, two-way, with an even split of traffic in each direction, over a width of 7.6 m. Thus the design traffic is 1800/2 = 900 v/l/d.

Therefore, using Equation 2 (Section 5.2.5), EHV (%) can be calculated:

EHV (%) = SHV(%) + (LHV(%) x 3)

= (35) + (0 x 3)

= 35%.

C.2.3 Aggregate

The aggregate properties are shown in Table C 5.

Table C 5: Aggregate properties

Attribute	Property	
	1st application	2nd application
Size/type	14 mm, basalt	7 mm, basalt
Flakiness index	16%	30%
ALD	8.7 mm	4.4 mm

C.2.4 Binder

A C170 binder will be used for this seal. The binder factor (BF) is 1.0 (Table 6.5).

C.2.5 Seal Design

A summary of the seal design is provided in Table C 6.

Table C 6: Design calculations

Attribute	Symbol	Units	1st Application (14 mm)	2nd Application (7 mm)
Traffic	–	AADT	1800	1800
Design traffic	–	v/l/d	900	900
Basic voids factor	Vf	–	0.13 (Figure 6.4)	0.16 (Figure 6.4)

Attribute	Symbol	Units	1st Application (14 mm)	2nd Application (7 mm)
Adjustments: Aggregate shape Traffic effects Other	 Va Vt –	 L/m²/mm L/m²/mm L/m²/mm	 0.0 (Table 6.1) –0.02 (Table 6.2) Nil	 –0.01 (Table 6.1) –0.02 (Table 6.2) Nil
Design voids factor Vf + Va + Vt	VF	L/m²/mm	0.11	0.13
ALD of aggregate	ALD	mm	8.7	4.4
Basic binder rate VF × ALD	Bb	L/m²	0.11 × 8.7 = 0.96	0.13 × 4.4 = 0.57
Binder factor	BF	–	1.0 (Table 6.5)	1.0 (Table 6.5)
Modified binder rate	Bbm	L/m²	0.96 × 1.0 = 0.96	0.57 × 1.0 = 0.57
Allowances: Surface texture Binder Abs. by Agg. Binder Abs. by Pav. Embedment	 Ast Aba Ap Ae	 L/m² L/m² L/m² L/m²	 +0.3 (Table 6.3) Nil (Section 6.2.4) Nil (Section 6.2.4) Nil (Section 6.2.3)	 N/A Nil (Section 6.2.4) N/A N/A
Design binder rate Bbm + Ast + Aba + Ae	Bd	L/m²	0.96 + 0.3 = 1.26 Adopt 1.3	0.57 Adopt 0.6
Aggregate spread rate	–	m^2/m^3	950/ALD = 109.2 (Table 6.11) Adopt 110	900/ALD = 204.5 (Table 6.12) Adopt 205

C.3 Single/single SAM Reseal

A rural road is to be resealed. The traffic loading is increasing over time, and the pavement is cracked extensively. There is no loss of shape, and the crack activity would be rated as low, with cracks generally only about 2 to 3 mm in width. As the sub-grade is considered moisture sensitive, it has been decided to apply a SAM to minimise reflection cracking.

C.3.1 Job Details

The alignment is across mildly undulating country.

Sealed width is 6.8 m.

Existing seal is a size 14 mm single/single, about 15-years old, with minor single-stone aggregate loss only.

Surface texture is fairly uniform, with an average of 1.8 mm as measured with the sand patch test.

A PMB binder is required for a SAM.

C.3.2 Traffic Data

Traffic is estimated to be 300 AADT, with 12% heavy vehicles consisting of:

- standard heavy vehicles = 10% (HV)
- large heavy vehicles = 2% (LHV).

The road section is two-lane, two-way, with an even split of traffic in each direction, thus the design traffic is 300/2 = 150 v/l/d. While the seal width is only 6.8 m wide, the traffic lanes are not considered to be narrow enough to cause channelisation, and traffic conditions are considered to be 'normal'.

Therefore, using Equation 2 (Section 5.2.5), EHV (%) can be calculated:

EHV (%) = SHV(%) + (LHV(%) x 3)

= (10) + (2 x 3)

= 16%.

C.3.3 Aggregate

The aggregate properties are shown in Table C 7.

Table C 7: Aggregate properties

Attribute	Property
Size/type	10 mm, schist (good quality local aggregate)
Flakiness index	18%
ALD	6.4 mm

C.3.4 Binder

Because the cracking is considered environmental and slow moving, suitable PMBs for the SAM are S10E, S35E or S45R (Table 4.7). The PMB selected is S35E. The binder factor (BF) is 1.2 for this PMB (Table 6.4).

C.3.5 Seal Design

A summary of the seal design is provided in Table C 8.

Table C 8: Design calculations

Attribute	Symbol	Units	10 mm reseal
Traffic	–	AADT	300
Design traffic	–	v/l/d	150
Basic voids factor	Vf	–	0.2 (Figure 6.1)
Adjustments: Aggregate shape Traffic effects Other	 Va Vt –	 L/m²/mm L/m²/mm L/m²/mm	 Nil (Table 6.1) –0.01 (Table 6.2) Nil
Design voids factor Vf + Va + Vt	VF	L/m²/mm	0.19
ALD of aggregate	ALD	mm	6.4
Basic binder rate VF × ALD	Bb	L/m²	0.19 × 6.4 = 1.22
Binder factor	BF	–	1.2 (Table 6.4)
Modified binder rate	Bbm	L/m²	1.22 × 1.2 = 1.46
Allowances: Surface texture Binder Abs. by Agg. Binder Abs. by Pav. Embedment	 Ast Aba Ap Ae	 L/m² L/m² L/m² L/m²	 +0.4 (Table 6.3) Nil (Section 6.2.4) Nil (Section 6.2.4) Nil (Section 6.2.3)
Design binder rate Bbm + Ast + Aba + Ae	Bd	L/m²	1.46 + 0.4 = 1.86 adopt 1.9

Attribute	Symbol	Units	10 mm reseal
Aggregate spread rate	–	m^2/m^3	900/ALD = 140.6 (Table 6.8) Adopt 140

C.4 Geotextile Reinforced Seal (GRS)

A two-lane, two-way rural highway is to be resealed.

A 14/7 double/double initial seal was placed 8 years ago. The seal has significant block cracking in the traffic lanes, where shrinkage cracks from the cementitious stabilised base have reflected through.

A geotextile reinforced seal will be placed in the traffic lanes, utilising a double/double seal over the geotextile layer. The shoulders will be sealed with a 7 mm single/single seal and will not utilise a geotextile.

C.4.1 Job Details

The alignment is straight and level. The sealed pavement consists of 2 traffic lanes of 3.7 m width, plus sealed shoulders of 1.0 m width on each side.

Both lanes have block cracking throughout. There has been no significant loss of shape.

The existing seal has a uniform surface texture, with an average of 1.5 mm as measured with the sand patch test. The texture in the shoulders is measured at 1.9 mm.

A recent traffic survey has indicated a traffic volume of 2000 AADT, with 25% heavy vehicles, 10% being large heavy vehicles.

C.4.2 Traffic Data

Traffic – 2000 AADT, including 25% heavy vehicles consisting of:

- standard heavy vehicles = 15% (SHV)
- large heavy vehicles = 10% (LHV).

The road section is two-lane, two-way, with an even split of traffic in each direction, over a width of 7.6 m. Thus the design traffic is 2000/2 = 1000 v/l/d.

Using Equation 2 (Section 5.2.5), EHV (%) can be calculated for the trafficked lanes:

EHV (%) = SHV(%) + (LHV(%) x 3)

= (15) + (10 x 3)

= 45%.

A traffic volume of < 100 v/l/d (with 0 EHV(%)) will be adopted for the shoulders.

C.4.3 Aggregate

A 14/7 double/double seal will be used for the traffic lanes. A 7 mm single/single seal will be used in the shoulders.

The aggregate properties are shown in Table C 9.

Table C 9: Aggregate properties

Attribute	Property	
	1st application	2nd application & shoulders
Size/type	14 mm, basalt	7 mm, basalt
Flakiness index	30%	24%
ALD	9.0 mm	4.6 mm

C.4.4 Binder

A C170 binder will be used for this seal. The binder factor (BF) is 1.0 (Table 6.5).

GRS seals are designed according to the conventional procedures, with allowances added for binder retention by the fabric.

A fabric with mass of 180 g/m^2 will be suitable for use with the overlying 14 mm aggregate (Section 3.3.9).

Using the procedure outlined in Section 6.5.1, a binder retention allowance of 1.2 L/m^2 has been selected. A bond coat application rate of 0.5 L/m^2 will be used (Section 6.5.2), resulting in the remaining 0.7 L/m^2 of the allowance being added to the first layer of the seal.

C.4.5 Seal Design

A summary of the seal design is provided in Table C 10.

Table C 10: Design calculations

Attribute	Symbol	Units	1st Application (14 mm)	2nd Application (7 mm)	Shoulders (7 mm)
Traffic	–	AADT	2000	2000	See Table 5.2
Design traffic	–	v/l/d	1000	1000	Adopt < 100
Basic voids factor	Vf	–	0.13 (Figure 6.4)	0.16 (Figure 6.4)	0.21 (Figure 6.1)
Adjustments: Aggregate shape Traffic effects Other	 Va Vt –	 L/m²/mm L/m²/mm L/m²/mm	 –0.01 (Table 6.1) –0.02 (Table 6.2) Nil	 0.0 (Table 6.1) –0.02 (Table 6.2) Nil	 0.0 (Table 6.1) 0.02 (Table 6.2) Nil
Design voids factor Vf + Va + Vt	VF	L/m²/mm	0.13 – 0.01 – 0.02 = 0.10	0.16 - 0.01 - 0.02 = 0.13	0.21 + 0.02 = 0.23
ALD of aggregate	ALD	mm	9.0	4.6	4.6
Basic binder rate VF × ALD	Bb	L/m²	0.10 × 9.0 = 0.90	0.13 × 4.6 = 0.60	0.23 × 4.6 = 1.06
Binder factor	BF	–	1.0 (Table 6.5)	1.0 (Table 6.5)	1.0 (Table 6.5)
Modified binder rate	Bbm	L/m²	0.9 × 1.0 = 0.9	0.60 × 1.0 = 0.60	1.06 × 1.0 = 1.06
Allowances: Surface texture Binder Abs. by Agg. Binder Abs. by Pav. Embedment	 Ast Aba Ap Ae	 L/m² L/m² L/m² L/m²	 + 0.4 (Table 6.3) Nil (Section 6.2.4) Nil (Section 6.2.4) Nil (Section 6.2.3)	 N/A Nil (Section 6.2.4) N/A N/A	 + 0.3 (Table 6.3) Nil (Section 6.2.4) Nil (Section 6.2.4) Nil (Section 6.2.3)
Design binder rate Bbm + Ast + Aba + Ae	Bd	L/m²	0.9 + 0.4 = 1.3	0.6	1.06 + 0.3 = 1.36 Adopt 1.4

Attribute	Symbol	Units	1st Application (14 mm)	2nd Application (7 mm)	Shoulders (7 mm)
Aggregate spread rate	–	m^2/m^3	950/ALD = 105.5 (Table 6.11) Adopt 105	900/ALD = 195.7 (Table 6.12) Adopt 195	900/ALD = 195.6 (Table 6.11) Adopt 195

The final step of the seal design is to apportion the geotextile binder retention allowance to the design binder application rates.

The bond coat will be applied at 0.5 L/m^2.

The remaining 0.7 L/m^2 of the binder retention allowance is added to the binder design rate of the first layer of the seal as follows:

First layer binder application rate = binder design rate + remaining geotextile binder retention allowance

= 1.3 + 0.7

= 2.0 L/m^2.

The second layer of the double/double binder is applied as designed in Table C 6.

Additionally, all longitudinal joints of geotextile reinforced seals are overlapped. Guidance for overlapping is provided in Austroads (2014b).

C.5 Quarry Access Road

C.5.1 Job Details

A single-lane road from a quarry is to be sealed. The road will carry traffic in one direction only, as vehicles are leaving the quarry site. The road is flat and straight.

A new cement stabilised pavement has been constructed. The pavement was primed with AMC00 at a rate of 0.7 L/m^2 based on guidance from Table 5.4 and the results of small-scale trials conducted on site. Traffic was diverted from the road for 5 days while the prime cured.

Following curing, a ball penetration test on the primed surface gave a value of 2.5 mm.

Traffic is estimated to be 250 AADT, with 50% of that traffic being heavy vehicles, made up of 35% SHV and 15% LHV.

A HSS1 seal will be used for the quarry access road.

C.5.2 Traffic Data

The road is a single-lane, one-way road, with a width of 4.0 m.

Traffic – 250 AADT, including 50% heavy vehicles consisting of:

- standard heavy vehicles = 35% (HV)
- large heavy vehicles = 15% (LHV).

Therefore, using Equation 2 (Section 5.2.5), EHV (%) can be calculated:

EHV (%) = SHV(%) + (LHV(%) x 3)

= (35) + (15 x 3)

= 80%.

As the EHV(%) exceeds 65%, it is recommended to follow the procedure outlined in Section 5.2.7 to determine a nominal traffic volume for selection of an alternative basic voids factor, as follows:

Nominal design traffic volume = (SHV + 3 × LHV) × 10 + number of light vehicles

= (250 × 0.35 + 3 × 250 × 0.15) × 10 + 125

= (88 + 113) × 10 + 125

= 2135.

The nominal design traffic volume of 2135 is used to determine the basic voids factor.

C.5.3 Aggregate

The aggregate properties are shown in Table C 11.

Table C 11: Aggregate properties

Attribute	Property
Size/type	14 mm, basalt
Flakiness index	22%
ALD	8.9 mm

C.5.4 Binder

S45R will be used for this HSS1. The binder factor (BF) is 1.1 (Table 6.4).

C.5.5 Seal Design

A summary of the seal design is provided in Table C 12.

Table C 12: Design calculations

Attribute	Symbol	Units	10 mm reseal
Traffic	–	AADT	250
Design traffic	–	v/l/d	2135
Basic voids factor	Vf	–	0.15 (Figure 6.2)
Adjustments: Aggregate shape Traffic effects Other	 Va Vt –	 L/m²/mm L/m²/mm L/m²/mm	 Nil (Table 6.1) Nil (Table 6.2) Nil
Design voids factor Vf + Va + Vt	VF	L/m²/mm	0.15
ALD of aggregate	ALD	mm	8.9
Basic binder rate VF × ALD	Bb	L/m²	0.15 × 8.9 = 1.34
Binder factor	BF	–	1.1 (Table 6.4)

Attribute	Symbol	Units	10 mm reseal
Modified binder rate	Bbm	L/m²	1.34 × 1.1 = 1.47
Allowances: Surface texture Binder Abs. by Agg. Binder Abs. by Pav. Embedment	 Ast Aba Ap Ae	 L/m² L/m² L/m² L/m²	 +0.2 (Section 6.2.2) Nil (Section 6.2.4) Nil (Section 6.2.4) –0.1 (Figure 6.5)
Design binder rate Bbm + Ast + Aba + Ae	Bd	L/m²	1.47 + 0.2 – 0.1 = 1.57 adopt 1.6
Aggregate spread rate	–	m^2/m^3	900/ALD = 101.1 (Table 6.8) Adopt 100

Appendix D Determination of Maximum Pavement Temperature

For this Guide, the pavement temperature regime is categorised as low, medium or high, based on maximum pavement temperatures determined in accordance with the procedures described below.

Pavement temperature categories used for the selection of modified binders are shown in Table D 1.

Table D 1: Pavement surface temperature

Maximum pavement surface temperature	Temperature category
< 52 °C	Low
52–58 °C	Medium
> 58 °C	High

The values contained in the following tables may be used to select a maximum pavement surface temperature (T_{max}) (°C) for use in assessing the pavement temperature regime (Table D 1).

The following method was used to calculate the T_{max} at each site using data from the Australian Bureau of Meteorology web site (http://www.bom.gov.au):

1. For each state or territory consult climate averages listed under climate information.
2. Select monthly statistics for the appropriate site from the alphabetical list. For example, Victorian sites are listed under http://www.bom.gov.au/climate/averages/tables/ca_vic_names.shtml.
3. Use 'all available' statistics to view detailed data.
4. Determine the highest 'decile 9 maximum temperature' (90^{th} percentile, or T_{90}, temperature) for the selected site.
5. Record the latitude of the site, also shown on the same web page.
6. Use the appropriate relationship from Table D 2 for the site latitude to determine T_{max} for the site.

Table D 2: T_{max} by latitude

Latitude	Relationship between T_{max} and T_{90}
> 41°S	$T_{max} = T_{90} + 20$ °C
35°S to 41°S	$T_{max} = T_{90} + 21$ °C
27°S to 35°S	$T_{max} = T_{90} + 22$ °C
24°S to 27°S	$T_{max} = T_{90} + 23$ °C
< 24°S	$T_{max} = T_{90} + 24$ °C

T_{max} values for various places in Australia are provided in Table D 3 and Table D 4.

Table D 3: T_{max} for Australian capital cities

Capital cities			
Site	Latitude	T_{90}	T_{max}
Adelaide airport	35.0	36.4	58
Brisbane	27.5	32.7	55
Canberra	35.3	35.0	56

Capital cities			
Site	**Latitude**	**T_{90}**	**T_{max}**
Darwin airport	12.4	34.9	59
Hobart	42.9	27.8	48
Melbourne	37.8	35.6	57
Perth airport	31.9	38.5	61
Sydney (CBD)	33.9	30.1	52

Table D 4: T_{max} for Australian locations

New South Wales & ACT			
Site	**Latitude**	**T_{90}**	**T_{max}**
Albury	36.1	37.9	59
Armidale	30.5	31.0	53
Bathurst	33.4	34.1	56
Bega	36.7	33.4	54
Bellingen	30.5	35.4	58
Blayney	33.5	31.7	55
Bourke	30.1	42.2	64
Braidwood	35.4	34.5	56
Broken Hill	32.0	39.8	62
Byron Bay	28.6	30.4	52
Campbelltown	34.1	35.8	58
Canberra	35.3	35.0	56
Casino	28.9	35.7	58
Cessnock	32.8	37.7	60
Cobar	31.5	41.1	63
Cooma	36.2	33.7	54
Coonabarabran	31.3	36.6	59
Cowra	33.9	37.8	60
Deniliquin	35.6	40.0	61
Dubbo	32.2	38.2	60
Forbes	33.4	39.8	62
Glen Innes	29.7	30.9	53
Gosford	33.4	33.9	56
Goulburn	34.8	35.0	57
Grafton	29.7	34.9	57
Griffith	34.3	37.4	59
Gundagai	35.1	38.6	60
Hay	34.5	40.0	62
Inverell	29.8	34.7	57
Katoomba	33.7	30.2	52

New South Wales & ACT			
Site	**Latitude**	**T_{90}**	**T_{max}**
Liverpool	33.9	34.6	59
Merimbula	36.9	27.3	48
Molong	33.1	36.1	58
Moree	29.5	38.2	60
Moruya	35.9	26.1	47
Moss Vale	34.5	31.5	55
Mudgee	32.6	36.2	58
Murwillumbah	28.4	33.6	56
Narooma	36.2	26.6	48
Narrabri	30.3	38.5	61
Narrandera	34.7	39.4	61
Newcastle	32.9	29.4	51
Nowra	34.9	31.9	54
Nyngan	31.6	40.0	62
Orange	33.3	33.3	55
Parkes	33.2	38.0	60
Parramatta	33.8	35.0	57
Port Macquarie	31.5	28.0	50
Richmond	33.6	35.5	58
Singleton	32.6	37.6	60
Sydney (CBD)	33.9	30.1	52
Tamworth	31.1	37.0	59
Taree	31.9	34.5	58
Tenterfield	29.1	31.5	54
Thredbo	36.5	27.0	48
Tumut	35.3	35.6	57
Wagga Wagga	35.2	37.9	59
Walgett	31.0	41.1	63
Wellington	32.5	36.8	59
Wentworth	34.1	40.0	62

New South Wales & ACT			
Site	Latitude	T_{90}	T_{max}
Kempsey	31.1	32.5	55
Kiandra	35.9	26.1	47
Lismore	28.8	34.5	57
Lithgow	33.5	32.0	54

New South Wales & ACT			
Site	Latitude	T_{90}	T_{max}
Wilcannia	31.6	42.0	64
Wollongong	34.4	30.4	52
Yass	34.8	36.0	58
Young	34.3	37.0	59

Victoria			
Site	Latitude	T_{90}	T_{max}
Bairnsdale	37.8	34.0	55
Ballarat	37.5	33.7	55
Benalla	36.6	37.0	58
Bendigo	36.8	36.1	57
Bright	36.7	34.9	56
Colac	38.3	35.0	56
Dandenong	38.0	35.0	56
Echuca	36.2	38.2	59
Frankston	38.2	32.3	53
Geelong	38.1	34.4	55
Horsham	36.7	37.8	59
Melbourne	37.8	35.6	57
Mildura	34.2	40.6	63
Nhill	36.3	37.8	59
Omeo	37.1	32.9	54
Orbost	37.7	34.3	55
Ouyen	35.1	39.9	61
Swan Hill	35.3	38.3	59
Wangaratta	36.4	37.2	58
Warragul	38.2	34.0	55
Warrnambool	38.4	32.3	53
Wodonga	36.1	37.8	59
Yallourn	38.2	33.0	54

Queensland			
Site	Latitude	T_{90}	T_{max}
Bowen	20.0	33.7	58
Brisbane	27.5	32.7	55
Cairns	16.9	34.4	58
Caloundra	26.8	29.8	53
Charleville	26.4	41.1	65
Charters Towers	20.1	38.6	63
Cooktown	15.5	33.9	58
Cunnamulla	28.1	41.1	63
Dalby	27.2	36.7	59
Emerald	23.5	38.9	63
Georgetown	18.3	39.4	63
Gympie	26.2	35.4	58
Ipswich	27.6	36.3	58
Kingaroy	26.6	33.7	57
Mackay	21.1	32.8	57
Maryborough	25.5	33.5	57
Miles	26.7	37.3	60
Monto	24.9	36.0	59
Mount Isa	20.7	41.7	66
Nambour	26.6	33.7	57
Rockhampton	23.4	35.8	60
Roma	26.6	38.9	62
Southport	28.0	31.2	53
St George	28.0	39.0	61
Toowoomba	27.6	32.2	54
Townsville	19.2	33.5	58
Warwick	28.2	34.5	57

South Australia			
Site	**Latitude**	**T_{90}**	**T_{max}**
Adelaide Airport	35.0	36.4	58
Ceduna	32.1	40.0	62
Coober Pedy	29.0	43.0	65
Keith	36.1	38.2	59
Mount Gambier	37.8	33.6	55
Murray Bridge	35.1	38.4	59
Port Augusta	32.5	40.2	62
Port Pirie	33.2	40.0	62
Renmark	34.2	39.8	62
Whyalla	33.0	39.0	61

Northern Territory			
Site	**Latitude**	**T_{90}**	**T_{max}**
Alice Springs	23.7	41.1	65
Barrow Creek	21.5	41.2	65
Daly Waters	16.3	40.6	65
Darwin Airport	12.4	34.9	59
Katherine	14.5	40.3	64
Tennant Creek	19.6	41.6	66

Tasmania			
Site	**Latitude**	**T_{90}**	**T_{max}**
Burnie	41.1	24.5	45
Campbell Town	41.9	30.3	50
Devonport	41.2	24.0	45
Flinders Island	40.1	27.5	49
Geeveston	43.2	28.9	49
Hobart	42.9	27.8	48
King Island	39.9	25.3	46
Launceston	41.5	28.5	49
New Norfolk	42.8	30.5	51
Queenstown	42.1	29.3	49
St Helens	41.3	28.2	48
Scottsdale	41.2	27.6	49
Swansea	42.1	27.2	47

Western Australia			
Site	**Latitude**	**T_{90}**	**T_{max}**
Albany	35.0	27.1	50
Broome	18.0	37.8	62
Bunbury	33.4	35.1	57
Cape Leeuwin	34.4	26.0	48
Carnarvon	24.9	37.8	63
Dampier	20.7	41.0	65
Esperance	33.8	34.8	57
Eucla	31.7	37.3	59
Fremantle	32.1	36.0	58
Geraldton	28.8	40.1	62
Kalgoorlie	30.8	40.6	63
Kununurra	15.8	41.4	65
Manjimup	34.3	34.4	56
Meekatharra	26.6	42.2	65
Merredin	31.5	40.0	62
Morawa	29.2	42.2	64
Mt Magnet	28.1	42.9	65
Narrogin	32.9	37.2	59
Norseman	32.2	39.1	61
Northam	31.7	40.5	63
Ongerup	34.0	36.0	58
Paraburdoo	23.2	44.1	68
Perth Airport	31.9	38.5	61
York	31.9	40.3	62

Appendix E Guidance to Field Application of PMBs and Multigrade Bitumens

Modified binders and multigrade bitumens are generally handled and applied similarly to C170 bitumen using conventional sprayed sealing equipment but require increased attention to detail and special consideration of the field construction practices to ensure satisfactory adhesion between the binder and the aggregate.

If using a particular class of PMB or multigrade bitumen for the first time, it is advisable to check with the manufacturer about any special handling or application requirements.

E.1 Adhesion and Cohesion Characteristics

The fluid characteristics of a PMB are very different from those of conventional bitumen. Increases in viscosity and binder cohesion (internal strength) as a result of polymer modification are usually accompanied by a decrease in binder wetting ability (adhesion) and therefore a reduction in the capacity for initial adhesion to the aggregate particle.

Particular attention is required to all aspects of field procedures that influence adhesion, including:

- use of adhesion agent
- aggregate condition and precoating
- cutting back
- ambient conditions and preparation of pavements
- spraying and covering of binder.

E.1.1 Use of Adhesion Agent

Recommended practice is to add adhesion agent to promote bonding with the aggregate particles. In most instances, double the amount of adhesion agent used for conventional C170 bitumen is required. It must be added to the sprayer about half an hour prior to spraying and the load thoroughly circulated. Most commonly used adhesion agents are not heat stable and should not be added to a tanker or other storage. Repeated dosage of adhesion agents to compensate for loss of effectiveness in storage can have an adverse effect on adhesion.

The adhesion agent selected must be compatible with the type of binder and the aggregate precoating material (see the discussion on aggregate precoating materials, below).

E.1.2 Aggregate Precoating

It is important to only use aggregate of good quality that is dry and free from dust. This applies to all PMB seals, including those applied on lower traffic volume roads. It is not uncommon for seals using PMB classes with relatively high polymer contents to perform satisfactorily in dry and warm weather but lose a considerable portion of the aggregate during the first wet and/or cold weather if precoating and work practices are inadequate.

With PMB seals, aggregate precoating is most important and a bitumen-based precoat, containing about 1% of adhesion agent, is recommended at all times to ensure both initial adhesion with, and longer-term retention of the aggregate.

The PMB/adhesion agent/aggregate/precoat system must be evaluated well in advance of the work, using both initial adhesion and plate stripping tests. Check with the adhesion agent supplier if unsure of the dosage details. It is also recommended that the user check with the local road agency regarding adhesion agents and/or precoating materials.

E.1.3 Cutting Back

Guidelines for cutting back of PMBs and multigrade bitumen are provided in Appendix E.2.

E.1.4 Ambient Conditions

For most SAM applications, the pavement and air temperatures need to be above 20 °C, and higher still where wind chill is expected to cool the binder quickly after spraying. Wind chill will cause the binder to 'skin' more quickly and this will delay, or prevent, wetting and adhesion.

The presence of moisture in any form should be avoided, and less risk taken with respect to expected changes in weather conditions. The SAM should be sprayed only on a dry pavement surface, using only dry precoated aggregate to ensure good results. This may require the aggregate stockpile to be covered with plastic or a similar waterproofing material.

Concrete and timber bridge decks will require priming with a light grade of cutback bitumen prior to the application of a modified binder seal to ensure proper bonding. The presence of certain curing compounds (chlorinated rubber, hydrocarbon resin) on concrete bridge decks can cause bonding problems and must be removed prior to application of the prime and/or seal coat. If in doubt, compatibility with the primer and/or modified binder should be investigated.

Warm and dry weather conditions before and after application of the PMB or multigrade bitumen seal are desirable. Subsequent cold and/or wet weather may result in the aggregate stripping if the adhesive bond is not adequate.

Ambient conditions are less critical for SAMI applications where an asphalt overlay is to be applied without trafficking of the SAMI.

E.1.5 Spraying of Binder, Spreading and Rolling of Aggregates

The time available to incorporate the aggregate into a PMB or multigrade bitumen is relatively short. Keeping aggregate spreading and rolling operations as close as possible behind the sprayer is more critical than when spraying C170 bitumen and may necessitate shorter-than-usual sprayer runs.

There must be sufficient rollers to cover the full sprayer run width with one pass and additional rollers may be required as compared to conventional bitumen work.

Some of the more viscous (high consistency) modified binders will require the use of larger spray nozzles, depending on binder viscosity, to ensure a uniform transverse binder application.

When field mixing crumb rubber binders, the material must be continually circulated to minimise settling out of any rubber particles. Failure to do this may result in blockages of the spraying jets and/or pipe work or spraying of a segregated product.

Field-produced crumb rubber mixtures should not be stored in bitumen sprayers, road tankers or bulk storage due to the potential problem of segregation and settling out of the rubber particles which may result in blocked pipe work.

In locations where a potential for early damage to a new single/single seal exists (e.g. farming entry points, minor intersections), the use of a scatter coat of small size aggregate (7 mm for a 14 mm seal and 5 mm for a 10 mm seal) or double/double seal should be considered.

E.1.6 Checking Adhesion

A field check should be made by lifting an aggregate particle from the binder about one minute after spreading or dropping into freshly sprayed binder. The aggregate should retain a coating of binder as it is removed from the pavement. Little or no adhering binder can indicate a need to vary procedures (e.g. extended rolling) to ensure adequate adhesion.

E.2 Cutting Back PMB or Multigrade Bitumen

This section provides guidance on the proportion of cutter to be added to the various classes of PMBs specified in Austroads (2014c) and multigrade bitumens in AS 2008.

The PMB cutting practice is based on the same principles that apply to C170 bitumen with the amount of cutter oil added related to the class of PMB, prevailing weather conditions, traffic, aggregate size, and type and condition of precoating. The primary purpose of cutting bituminous binders is to soften the binder temporarily to enable it to achieve adhesion and to keep the binder soft enough to allow traffic to fully embed the aggregate into the binder.

E.2.1 Safety

Cutting back hot bituminous binders can be a hazardous operation. Guidelines for safe handling and cutting back of bituminous binders are provided in the *Bituminous Materials Safety Guide* (Austroads 2015) including special requirements for the field blending of PMB materials.

E.2.2 Pavement Temperature Assessment

In sprayed work, it is critical to correctly assess the pavement surface temperature applicable for determining the concentration of cutter oil, and this is even more important for polymer modified binder seals. Measurement of pavement temperature should give due consideration to the conditions that the pavement will be subjected to over the day and following night. For example, a pavement that is in sunshine during the middle of the day may be in the shade of trees or shadowed within a roadway cutting during the remainder of the day. In this case the quantity of cutter oil added should be based on the likely temperature of the shaded areas of pavement.

The expected prevailing weather conditions for the next few weeks should also be considered. If in doubt, the cutter oil requirement should be based on the worst of the expected conditions.

E.2.3 Type of Cutter Oil

In most cases, conventional cutter oils (e.g. lighting kerosene or aviation jet fuel) are satisfactory. Some polymers may require a particular type of cutter oil for compatibility. If unsure, check with the manufacturer regarding the type of cutter oil recommended.

The crumb rubber modified binders can be cut back using conventional cutter oils.

E.2.4 Selecting the Proportion of Cutter Oil

Table E 1 is a guide to the concentration of cutter oil that should be added to PMBs. Table E 1 refers to the use of cutter oil in single application seals or the second application of double/double seals. In double/double seal applications, where the second application is applied with little or no trafficking between applications, the proportion of cutter oil in the first application should be reduced to a maximum of 4 parts.

In SAMI applications, where the seal is to be covered with asphalt within a short period (e.g. several days), it is undesirable to add any cutter oil. However, if used, the maximum added should not exceed two parts of cutter oil.

Table E 1: Guide to cutting practice for PMBs

Guide to cutting practice for PMBs (1), (2) (parts by volume of cutter oil to be added to 100 parts of PMB measured at 15 °C (3), (4))						
Pavement temperature (°C) (5)	Traffic v/l/d* (traffic used to design rates of application)	Class of PMB (2, 3)				
		S10E	S15E	S20E	S35E	S45R (6) S15RF
20–25	< 1000 ≥ 1000	6 4	6–8 4–6	8 6–8	6 4	10 8
26–32	< 1000 ≥ 1000	4 2	4–6 2–4	6 4–6	4 2	6–8 6
33–38	< 1000 ≥ 1000	2 2	2–4 2	4 2–4	2 2	6 4–6
39–45	< 1000 ≥ 1000	0–2 0–2	2 2	2 2	0–2 0–2	4–6 4
> 45	All traffic	0–2	2	2	0–2	4

1 *In SAMI applications, where the seal is to be covered with asphalt within a short period, it is undesirable to add any cutter oil at all, and the maximum added should not exceed 2 parts of cutter oil.*

2 *Proportions of cutter oil refer to use in single/single seals or the second application of double/double seals. In double/double seal applications, where the second application is applied with little or no trafficking between applications, the proportion of cutter oil in the first application should be reduced to 2–4 parts maximum.*

3 *Where cutter proportions are added as a percentage of total binder, the proportions shown here as parts per 100 parts of PMB may be taken as a reasonable approximation of percentage by volume.*

4 *At high rates of application of PMB, say over 2 L/m², the cutter oil may be reduced by 2 parts.*

5 *Pavement temperatures used to determine the proportion of cutter oil should consider the effect of shaded areas of pavement and cooling of pavements at the end of the day.*

6 *Pre-blended crumb rubber (R classes) may contain combining/process oils that influence the proportion of cutter oil required. Where appropriate, manufacturer's guidelines should be followed.*

** v/l/d = vehicles per lane per day.*

In aggregate retention applications using binders with low levels of polymer, e.g. S10E and S35E, or small proportions of crumb rubber (≤ 10%) the binder should be cut back as per C170 bitumen. A guide to standard cutting practice with C170 bitumen is provided in *Sprayed Seal Cutting Practice* (Austroads 2010d).

Proprietary blends of PMB should be cut back in accordance with the recommendations of the manufacturer.

Multigrade bitumens may be cut back using the same proportions of cutter oil as that used for C170 bitumen.

Table E 1 is based on the assumptions that good work practices have been adopted and good quality aggregate is adequately precoated.

Appendix F Summary of Tables and Design Factors

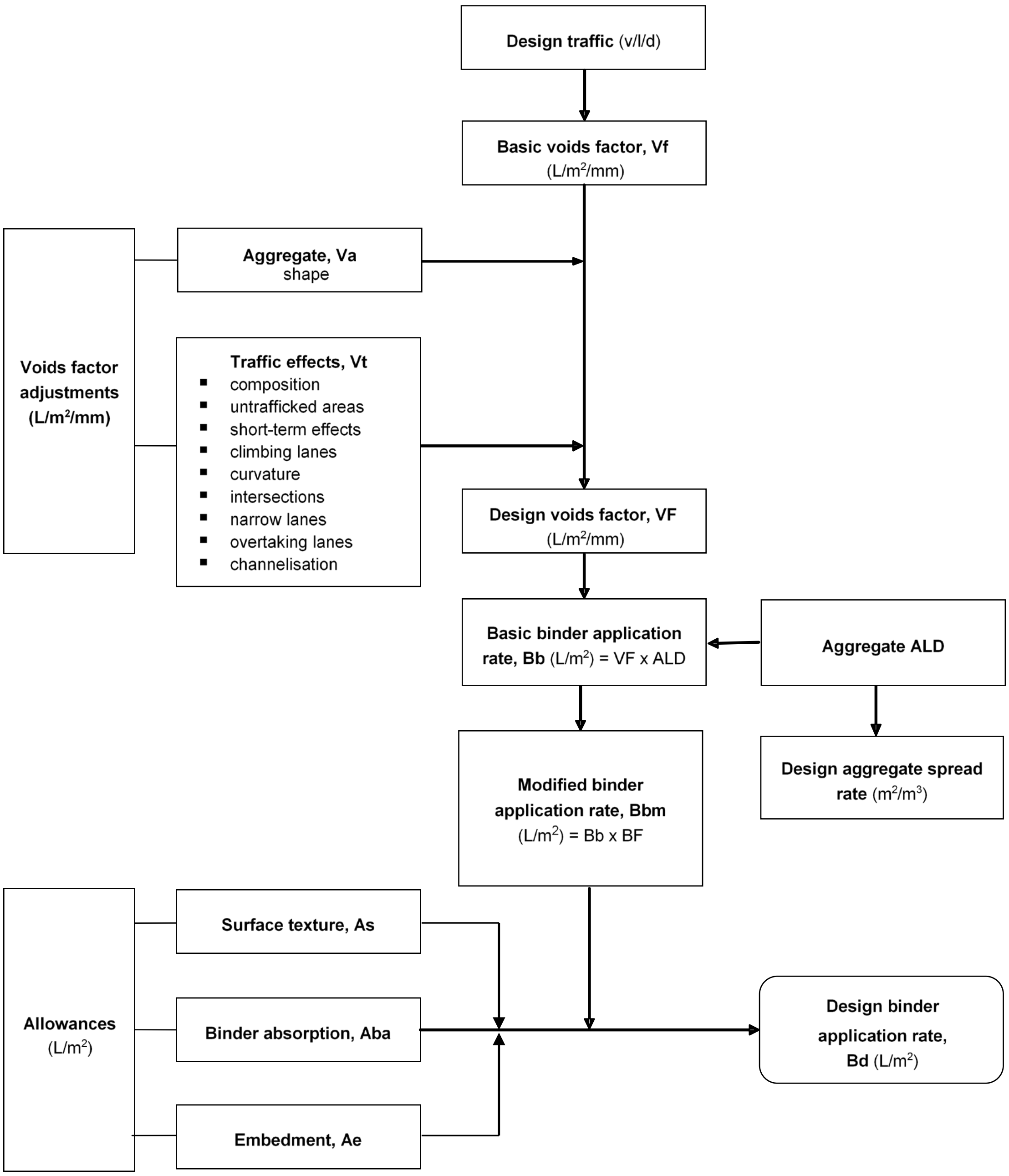
The procedure outlined in this appendix is a summary of the design factors and tables contained in Sections 5 and 6. For interpretations and guidance in the use of the tables and design procedure, reference should be made to those sections.

F.1 Design Process

F.1.1 Single/single Sprayed Seal

A general schematic of the process for determination of binder and aggregate application rates for single/single seals is shown in Figure 5.2.

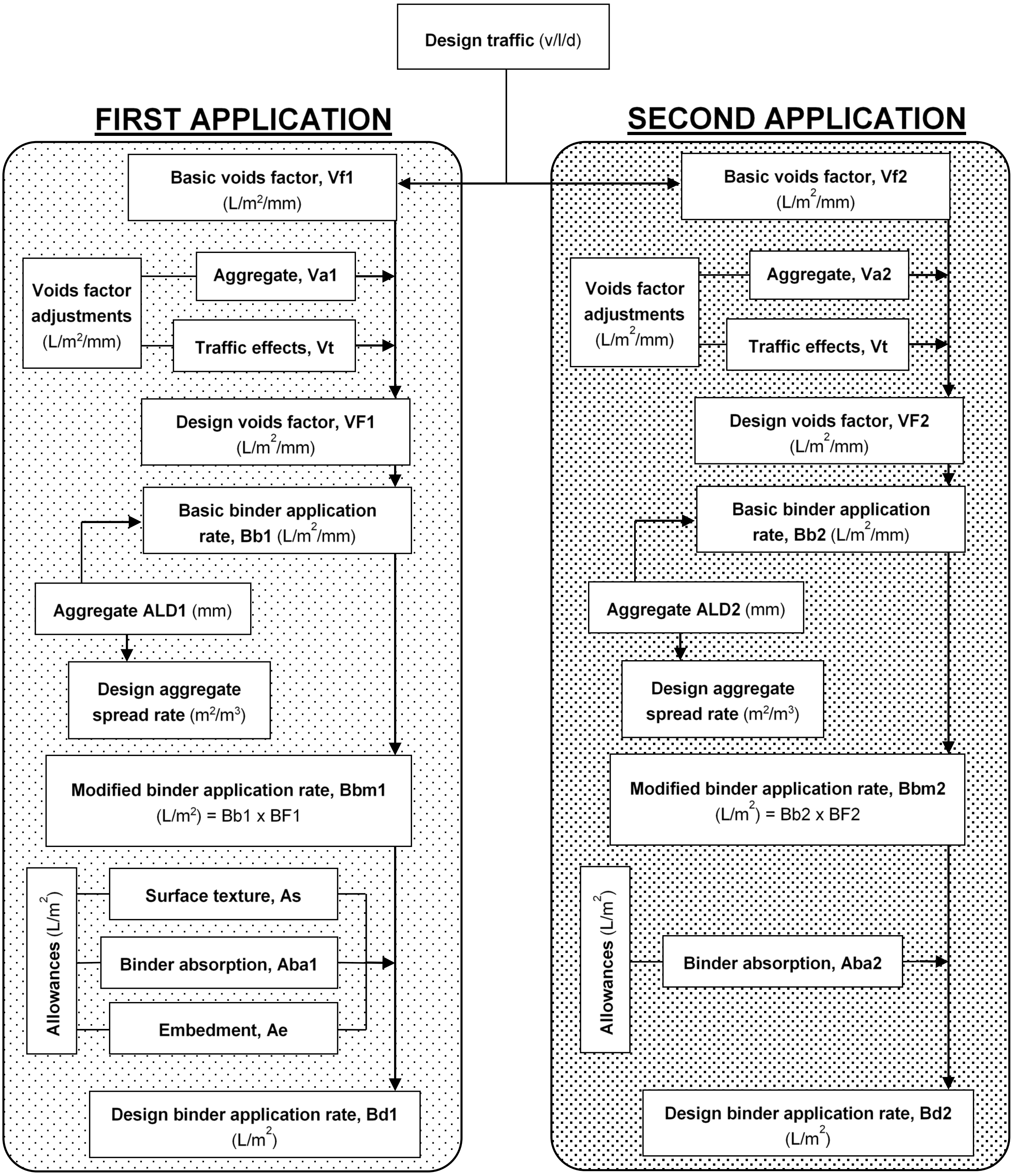
Figure 5.2 (rpt): Flow chart for design of a single/single seal



F.1.2 Double/double sprayed seal

A general schematic of the process for determination of binder and aggregate application rates for double/double seals is shown in Figure 5.3.

Figure 5.3 (rpt): Flow chart for design of a double/double seal



F.2 Abbreviations

The following terms and abbreviations are used in the procedures for the design of the binder application rate:

Aba = Allowance for binder absorption

Ae = Allowance for embedment

As = Allowance for surface texture

Bb = Basic binder application rate (before application of allowances)

Bbm = Modified binder application rate

Bd = Design binder application rate (after application of allowances).

BF = Binder factor (applied to basic binder application rate)

Va = Voids factor adjustment applied to aggregate shape

Vf = Basic voids factor

VF = Design voids factor

Vt = Voids factor adjustment applied to traffic effects.

F.3 Voids Factor

F.3.1 Basic Voids Factor

For single/single seals, Vf is determined from Figure 6.1 or Figure 6.2 (depending on traffic volume).

For double/double seals, Vf is determined from Figure 6.3 or Figure 6.4 (depending on traffic volume). The voids relationship in the first application/layer seal of a double/double seal is affected by the use of the smaller aggregate in the second application, which partially fills and therefore reduces the air voids. This is compensated for by using a reduced basic voids factor for this first application/layer.

In all cases, Vf should be read to the nearest 0.01 L/m^2/mm.

Figure 6.1 (rpt): Basic voids factor (Vf) for single/single seal – traffic volume 0 to 500 vehicles/lane/day

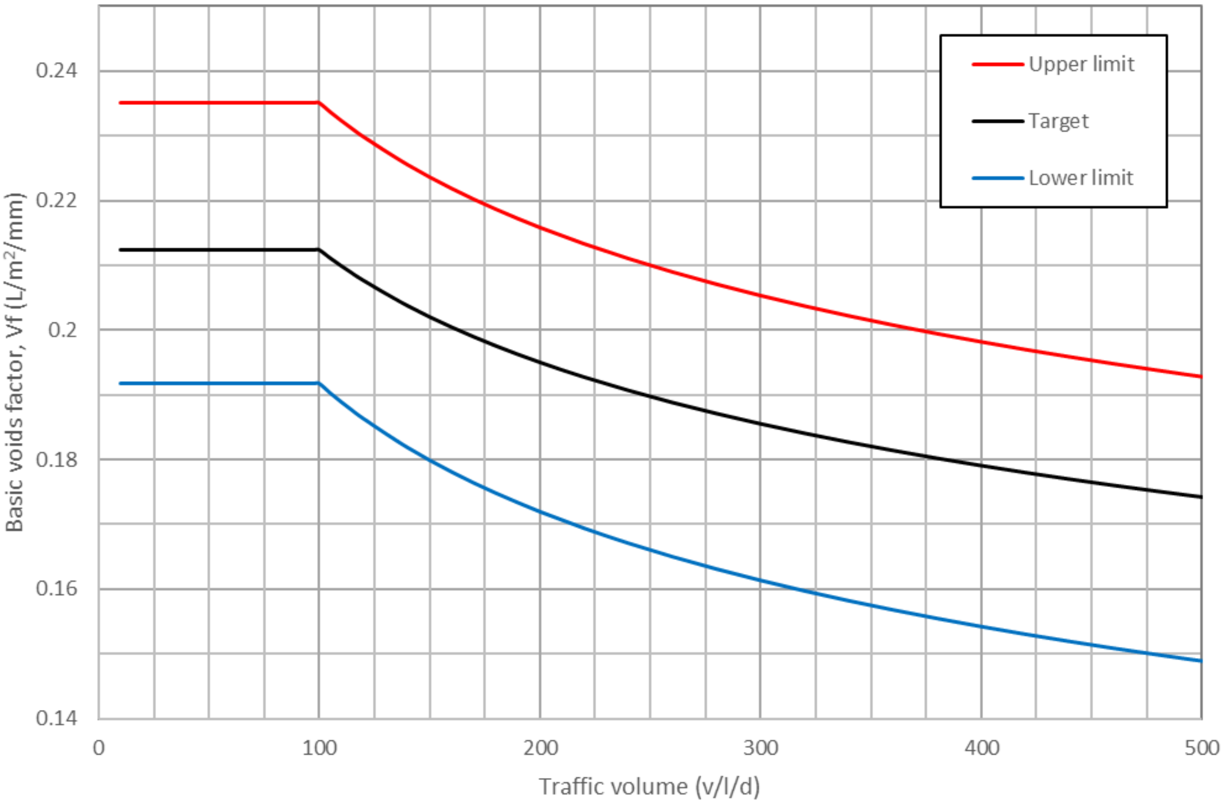


Figure 6.2 (rpt): Basic voids factor (Vf) for single/single seal – traffic volume 500 to 10 000 vehicles/lane/day

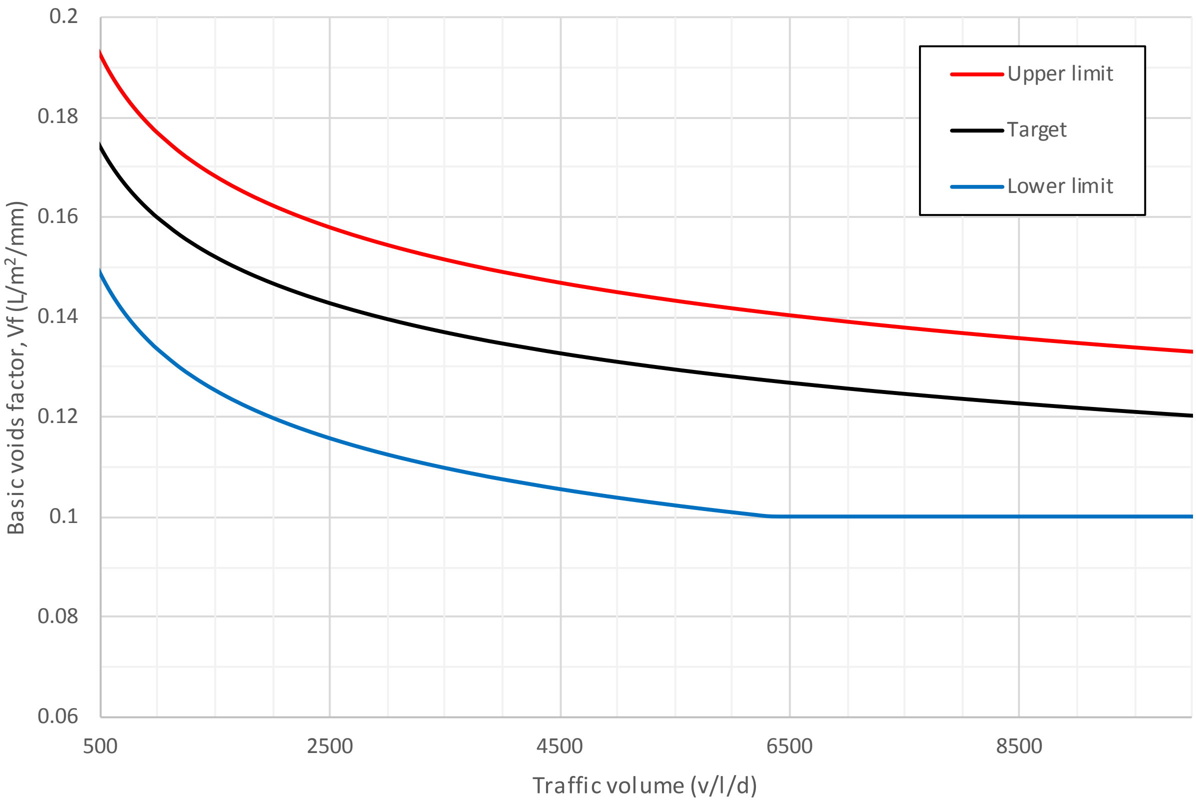


Figure 6.3 (rpt): Basic voids factor (Vf) for double/double seal – traffic volume 0 to 500 vehicles/lane/day

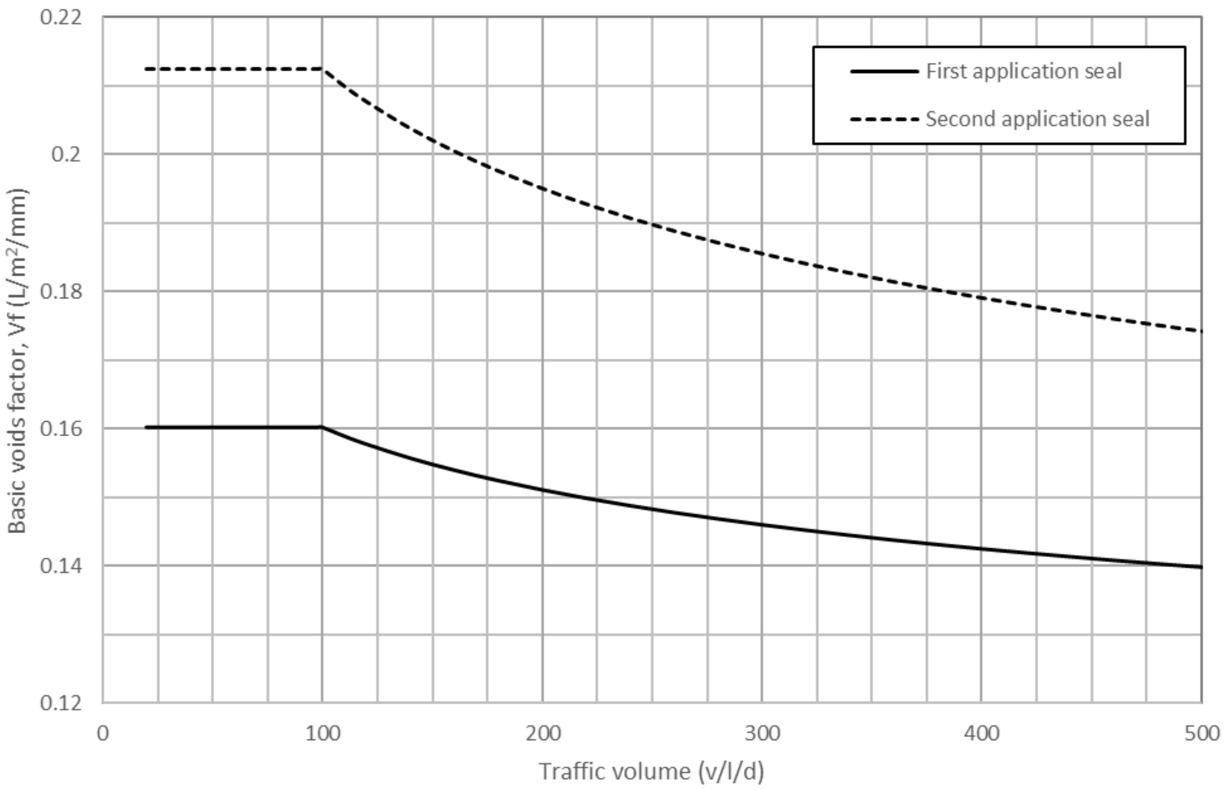
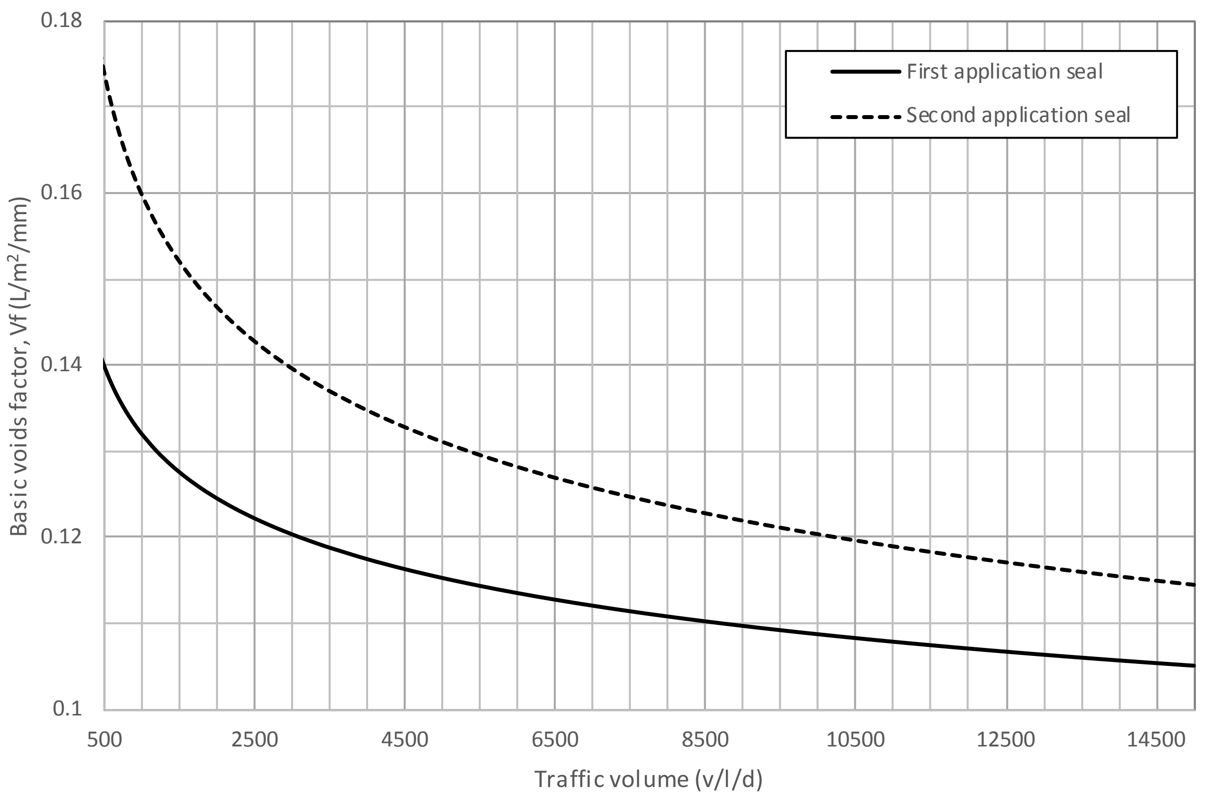


Figure 6.4 (rpt): Basic voids factor (Vf) for double/double seal – traffic volume 500 to 15 000 vehicles/lane/day



F.3.2 Adjustments to the Basic Voids Factor

The design voids factor, VF (L/m^2/mm), is determined by adjusting the basic voids factor (Vf) to account for abnormal aggregate shape (Va) and effect of traffic (Vt). These factors may be positive or negative and are cumulative.

Adjustment for aggregate shape (Va)

Table 6.1 (rpt): Adjustment to basic voids factor for aggregate shape (Va)

Aggregate type	Aggregate shape	Flakiness index (%)	Shape adjustment Va (L/m^2/mm)
Crushed or partly crushed	Very flaky	> 35	Considered too flaky and not recommended for sealing
	Flaky	26 to 35	–0.01
	Angular	16 to 25	Nil
	Cubic	10 to 15	+0.01
	Very cubic[(1)]	< 10	+0.02
	Rounded	n.a	+0.01
Not crushed	Rounded	n.a	+0.01

1 *Not recommended for bottom layer of D/D seal as insufficient angularity does not promote interlock with top layer.*

Adjustment for traffic effects (Vt)

Table 6.2 (rpt): Adjustment (Vt) to basic voids factor for traffic effects

Traffic	Adjustment to basic voids factor (L/m^2/mm)			
	Flat or downhill		Slow moving – climbing lanes	
	Normal	Channelised*	Normal	Channelised*
On overtaking lanes of multi-lane rural roads where traffic is mainly cars with ≤ 10% of HV	+0.01	0.00	n.a.	n.a.
Non-trafficked areas such as shoulders, medians, parking areas	+0.02	n.a.	n.a.	n.a.
0 to 15 (EHV(%))	Nil	–0.01	–0.01	–0.02
16 to 25 EHV(%)	–0.01	–0.02	–0.02	–0.03
26 to 45 EHV(%)	–0.02	–0.03	–0.03	–0.04
46 to 65 EHV(%)	–0.03	–0.04	–0.04	–0.05
> 65 EHV(%)	Use the process described in Section 5.2.7 for access roads to quarries, mining locations, etc.			

n.a. Not applicable

EHV(%) Equivalent heavy vehicles, includes both standard heavy vehicles and large heavy vehicles (see Equation 2, Section 5.2.5).

* *Channelisation – a system of controlling traffic by the introduction of an island or islands, or markings on a carriageway to direct traffic into predetermined paths, usually at an intersection or junction. This also applies to approaches to bridges and narrow culverts.*

F.3.3 Design Voids Factor

The Design Voids Factor is now calculated by Equation 5.

$$\text{Design voids factor, } VF = Vf + Va + Vt \qquad (5)$$

where

Vf = basic voids factor

Va = adjustment for aggregate shape

Vt = adjustment to basic voids factor for traffic effects

If adjustments for aggregate shape and traffic effects result in a reduction in basic voids factor of 0.04 L/m^2/mm or more, special consideration should be given to the suitability of the treatment and possible selection of alternative treatments.

Selection of an alternative type of treatment should be considered where the design voids factor is at, or close to, the minimum recommended value of 0.10 L/m^2/mm. For example, use of a polymer modified binder to aid aggregate retention or a double/double seal to provide a more robust treatment.

F.4 Binder Application Rate

F.4.1 Basic Binder Application Rate (Bb)

The basic binder application rate is calculated by Equation 6:

$$Bb = VF \times ALD \ (L/m^2) \qquad (6)$$

where

VF = design voids factor

ALD = average least dimension of aggregate

F.4.2 Allowances Applied to Basic Binder Application Rate

The following allowances need to be considered to complete the design. Allowances are determined to the nearest 0.1 L/m^2 and are cumulative. They must be added to or subtracted from the basic binder application rate, Bb (L/m^2), to determine the design binder application rate, Bd (L/m^2).

Surface texture allowance (As)

Surface texture allowance for existing seals

Table 6.3 provides a guide to binder application rate allowances for different sizes of aggregate for a seal over various existing seal sizes and textures.

Table 6.3 (rpt): Surface texture allowance for existing surfacing, As (L/m²)

Existing surface	Aggregate size of proposed seal (Note 4)	Measured texture depth (mm)	Surface texture allowance (L/m²)
14, 16 or 20 mm seal	5 or 7 mm	0 to 0.3	**Note 1**
		0.4 to 0.6	**Note 2**
		0.7 to 0.9	+0.1
		1.0 to 1.3	+0.2
		1.4 to 1.9	+0.3
		2.0 to 2.9	+0.4
		> 2.9	+0.5
	10 mm	0 to 0.3	–0.1
		0.4 to 0.5	0
		0.6 to 0.7	+0.1
		0.8 to 0.9	+0.2
		1.0 to 1.3	+0.3
		1.4 to 1.8	+0.4
		> 1.8	**Note 3**
	14 mm	0 to 0.3	–0.1
		0.4 to 0.5	0
		0.5 to 0.6	+0.1
		0.6 to 0.7	+0.2
		0.8 to 0.9	+0.3
		1.0 to 1.3	+0.4
		1.4 to 1.8	+0.5
		> 1.8	**Note 3**
10 mm seal	5 or 7 mm	0 to 0.3	**Note 1**
		0.4 to 0.9	+0.1
		1.0 to 1.4	+0.2
		1.5 to 2.0	+0.3
		2.1 to 2.7	+0.4
		> 2.7	+0.5
	10 mm	0 to 0.3	**Note 1**
		0.4 to 0.7	+0.1
		0.8 to 1.1	+0.2
		1.2 to 1.7	+0.3
		> 1.7	**Note 3**
	14 mm	0 to 0.2	**Note 1**
		0.3 to 0.6	+0.1
		0.7 to 0.9	+0.2
		1.0 to 1.2	+0.3
		1.3 to 1.7	+0.4
		> 1.7	**Note 3**

Existing surface	Aggregate size of proposed seal (Note 4)	Measured texture depth (mm)	Surface texture allowance (L/m²)
5 or 7 mm seal	5 or 7 mm	0 to 0.3	**Note 1**
		0.4 to 0.9	+0.1
		1.0 to 1.5	+0.2
		1.6 to 2.2	+0.3
		2.3 to 3.2	+0.4
		> 3.2	+0.5
	10 mm	0 to 0.3	**Note 1**
		0.4 to 0.7	+0.1
		0.8 to 1.1	+0.2
		1.2 to 1.8	+0.3
		> 1.8	**Note 3**
	14 mm	0 to 0.2	**Note 1**
		0.3 to 0.6	+0.1
		0.7 to 0.9	+0.2
		1.0 to 1.4	+0.3
		1.5 to 2.0	+0.4
		> 2.0	+0.5
Asphalt/microsurfacing	All	0 to 0.1	0
		0.2 to 0.4	+0.1
		0.5 to 0.8	+0.2
		0.9 to 1.4	+0.3
		> 1.4	+0.4

Notes:

1 *Embedment considerations dominant.*

2 *Specialised treatments necessary.*

3 *This treatment might not be advisable depending on the shape and interlock of aggregates so alternative treatments (surface enrichment, small size seal or others) should be considered.*

4 *For application of aggregate sizes greater than 14 mm, adopt allowances applicable to 14 mm aggregate.*

Texture allowance for microsurfacing

For microsurfacing, a typical allowance is between +0.0 to +0.3 L/m².

Texture allowance for concrete surfaces

The concrete must be primed and, in order to get a satisfactory seal over a well-primed concrete surface, the allowance should be +0.2 to +0.4 L/m², even on smooth surfaces, to compensate for the lack of aggregate embedment and interlock into the texture of the concrete surface. For broom dragged or tyned surfaces, the allowance can be as high as +0.4 to +0.5 L/m².

Texture allowance for timber surfaces

Timber may be untreated, primed, coated or impregnated. Similar to concrete, and as a guide, an allowance of between +0.2 to +0.4 L/m² may be appropriate.

Texture allowance for primes or initial seals

Texture allowance for these seals includes:

- initial seals – a texture allowance is determined similar to existing sealed surfaces
- primes – some pavement materials present a coarse textured surface and it may be possible to measure surface texture. If not, and based on experience, the texture allowance is generally in the order of +0.0 to +0.3 L/m^2.

Texture allowance for regulation or patched areas

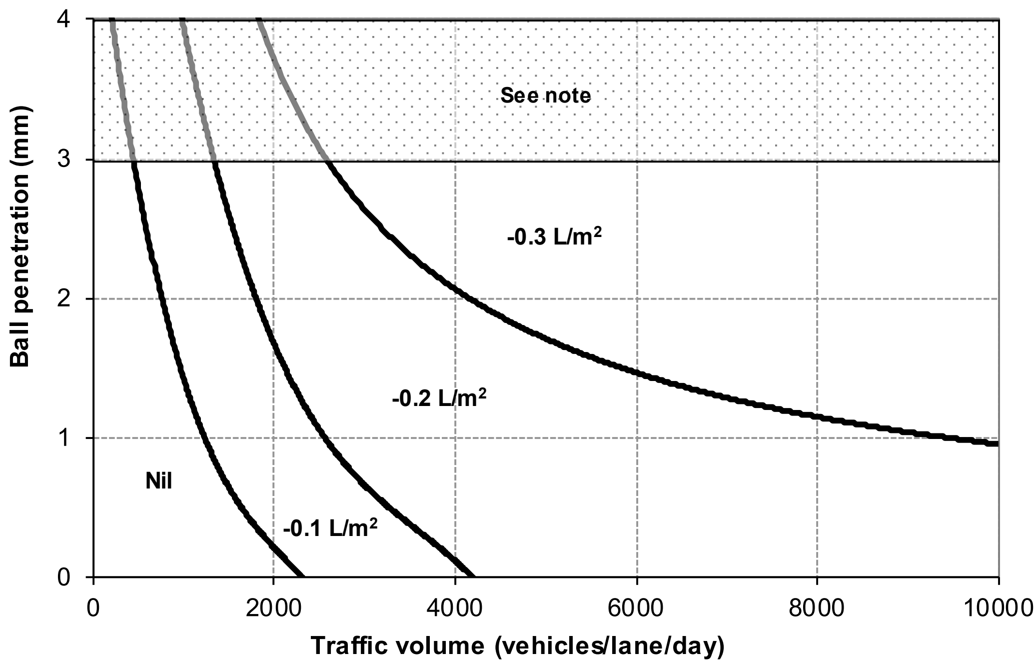
Variations in texture as well as curing of patching materials should be considered.

F.4.3 Embedment Allowance (Ae)

Initial treatments

Typical embedment allowances (in L/m^2) are shown in Figure 6.5.

Figure 6.5 (rpt): Embedment allowance for initial treatments



Note: It is recommended that the following alternatives be considered where the ball embedment value exceeds 3 mm:

- *If due to moisture, defer sealing to allow the surface to harden as it dries back. The surface should be retested once it has dried sufficiently.*
- *Apply a small aggregate seal as the first seal to act as an armour-coat and minimise the amount of embedment of the larger aggregate applied at a later date, say after about 12 months.*

Reseals

Embedment of aggregate may occur in reseals:

- if there is free binder on the surface being resealed
- when applying a reseal over fresh asphalt or microsurfacing
- when applying a reseal over fresh maintenance patching.

Binder absorption by pavement

Initial treatments

Binder from a seal may drain into voids in the surface of the base course if these have not been adequately filled by a prime or initial seal. This is most likely to occur in sandy or silty rubble base materials (sandstone, limestone or silty gravels) in a hot dry climate.

It is strongly recommended that all new pavement surfaces should be primed or initial sealed. However, in some areas a seal is applied directly to the prepared granular pavement and the following binder absorption allowances provide a guide for use in these situations:

- granular unbound pavements — allow +0.1 to +0.2 L/m^2
- pavements using cementitious binders — allow +0.0 to +0.1 L/m^2
- bitumen stabilised pavements — allow -0.1 to +0.1 L/m^2
- pavements using chemical binders — For the use of chemical binders, refer to Austroads Guide Part 4D (Austroads 2006)

Reseals

Binder absorption into the existing surface will seldom be a problem unless the existing surface is visibly open and porous.

Binder absorption by aggregate

Absorptive aggregates may fall into two general categories:

- Porous, e.g. sandstone, rhyolite etc.
- Vesicular (full of cavities), e.g. scoria, slags etc.

In general, binder absorption into aggregate is not applicable, but if an allowance is required, it does not usually exceed 0.1 L/m^2.

F.5 Binder Factor

The type of binder used in a sprayed seal effects the required application rate. The binder factor is applied to the Basic Binder Application Rate, to create a modified basic binder application rate, Bbm, which is calculated using Equation 7:

$$\text{Modified basic binder application rate, } Bbm = Bb \times BF \text{ (L/m}^2\text{, rounded to nearest 0.1)} \qquad (7)$$

where

Bb = basic binder application rate

BF = binder factor

Table 6.4 (rpt): Binder factors for single/single seals

Treatment type	Binder	Binder factor
Conventional seal	C170, C240, C320	1.0
	M500	1.1
Unmodified emulsion seal	Conventional emulsion (60%)	1.0
	High bitumen content emulsion (≥ 67%)	1.1
Modified emulsion seal	User binder factors below for the PMB that has been emulsified	
Aggregate retention (AR)	S35E	1.0
	S10E	1.1
High stress seal (HSS1)	S10E, S15E, S35E	1.0
	S20E, S45R, S15RF	1.1
Strain alleviating membrane (SAM)	S10E, S15E, S35E	1.2
	S20E, S45R, S15RF	1.3
Strain alleviating membrane interlayer (SAMI)	S25E	1.6

Table 6.5 (rpt): Binder factors for double/double seals

Treatment type	Binder	Binder factor(1)
Conventional seal	C170, C240, C320	1.0
	M500	1.1
Unmodified emulsion seal	Conventional emulsion (60%)	1.0
	High bitumen content emulsion (≥ 67%)	1.1
Modified emulsion seal	User binder factors below for the PMB that has been emulsified	
High stress seal (HSS2)	S10E, S15E, S35E	1.0
	S20E, S45R, S15RF	1.1
Extreme stress seal (XSS)	S20E	1.1
	S45R, S15RF	1.1
Strain alleviating membrane (SAM)	S10E, S15E, S35E, S20E	1.1
	S45R, S15RF	1.1

1 *Under very heavy traffic conditions with high percentages of heavy vehicles these factors may be reduced by 0.1 but should not reduce the binder factor to less than 1.0.*

F.6 Design Binder Application Rate (Bd)

The design binder application rate, Bd, is determined by Equation 8:

$$Bd = Bbm + \text{allowances } (L/m^2) \qquad 8$$

where

Bbm = modified basic binder application rate (rounded to the nearest 0.01 L/m^2)

Allowances = any applicable allowances as per Section 6.2.2

F.7 Aggregate Spread Rate

Table 6.8 (rpt): Aggregate spread rates for single/single seals

Binder	Aggregate spread rate (m^2/m^3)
C170, C240, C320, multigrade bitumen, PMB	900/ALD
Emulsion, AMC4 & AMC5 cutback binders	800/ALD

Table 6.9 (rpt): Aggregate spread rates for scatter coat

Application	Aggregate spread rate (m^2/m^3)
Scatter coat	400

Table 6.10 (rpt): Aggregate spread rates for SAMI

Application	Aggregate spread rate (m^2/m^3)
SAMI	1000/ALD to 1100/ALD

Table 6.11 (rpt): Double/double seal design aggregate spread rates for first application seal, little or no trafficking between applications

Binder	Aggregate spread rate (m^2/m^3)
C170, C240, C320, multigrade bitumen, PMB	950/ALD
Emulsion, AMC4 & AMC5 cutback binders	850/ALD

Table 6.12 (rpt): Double/double seal design aggregate spread rates for second application, little or no trafficking between applications

Binder	Aggregate size (mm)	Aggregate spread rate (m^2/m^3)
All binder types	10, 7	900/ALD
	5 (no ALD)	225

Austroads' **Guide to Pavement Technology Part 4K: Selection and Design of Sprayed Seals** is a guide to the procedures for the selection and design of sprayed seals. The Guide discusses the historical background and operational environment of sprayed seals, alongside design, selection and construction procedures for various types of sprayed seals.

Guide to Pavement Technology Part 4K

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