Austroads

SUPERSEDED PUBLICATION

This document has been superseded.

It should only be used for reference purposes.

For current guidance please visit the Austroads website:

www.austroads.gov.au

Guide to Pavement Technology Part 3
Pavement Surfacings

Austroads

Guide to Pavement Technology Part 3: Pavement Surfacings

Austroads

Sydney 2009

Guide to Pavement Technology Part 3: Pavement Surfacings

First edition project manager: David Hubner

First edition prepared by: John Rebbechi and Kieran Sharp

Abstract

Part 3 of the Guide to Pavement Technology addresses the selection of the most appropriate pavement surfacing. It identifies the significant factors that need to be considered in the selection of the most appropriate surfacing, their inter-relationships and the rationale for assessing the surfacing options available. User requirements will vary with speed, road geometry and environment, while material requirements will be affected by traffic and environmental factors, the availability of suitable materials, and cost.

Keywords

pavement surfacing, road surfacings, sprayed seals, asphalt, slurry surfacing, concrete, pavement types

Edition 1.1 published August 2018

- Format updated.

Edition 1 published July 2009

ISBN 978-1-921551-60-4

Austroads Project No. TP1565

Austroads Publication No. AGPT03-09

Pages 68

Publisher

Austroads Ltd.
Level 9, 287 Elizabeth Street
Sydney NSW 2000 Australia

Phone: +61 2 8265 3300

austroads@austroads.com.au
www.austroads.com.au

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.

Austroads is governed by a Board consisting of senior executive representatives from each of its eleven member organisations:

- Roads and Maritime Services New South Wales
- Roads Corporation Victoria
- Queensland Department of Transport and Main Roads
- Main Roads Western Australia
- Department of Planning, Transport and Infrastructure South Australia
- Department of State Growth Tasmania
- Department of Infrastructure, Planning and Logistics Northern Territory
- Transport Canberra and City Services Directorate, Australian Capital Territory
- Australian Government Department of Infrastructure and Regional Development
- Australian Local Government Association
- New Zealand Transport Agency.

Acknowledgements

Membership of Austroads Working Group:

Greg Hall	Roads and Traffic Authority New South Wales
Sai Yin	Roads and Traffic Authority New South Wales
John Esnouf	VicRoads
Gavin Soward	Department of Transport and Main Roads Queensland
Steve Halligan	Main Roads Western Australia
John Nichols	Cement Concrete & Aggregates Australia
John Rebbechi	Roadcor
Kym Neaylon	ARRB Group
Kieran Sharp	ARRB Group

Contents

Tables

Figures

1. Introduction

The pavement surfacing, or wearing surface, is defined in the *Glossary of Austroads Terms* (Austroads 2008a) as 'that part of the pavement or bridge deck specifically designed to resist abrasion from traffic and to minimise the entry of water'.

Part 3 of the *Guide to Pavement Technology* addresses the selection of the most appropriate pavement surfacing. It is based on the *Guide to the Selection of Road Surfacings* (Austroads 2003b), but has been updated to include the results of recent Austroads research into bituminous surfacings and other relevant material.

This guide identifies the significant factors that need to be considered in the selection of the most appropriate surfacing, their inter-relationships and the rationale for assessing the surfacing options available. User requirements will vary with speed, road geometry and environment, while materials requirements will be affected by traffic and environmental factors, the availability of suitable materials and cost.

The absence of hard and fast rules or mandatory requirements may result in several options being available. The solution adopted needs to be the best compromise based on risk assessment, whole-of-life costing and prioritising of available funds.

The use of this guide does not reduce the need to apply experienced engineering judgement to the complexities that influence the performance of pavement surfacings.

1.1 Guide to Pavement Technology

The *Guide to Pavement Technology* consists of the following parts:

- Part 1: Introduction to Pavement Technology – a background document including purpose and function of pavements, pavement types and their components, pavement materials, types of pavements and an introduction to the fundamentals of pavement behaviour.
- Part 2: Pavement Structural Design – the structural design of sealed road pavements
- Part 3: Pavement Surfacings
- Part 4: Pavement Materials – the selection of all types of road pavement materials; detailed advice on individual materials is available in the following sub-parts:
  - Part 4A: Granular Base and Subbase Materials
  - Part 4B: Asphalt
  - Part 4C: Materials for Concrete Road Pavements
  - Part 4D: Stabilised Materials
  - Part 4E: Recycled Materials
  - Part 4F: Bituminous Binders
  - Part 4G: Geotextiles and Geogrids
  - Part 4H: Test Methods
  - Part 4I: Earthworks Materials
  - Part 4J: Aggregates/Source Rock
  - Part 4K: Seals
  - Part 4L: Stabilising Binders

- Part 5: Pavement Evaluation and Treatment Design – the investigation of existing sealed road pavements
- Part 6: Unsealed Pavements – the management of unsealed road pavements
- Part 7: Pavement Maintenance – techniques and methods for carrying out routine maintenance tasks; it complements Part 5
- Part 8: Pavement Construction and Construction Assurance – pavement construction and how to ensure that the 'as constructed' pavement layers meet design requirements
- Part 9: Pavement Work Practices – technical notes and similar publications related to pavement work practices
- Part 10: Sub-Surface Drainage.

1.2 Development of Pavement Surfacings in Australasia

The need for a low-cost, good performing surface treatment was highlighted during the 1920s as the use of pneumatic-tyred vehicles became more widespread. The seal coat, or sprayed seal (Australian terminology) or chip seal (New Zealand terminology), was developed in response to these needs. It is a major Australasian contribution to international road-making practice. The majority of pavements surfaced with these seals consist of an unbound granular base, either crushed rock or gravel. The development of this low-cost technique led to the rapid expansion of all-weather, dust-free roads in sparsely populated areas. A summary of the development of pavement surfacings in Australasia is presented in Austroads (2005).

Whilst many roads in rural areas are surfaced with a sprayed seal, it has limitations in terms of its ability to cope with heavy vertical loads and shearing stresses generated on steep grades, at intersections or on sharp curves. On more heavily trafficked roads, and in urban areas, asphalt is more commonly used because it has a greater resistance to trafficking effects, a higher durability and provides a smoother riding surface. Concrete pavements are also used in such areas for similar reasons. Both asphalt and concrete can contribute to the structural strength of the pavement structure whereas a sprayed seal surfacing has no structural contribution.

The structural design of new pavements, and the strengthening of existing pavements, is not addressed in this Guide. Readers are referred to the *Guide to Pavement Technology – Part 2: Pavement Structural Design* (Austroads 2008b) and *Part 5: Pavement Evaluation and Treatment Design* (Austroads 2008e).

1.3 Overview

The selection of the most appropriate pavement surfacing requires that the needs of road asset managers, road users and the broader community are balanced (Table 1.1).

Table 1.1: Needs of principal stakeholder groups in surfacing selection

Considerations	Stakeholders		
	Road asset managers	**Road users**	**Community groups**
Practicality	• Levels and clearances: - interference with drainage - openings under structures - opportunity for milling • Existing shape and texture • Existing pavement composition • Climate: temperature and rainfall • Treatment availability		
Cost	• Initial costs including traffic management • Maintenance under traffic • Replacement costs of markings and delineation • Lighting	• Delays to road users during construction, maintenance and rehabilitation • Fuel consumption: - rolling resistance • Vehicle depreciation: - wear and tear - windscreen damage	• Damage to goods • Haulage
Longevity	• Existing pavement condition: - surface cracking - structural strength - adequacy of drainage • Traffic: - volume, composition and speed - turning/stopping - vertical and horizontal geometry • Performance of surfacing: - fatigue resistance - deformation resistance - skid resistance - potential to clog/flush		
Safety associated with construction, maintenance and use	• Accident history and statistics • Site vulnerability for accidents - speed environment - traffic density - site geometry - delineation effectiveness • Surface drainage requirements • Skid resistance requirements	• Skid resistance: - frost and ice • Visibility: - glare and reflection - conspicuity of delineation - spray generation • Windscreen damage • Traffic management during operations • Drop-off at pavement edges	• Construction workers and adjacent residents: - fumes and dust - traffic management during operations • Pedestrians/cyclists: - conspicuity - surface texture
Environmental	• Legislative responsibility • Recycling potential • Pollution, air, noise and water	• Noise and dust • Aesthetics: - uniformity and colour • Pick up of bitumen by vehicles	• Adjacent residents: - noise and dust - vibrations - fumes during construction and use

Guidance is provided in this guide on:

- surfacing types
- surfacing performance characteristics that may influence the choice of pavement and surfacing type
- the selection of surfacings for new pavements
- the selection of surfacings for retreatments.

A more detailed guide to the characteristics of the various pavement materials is contained in the relevant sub-parts to the Guide to Pavement Technology – Part 4: Pavement Materials (Austroads 2007c).

In addition to evaluating the characteristics of the surfacing, the selection of the most appropriate surfacing also requires consideration of a number of other critical matters including:

- disruption to traffic during construction and maintenance
- safety of the workforce and public during construction and maintenance
- stage construction opportunities
- whole-of-life costing
- road alignment and geometry
- allowable axle loads, including allowable axle loads on bridges
- environmental issues, including noise and dust.

Readers are also referred to the various sub-parts of the *Guide to Asset Management – Part 5*: *Pavement Performance* (Austroads 2009a) for guidance on the establishment and maintenance of asset inventories and the monitoring of asset performance including roughness, rutting, strength, cracking, skid resistance and texture.

2. Surfacing types

Each surfacing type has particular characteristics that will make it suitable for a particular set of service conditions. A brief description of the principal types of surfacing used for new pavements and resurfacing follows.

2.1 Sprayed Treatments

Sprayed treatments involve a thin layer of binder sprayed onto a pavement surface with a layer of aggregate incorporated. The main types of sprayed treatments as defined in the *Glossary of Austroads Terms* (Austroads 2008a) are as follows:

Treatment	Definition
prime (prime coat)	An application of a primer to a prepared base, without cover aggregate, to provide penetration of the surface, temporary waterproofing and to obtain a bond between the pavement and the subsequent seal or asphalt. It is a preliminary treatment to a more permanent bituminous surfacing.
primerseal	Applications of a primerbinder with a fine cover aggregate to a prepared base to provide penetration of the surface and retain a light cover of aggregate. It is used as a preliminary treatment to a more permanent bituminous surfacing. It is intended to carry traffic for a longer period than a prime.
initial seal	A seal placed on a prepared basecourse that has not been primed.
first coat seal	The term used in New Zealand which is equivalent to an initial seal in Australia.
sprayed seal	A thin surface layer of bituminous material into which aggregate is incorporated and which is impervious to water.
chip seal	The term used in New Zealand which is equivalent to a sprayed seal in Australia
fibre reinforced seal	A seal consisting of a specially formulated polymer modified binder with chopped glass fibres.
geotextile reinforced seal	An application of a bituminous binder into which both geotextile and aggregate are incorporated to provide a durable wearing surface. A layer of binder is applied first, followed by a layer of geotextile fabric, then a second coat of binder, followed by the aggregate.
surface enrichment	A light application of bituminous binder over an existing seal, without aggregate. It is used to increase the binder content, and extend the life, of a bituminous road surfacing.
surface rejuvenation	A light application of an emulsified fraction of a bituminous binder. It is used to extend the life of a bituminous road surfacing.

Differences in terminology and usage exist between Australia and New Zealand, particularly the use in New Zealand of the terms chippings (aggregates), chip seal (sprayed seal) and first coat seal (primerseal). For ease of readability the Australian terms of aggregate, sprayed seal and primerseal have been adopted in this document. A detailed guide to sprayed sealing (chip sealing) practice in New Zealand is provided in Transit New Zealand, Road Controlling Authorities & Roading New Zealand (2005).

The sprayed sealing process is shown in Figure 2.1 (application of bituminous binder) and Figure 2.2 (application of aggregate) respectively, whilst Figure 2.3 shows a typical 10 mm sprayed seal surfacing.

Figure 2.1: Sprayed seal: application of bituminous binder

Source: ARRB Group

Figure 2.2: Sprayed seal: application of aggregate

Source: ARRB Group

Figure 2.3: 10 mm sprayed seal surfacing

Source: Roadcor

2.2 Asphalt

Asphalt is a mixture of bituminous binder and aggregate with or without mineral filler. It is produced hot in a mixing plant and delivered, spread and compacted while hot (Figure 2.4). Unlike sprayed seals, asphalt usually acts as a structural layer in a pavement, although thin asphalt layers, say 25–30 mm, are not considered to offer a significant structural contribution to a pavement. The most common types of asphalt surfacing are as follows:

Treatment	Definition
dense graded asphalt (see Figure 2.5)	A mixture of coarse aggregate, fine aggregate, filler and bitumen, placed hot and compacted to a dense state as a pavement layer or resurfacing.
open graded asphalt (see Figure 2.6)	A mix containing only small amounts of fine material. It provides a high percentage of air voids.
stone mastic asphalt (SMA) (see Figure 2.7)	A gap graded wearing course mix with a high proportion of coarse aggregate, which interlocks to form a skeletal structure to resist permanent deformation. It has a high binder content.
fine gap graded asphalt (see Figure 2.8)	A mix in which gap graded aggregate is used. A fine gap graded mix contains a large proportion of fine aggregate and a lesser proportion of coarse aggregate.

Figure 2.4: Asphalt paving

Source: Roadcor

Figure 2.5: Dense graded asphalt

Source: Roadcor

Figure 2.6: Open graded asphalt

Source: Roadcor

Figure 2.7: Stone mastic asphalt

Source: Roadcor

Figure 2.8: Fine gap graded asphalt

Source: Roadcor

2.3 Bituminous Slurry Surfacing

The two types of bituminous slurry surfacing are slurry seal and microsurfacing. They are generally used in light to medium duty applications only. A further application of slurry surfacing is in combination with a sprayed seal as a 'cape seal'.

Treatment	Definition
slurry	A stable suspension of aggregate and filler in a less dense, liquid bitumen emulsion.
slurry surfacing (Figure 2.9 and Figure 2.10)	A general term for slurry seal and microsurfacing
slurry seal	A thin layer of bituminous slurry surfacing, usually without a polymer modifier.
microsurfacing	A bituminous slurry surfacing, usually containing polymer, which is capable of being spread in layers up to 30 mm thick for rut-filling and correction courses, and for wearing course applications where good surface texture is required to be maintained throughout the service life.
cape seal (Figure 2.11)	A treatment consisting of a slurry seal over a sprayed seal providing an asphalt-like appearance.

Figure 2.9: Placing bituminous slurry surfacing

Source: ARRB Group

Figure 2.10: Slurry surfacing

Source: Roadcor

Figure 2.11: Placing cape seal showing sequence of sprayed seal binder, aggregate and application of slurry surfacing

Source: ARRB Group

2.4 Concrete

Concrete is a mixture of fine and coarse aggregate, water, cementitious binder and admixtures. It is used in pavements is a number of ways. Principal pavement types are as follows:

Treatment	Definition
plain concrete pavement (Figure 2.12)	A concrete pavement which is unreinforced.
jointed reinforced concrete pavement	A concrete pavement which is typically mesh reinforced, with square dowelled joints at spacings of 8–12 m. The longitudinal reinforcement does not cross the transverse joints.
continuously reinforced concrete pavement (Figure 2.13)	A concrete pavement containing relatively heavy longitudinal reinforcement and having no transverse joints.
fibre reinforced concrete pavement	A concrete pavement reinforced with steel fibres.
concrete segmental pavement (Figure 2.14)	A pavement consisting of a surfacing of interlocking precast concrete pavers.

Figure 2.12: Placing plain concrete pavement

Source: CCAA

Figure 2.13: Placing continuously reinforced concrete pavement

Source: CCAA

Figure 2.14: Concrete segmental pavement

Source: CCAA

A range of surface finishes are available for new concrete pavements, including:

- transverse tined
- longitudinal tined
- hessian drag
- wood float
- broomed.

Surface finishes for texturing of road pavements are discussed in more detail in Section 7 of this guide.

In addition, a variety of decorative finishes can be applied, including exposed aggregate, colours, stamped (impressed) and stencilled patterns as discussed in Section 3.3.9.

3. Function and Characteristics of Surfacings

3.1 General

This section describes the function of road surfacings and desired performance characteristics in terms of road user and community comfort, safety and serviceability.

3.2 Function of Road Surfacings

A wearing surface or surfacing is the uppermost layer of a pavement structure on which the traffic runs. The purpose of surfacings is to:

- provide a riding surface of suitable smoothness
- provide a safe, economical, durable and well-drained all-weather surface
- provide the necessary skid resistance
- minimise vehicle operating and maintenance costs
- provide a dust-free surface
- minimise the rate of pavement wear and maintenance costs
- reduce moisture infiltration into the pavement (except for open graded asphalt)
- provide suitable properties for the local environment, e.g. noise reduction and surface texture.

In addition, surfacings may also be required to perform other aesthetic or technical functions such as:

- delineating traffic lanes and shoulders, traffic islands, bicycle paths, traffic calming devices and changes in road class
- visually enhancing the road environment for road users and adjacent residents
- improving the efficiency of street lighting through the use of light coloured surfacings.

3.3 Surface Characteristics and Performance

Typical parameters include:

- longitudinal profile and roughness
- transverse profile and rutting
- skid resistance
- texture
- noise
- conspicuity of markings/reflectivity
- delineation
- water spray generation
- appearance
- pavement strength
- cracking

- resistance to shear forces.

In practice, many of these factors are inter-related, for example:

- Increasing roughness or rutting is often an indication of deterioration in structural strength.
- Bleeding in asphalt or sprayed seals, or severe stripping, will lead to a loss of surface texture and poor skid resistance.
- Ageing of surfaces may lead to cracking or increased permeability, thereby allowing moisture to enter and weaken the pavement structure; ageing may also lead to surface aggregate loss and ravelling.
- The texture depth of bituminous surfaces may be reduced by wear and embedment of aggregate in sprayed seals or densification of asphalt mixes.
- Rutting or poor drainage can increase the amount of surface water and the risk of skidding; the potential for skidding may be influenced by road geometry, surface roughness and surface texture as well as surface friction characteristics.

3.3.1 Longitudinal Profile and Roughness

Roughness influences:

- safety
- the comfort of vehicle occupants
- wear and tear on vehicles and a consequent increase in operating cost
- the possibility of damaged transported goods.

It should be noted that roughness, by itself, may not justify retreating a pavement. Further factors to be considered include:

- road user costs
- excessive maintenance costs compared to the network average for the type of pavement
- the rate of change of roughness
- speed of traffic using the road
- the cause of roughness, e.g. loss of shape in the formation, pavement or wearing surface, or a combination of these.

Shape variation can be a measure of:

- rutting, as applied transversely across a pavement
- edge drop-off, particularly as it relates to pavement/shoulder areas
- surface irregularities, including irregularities due to uneven service pit covers and changes in surface type
- lack of local smoothness as it applies particularly to areas used by pedestrians.

Details of the measurement of pavement surface shape (roughness) are contained in the *Guide to Asset Management – Part 5B*: *Roughness* (Austroads 2007a).

3.3.2 Transverse Profile and Rutting

Rutting is a form of deformation in flexible pavements that is caused by the passage of wheels over the pavement surface and is measured as the maximum vertical displacement in the transverse profile.

Rutting can be an outcome of insufficient pavement strength or a result of deformation and displacement in the upper pavement layers.

As with roughness, rutting, by itself, may not justify retreating a pavement. Further factors to be considered include climate, road geometry, surface texture, traffic speed and proximity to traffic control devices.

Details of the measurement of pavement transverse profile and rutting are contained in the *Guide to Asset Management – Part 5C: Rutting* (Austroads 2007b).

3.3.3 Skid Resistance

Skid resistance is a measure of the friction between the vehicle tyre and the road surface. It will depend on both the microtexture of the aggregate in the surfacing and the macrotexture (surface texture) of the surfacing, as well as the presence of moisture and its film thickness.

For bituminous surfaces, microtexture relates primarily to the surface texture of the individual aggregate particles which is, in turn, influenced by the degree of polishing of the aggregate. Guidelines for the quality of aggregates and polishing characteristics are provided in the *Guide to Pavement Technology – Part 4J: Aggregates and Source Rock* (Austroads 2008d).

Macrotexture is primarily provided by the shape of, and the space between, the aggregate particles. This is also discussed in relation to texture depth in Section 3.3.4.

For concrete surfaces, microtexture is provided by the fine aggregate particles in the mix, and macrotexture is provided by texturing, such as tining, applied during placing and finishing. Concrete surface texturing techniques are further discussed in Section 7.

At low speeds, a fine macrotexture may provide an adequate level of skid resistance because the friction that can develop between the surfacing and the tyre depends primarily on the microtexture of the aggregate. As road speed increases, a greater level of macrotexture is required in order that the vehicle tyre can move water away from the tyre/road surface interface and maintain surface contact.

Details of the measurement of pavement skid resistance are contained in the *Guide to Asset Management – Part 5F: Skid Resistance* (Austroads 2009b).

3.3.4 Texture

Surface irregularities are usually defined in terms of microtexture, macrotexture, megatexture and roughness. These parameters are usually assessed over a considerable area (or length) of pavement. Other, more localised, surface irregularities (such as potholes) also play a significant role in defining the serviceability of a pavement surfacing.

The definitions of microtexture, macrotexture, megatexture and roughness in terms of the wave-lengths of the surface irregularities are shown in Table 3.1.

Table 3.1: Categories of surface irregularity

Category	Wavelength
Microtexture	< 0.5 mm
Macrotexture	0.5 mm to 50 mm
Megatexture	50 mm to 500 mm
Roughness	500 mm to 50 m

Source: Descornet (1989).

Megatexture and roughness relate to pavement shape and ride quality or smoothness of a road surface (Section 3.3.1).

Microtexture particularly relates to the surface texture of aggregates. Although Descornet defines macrotexture as having a wavelength of up to 50 mm, road asset managers generally regard macrotexture in terms of the space between aggregate particles, otherwise referred to as texture depth.

Texture depth is an indication of the volume through which water may escape from the interface between a tyre and the road surface. It is thus an important component of skid resistance, for without sufficient texture depth to allow the removal of water, aquaplaning may occur.

It must be noted that texture depth requirements should be considered in the light of a number of factors:

- vehicle speeds
- the measured skid resistance of the surface (which is influenced by the polishing of the surface aggregates)
- rainfall characteristics
- surface drainage characteristics such as crossfall
- other risk factors such as steep grades, curves, stop lights, roundabouts and the need to stop or decrease speed.

Tolerable texture depths for particular situations need to be determined from consideration of the above factors as well as looking at accident statistics, traffic density and the need to alleviate the spray and noise characteristics of the surfacing.

A guide to typical relative texture depths of new surfaces is provided in Table 3.2 and Table 3.3. It should be noted that the texture depth of aged surfaces can be significantly influenced by subsequent traffic. For example, texture depth of bituminous surfaces may be reduced by wear and embedment of aggregate in sprayed seals or densification of asphalt mixes, whereas texture depth on lightly trafficked pavements may increase due to weathering of binder and fine aggregate loss to expose the coarse aggregate particles in the asphalt mix. Texture depth of asphalt mixes can also be influenced by particle size distribution and binder content adopted in the design of the mixture.

Table 3.2: Typical relative texture depths of new bituminous surfacings

Surfacing	Relative texture depth
Spray seals, 10 mm or larger	Greatest
Open graded asphalt	
Ultra thin asphalt	
Spray seals, 7 mm	
Stone mastic asphalt	
Microsurfacing	
Dense graded asphalt	
Fine gap graded asphalt	Least

Table 3.3: Typical relative texture depths of new concrete surfacings

Concrete surface finish	Relative texture depth
Tined	Greatest
Hessian drag	Least

Details of the measurement of pavement texture are contained in the *Guide to Asset Management – Part 5G: Texture* (Austroads 2009c).

3.3.5 Noise

Traffic noise is the accumulation of noise from many sources, of which the tyre/road noise is just one. Other noise sources include exhaust, engine, aerodynamic and transmission noise.

Tyre/road noise is influenced mainly by the:

- type of surfacing treatment
- roughness of the road surface
- shape of the road surface
- texture of the road surface
- tyre pattern
- vehicle speed
- proportion of trucks to cars.

It should be noted that:

- engine and transmission noise is dominant below about 50 km/h for cars and 70 km/h for trucks
- above these speeds tyre/road noise predominates
- at speeds above 70 km/h, trucks may generate noise levels of up to 10 dB(A) higher than cars.

As tyre/road surface interaction is only one component of road noise, the noise level characteristics of a particular road surface cannot be expressed as an absolute level. Guidance, however, is given in Table 3.4 and Table 3.5 on the relative noise levels of different new surfacing types.

The road asset manager can thus select various surfacings to assist in achieving the target noise levels.

It should be noted that surface noise levels will vary with time, decreasing due to wear and increasing smoothness, or increasing due to weathering, ravelling, or increasing roughness and increasing traffic volume. An increase in noise level with time occurs with open graded asphalt where the voids close or clog up, unless periodically cleaned.

Table 3.4: Typical relative noise levels of new bituminous surfacings

Surfacing	Relative noise level
Spray seals, 10 mm or larger	Greatest
Spray seals, 7 mm	
Microsurfacing	
Fine gap graded asphalt	
Dense graded asphalt	
Stone mastic asphalt	
Ultra thin asphalt	
Open graded asphalt	Least

Table 3.5: Typical relative noise levels of new concrete surfacings

Concrete surface finish	Relative noise level
Transverse tined concrete	Greatest
Hessian drag	Least

3.3.6 Conspicuity of Line Markings

Conspicuity of line markings is generally not used as a primary criterion for the selection of pavement surfacings and therefore does not appear explicitly in the methodologies presented in this Guide. However, the type and surface texture of the surfacing can play a role in enhancing the conspicuity of road markings as an outcome of the contrast between the road marking and the background colour of the surfacing (daytime) or depth of surface water (night time).

A guide to the design and use of pavement markings and delineation is provided in the *Guide to Traffic Management – Part 10: Traffic Control and communication devices* (Austroads 2009f).

3.3.7 Delineation

Coloured surfacings may be used to designate particular lanes or pavement areas such as bus lanes (red), cycle paths (green) and pedestrian paths or crossings (yellow) (Figure 3.1).

Variations to surface colour, pavement type or decorative surfaces may also be used to highlight areas such as shared pavements, entrance to residential areas and presence of traffic calming devices.

Colour and appearance of pavement surfacings are described in Section 3.3.9. Where coloured surfacings are used for delineation of bus lanes etc., they must meet appropriate standards for colour intensity and durability and usually consist of specialty surface coatings that may combine both coloured binder and coloured aggregate (Section 4.9) or pigmented asphalt mixtures as described in Section 3.3.9.

Figure 3.1: Delineation of bus lane with coloured asphalt surface

Source: Roadcor

3.3.8 Water Spray

Water spray or misting is the result of vehicles travelling on wet pavements and 'throwing up' small droplets of water. Water spray can affect visibility and hence the safety of motorists and others using the road system.

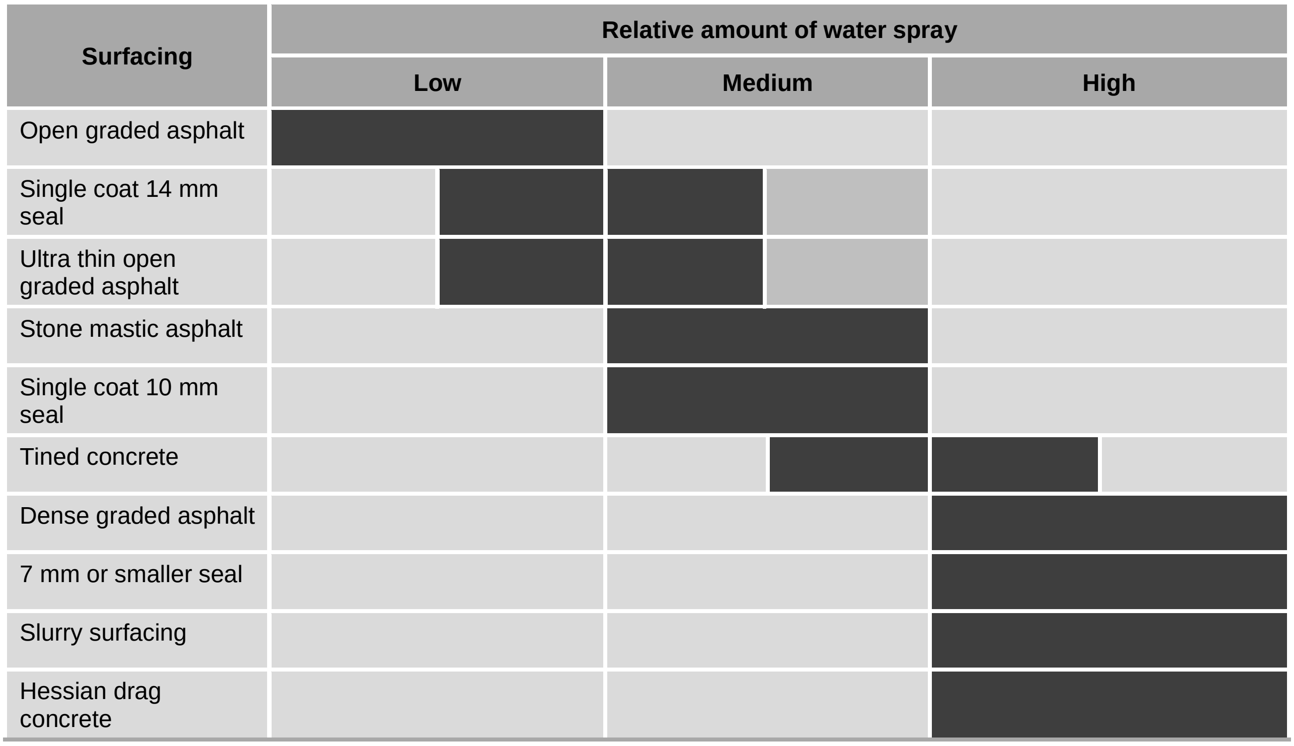
Water spray is directly related to the amount of water on the surface and the surface texture. It can be substantially reduced by the use of coarse textured surfaces, which reduce the amount of surface water (Figure 3.2). However, water spray is increased, regardless of texture, if surface drainage is poor due to pavement irregularities, long drainage paths or 'boxed-in' pavement edges.

Figure 3.2: Comparative water spray from dense graded asphalt (left) and open graded asphalt (right)

Source: Roadcor

Minimising water spray is particularly important on heavily trafficked, high-speed, multi-lane roads such as freeways, highways and heavily trafficked urban roads. The relative water spray characteristics of various surfacings are given in Table 3.6.

Table 3.6: Relative water spray characteristics of common surfacings



Note: The dark shaded areas represent the relative operational water spray characteristics for particular surfacing types.

3.3.9 Appearance

For low-speed roads such as residential streets or urban roads through commercial districts such as shopping centres, aesthetics are a vital part of the streetscape and pavement design.

Landscape architects and urban designers often specify various architectural finishes, or combinations of finishes, in order to develop an individual streetscape which may take into account the following factors:

- history
- culture
- environment
- use of the street
- traffic calming
- safety and amenity.

In sprayed seals, the final surface colour is a direct outcome of the colour of aggregate used. Some delineation or aesthetic outcomes can therefore be obtained by the selection of suitable coloured aggregates.

The surface colour of asphalt manufactured with conventional bitumen is initially black. Wear and weathering of the surface binder can expose the natural colour of the aggregates. Asphalt surfacings with light coloured aggregates thus weather to a lighter colour.

Conventional asphalt may be coloured by the addition of colour pigments, typically red (Figure 3.3). The intensity of the colour depends on the proportion of added pigment.

Figure 3.3: Coloured asphalt surface with pigmented binder

Source: Roadcor

A greater intensity of colour in asphalt, as well as a wider choice of colours, can be obtained by using specialty colourless (pigmentable) binders. When pigmentable binders are combined with an appropriately coloured aggregate, a durable colour can be obtained that is suitable for both delineation and aesthetics.

The intensity of colour in asphalt mixes made with bitumen binder and dark coloured aggregates will eventually reduce due to weathering and wear of the surface binder to expose the natural aggregate colour. On lightly trafficked pavements, particularly areas predominantly used by pedestrians, the rate of wear of the coloured binder is considerably delayed and provides an economical alternative to the more expensive specialty binders or surface coatings.

Decorative finishes can be incorporated into in situ concrete and a wide variety of permanent pattern, colour and texture effects are available including examples shown in Figure 3.4, Figure 3.5 and Figure 3.6.

Figure 3.4: Exposed aggregate concrete

Source: CCAA

Figure 3.5: Stencilled concrete surface

Source: CCAA

Figure 3.6: Stamped concrete surface

Source: CCAA

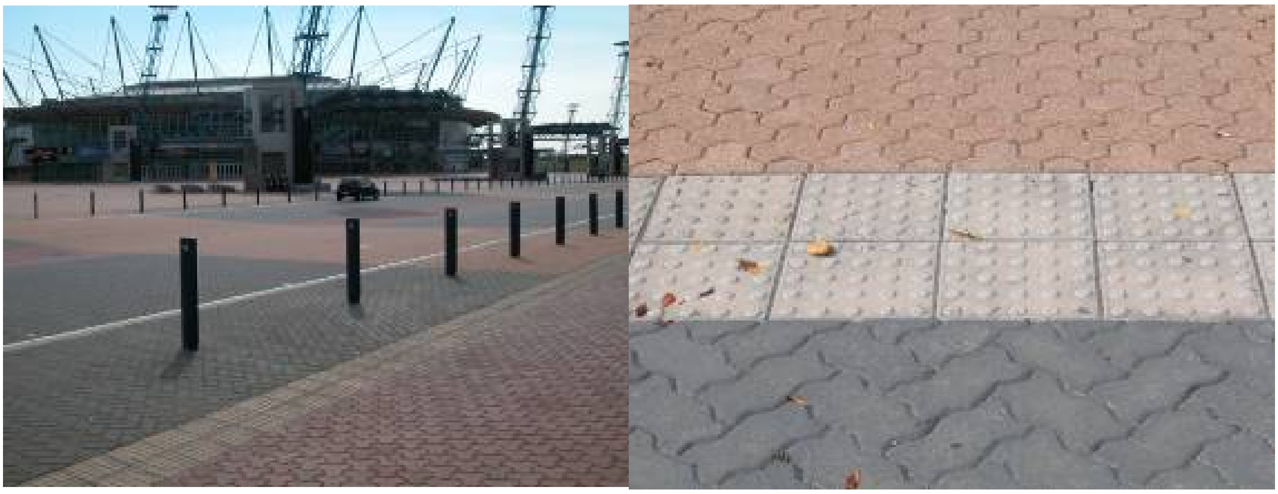
Coloured, patterned surface finishes can also be incorporated in asphalt (Figure 3.7).

Figure 3.7: Coloured embossed/stencilled asphalt surface

Source: MPS Paving Systems

Variations in the colour and pattern can be incorporated in segmental paving to provide both delineation and decorative effects (Figure 3.8).

Figure 3.8: Concrete segmental paving



Source: CCAA

The quality of appearance for decorative purposes is subjective and, for the purpose of this Guide, it is left to the owners of the asset to determine and set an appropriate standard. It is, however, important that the road user and asset manager recognise the importance of appearance.

3.3.10 Strength

The surface deflection of a flexible pavement under an applied load is an important indicator of its structural condition. It is also an important parameter in the design of structural overlays.

As an indicator of structural condition, deflection testing of flexible pavements aids the selection of appropriate rehabilitation treatments, if any is required, by identifying:

- the structural adequacy of the overall pavement
- homogenous lengths of pavement that may be treated similarly
- areas of weak pavement (inadequate thickness, poor quality of pavement materials, soft subgrade) requiring specific treatment (e.g. patching)
- areas for more detailed pavement investigation.

Deflection testing of rigid pavements has a much more limited application. Typically it is used to assess:

- the ability of joints to transfer loads between adjacent slabs
- the presence of voids under joints or cracks.

Details of the measurement of pavement strength are contained in the *Guide to Pavement Technology – Part 5: Pavement Evaluation and Treatment Design* (Austroads 2008e).

3.3.11 Cracking

Cracking of a pavement consists of visible discontinuities in the surface and can be:

- an indication of the structural condition of a pavement, or
- a reaction of the pavement due to:
  - expansive subgrades, moisture changes, or trees, or
  - shrinkage cracking in cemented materials.

Cracking associated with structural pavement deficiencies is typically seen as crocodile cracking which may also be associated with rutting and, in severe cases, pumping of fines after rain.

Cracking associated with expansive subgrades, moisture changes and trees is normally manifest as single longitudinal cracks, 1 to 2 m in from the edge of the pavement. In the case of cemented pavement materials, shrinkage cracking is usually manifest as a block pattern of widely spaced transverse and longitudinal cracks.

Guidance on the assessment and measurement of cracking is provided in the *Guide to Asset Management – Part 5E: Cracking* (Austroads 2006a) whilst guidance on identifying crack types and treatment of pavement deficiencies is provided in the *Guide to Pavement Technology – Part 5*: *Pavement Evaluation and Treatment Design* (Austroads 2008e).

3.3.12 Resistance to Shear Forces

Factors that contribute to the development of horizontal stresses in pavement surfacings are:

- the motion of the wheel (braking, accelerating, turning)
- wheel loading, tyre type, inflation pressure
- the coefficient of friction between the pavement surface and the tyre rubber.

Regardless of the motion of the vehicle (braking, acceleration or turning action), these three factors control the level of the horizontal stress. In each of these driving actions, a limiting force and thus stress results from tyre slippage (skidding). Braking sometimes leads to slippage; acceleration rarely results in slippage; but turning (for a multi-wheel multi-axle assembly) always results in slippage where the turning circle is reduced to the point where the capacity of the tyre tread and side-wall compliance to accommodate the developed strain is reached. Tyre pressure affects the compliance of the tyre wall and therefore the tyre's capacity to accommodate this movement. Surfacing stress resulting from the action of turning vehicles is thought to be a major cause of distress in bituminous surfacings.

Resistance to shear forces can be an important factor in selection of surfacing type. A guide to typical relative resistance to shear stress of various surfacing types is provided in Table 3.7.

Table 3.7: Typical relative resistance to shear forces

Relative resistance	Surfacing
Greatest	Concrete
	Dense graded asphalt (thermosetting resin binder)
	High friction surface treatment (thermosetting resin binder)
	Dense graded asphalt (PMB binder)
	Stone mastic asphalt (PMB binder)
	Dense graded asphalt (bitumen binder)
	Stone mastic asphalt (bitumen binder)
	Cape seal
	Microsurfacing
	Fine gap graded asphalt
	Thin open graded asphalt (PMB binder)
	Open graded asphalt (PMB binder)
	Double/double seal (including geotextile reinforced double/double seal)
	High stress seal (single/single seal with PMB binder)
	Fibre reinforced seal
	Slurry seal
	Single/double seal (racked-in seal)
Least	Single/single seal (bitumen binder)

3.4 Service Life

For surfacings that perform well and continue to meet the requirements of roughness, shape, texture and skid resistance, there is still a need to inspect the surfacings from time to time to assess the effects of ageing.

The major factor that contributes to ageing of bituminous surfacings is the gradual hardening of the bituminous binder as a result of oxidation.

Hardening of the binder in sprayed seals can lead to aggregate loss or cracking that can become a source for moisture entry leading to surface breaking and potholing.

Hardening of the binder in an asphalt mix can result in ravelling and loss of both fine and coarse aggregate particles from the surface. Open graded asphalt should also be inspected regularly for reduced effectiveness due to clogging and loss of permeability.

Whilst concrete pavements have very durable wearing surfaces, periodic inspection is still required to detect deterioration in joint sealing materials or uncontrolled random cracking that can lead to structural deterioration.

Periodic inspection of surfacings allows a comparison to be made of the cost of ‘retreating now’ to the estimated cost of ‘retreat some time in the future’. The cost of retreating a pavement early may be significantly less than the cost of a treatment which is delayed until deterioration has become advanced. The relative whole-of-life costs of early or late retreatments will vary according to the surfacing and pavement type and operating conditions.

Table 3.8 lists typical characteristic service lives for different surfacing types. The service lives presented are for average conditions and structurally sound pavements. Service conditions which affect the expected life include:

- traffic volume: the service life in areas subject to high traffic volumes and high stresses associated with braking and turning traffic will tend to be near the low end of the range
- climate: high service temperatures and high rainfall are generally associated with reduced service life.

Clogging or a reduction in voids in open graded asphalt or ultra thin open graded asphalt may influence effectiveness of noise reduction and water spray.

The age of a surfacing is not, by itself, a sufficient reason for retreating a surface. While deteriorating condition or loss of performance are genuine reasons for treatment, age can be used as a guide to the possible need for close investigation of some aspects of the condition. This is particularly important with sprayed seal surfacings which can be associated with rapid deterioration of the pavement structure in the presence of moisture and traffic once surfacings have started to show signs such as oxidation and stripping.

Table 3.8: Typical service lives

Surfacing type	Expected average service life (years)[1]
Sprayed seal (5 mm and 7 mm)	5–7
Sprayed seal (≥ 10 mm)	8–15
Double application seal	8–15
Open graded asphalt[2]	7–10 (standard binder) 10–15 (modified binder)
Thin open graded asphalt[2]	7–10 (standard binder) 8–12 (modified binder)
Dense graded asphalt	8–20
Stone mastic asphalt	10–20
Fine gap graded asphalt	15–25
Slurry/micro surfacing	5–10
Cape seal	8–15
Concrete[3]	30–40

Notes:

1 *The service lives in this table are for average conditions and assume that the pavements are structurally sound. Service conditions that affect the expected life include:*
   - *Traffic volume. High traffic volumes and high stress areas where there is turning and braking traffic will tend to give a service life near the low end of the range whereas lesser traffic volumes will result in longer service life.*
   - *Climate. High service temperatures generally reduce service life. High rainfall may also reduce service life.*

2 *Clogging or reduction in voids of open graded and thin open graded asphalt may reduce effective life*

3 *Maintenance issues in concrete pavements are normally related to construction problems, joints and cracking*

4. Sprayed Seals

4.1 General

This section of the Guide provides a general guide to the main types of sprayed seal surfacings and their application. Detailed guides to the selection, design and construction of sprayed seals are provided in the *Guide to Pavement Technology – Part 4K: Seals (Austroads 2009d), Part 8: Pavement Construction* (Austroads 2009e) and (Austroads 2006e).

The principal use of sprayed seals in Australia and New Zealand is in the surfacing of unbound granular pavements and stabilised pavements. Sprayed seals may also be used to restore surface characteristics or provide waterproofing on asphalt and concrete pavements.

Sprayed seal types are classified and/or selected based on the size of aggregate, type of binder and the number of applications of binder and aggregate. Sprayed seals may also be reinforced with the incorporation of geotextile fabrics or glass fibres.

Sprayed seals used as initial treatments on unbound granular, concrete, or timber surfaces generally require the use of either a prime or primerseal.

Specialised surface treatments such as surface enrichment and rejuvenation, high friction surface treatment and coloured surface treatments and are also included in this section.

4.2 Aggregate Size

4.2.1 Size Range

Aggregate sizes ranging from sand up to 14 mm are used in single application (single/single) seals. Size 16 mm and 20 mm aggregates are occasionally used in single application (single/single) seals as surfacings, but more commonly their use is restricted to the larger aggregate in multiple application seals.

4.2.2 Sand

The use of sand as a sealing aggregate is generally limited to reseals on lightly trafficked roads, or applications requiring a smooth final surface such as footpaths and tennis courts.

4.2.3 5 mm and 7 mm

These aggregate sizes may be used:

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

4.2.4 10 mm and 14 mm

These aggregate sizes are the most commonly used sizes in single/single seals. They may also be used as the first application in double/double and single/double seals.

4.2.5 16 mm and 20 mm

These aggregate sizes are usually used in combination with a smaller sized aggregate in a multiple application (double/double or single/double) seals (Section 4.6).

Single/single seals using 16 mm and 20 mm aggregates are more durable than smaller aggregate sizes and can be less process sensitive. However, they have the following disadvantages:

- high tyre/road noise
- higher binder application rates
- increased cost
- increased risk of damage to vehicles from flying loose aggregate particles on new work.

4.3 Binder

4.3.1 Bitumen

Bitumen used in Australia is classified by its viscosity at 60°C (AS 2008–1997). The class of binder most commonly used for sprayed sealing is Class 170 bitumen. Class 320 bitumen is also used in limited amounts, usually where there is no practical alternative or on heavily trafficked pavements in hotter areas where the improved performance at high temperatures is considered to outweigh the loss in durability.

In New Zealand, bitumen is classified by penetration at 25°C. Typically, 130/150 bitumen is used in warmer areas and 180/200 bitumen elsewhere. 80/100 bitumen is also occasionally used where extra binder strength is required.

Whilst bitumen classified by viscosity and penetration are similar, there is no direct correlation between viscosity and penetration classifications.

Bitumen is normally a semi-solid, which softens on heating. Systems used for delivery of binder at a suitable viscosity for sprayed seal applications include:

- Reduction in viscosity by heating.
- Reduction in viscosity by addition of cutter oils and/or flux oils. Small amounts of cutter oil may be used in hot bitumen to improve spraying uniformity and adhesion in cool conditions. Increased proportions of cutter oil are used in primersealing work to assist in bonding to the untreated base, while even greater proportions are used in priming materials to achieve penetration of the base. Flux oils are used where a softer grade of residual binder is required to improve the life of lightly trafficked seals.
- Emulsification involving fine droplets of bitumen suspended in water. Typical emulsions used in sprayed sealing contain 60–76% bitumen.
- Addition of a small amount of water to hot bitumen to create an expanded volume through controlled foaming.

4.3.2 Polymer Modified Binders (PMBs)

Polymer modified binders (PMBs) are used in sprayed sealing work to achieve enhanced performance where there is a need to:

- improve shear resistance in high-stress (vertical and horizontal) applications
- minimise or delay reflection cracking
- reduce water penetration

- improve aggregate retention
- reduce temperature dependence
- reduce oxidation in high temperature regimes.

PMBs can be used in sprayed sealing applications for high stress seals (HSS), strain alleviating membranes (SAMs) and strain alleviating membrane interlayers (SAMIs).

A detailed guide to PMB classes and applications is provided in the *Guide to Pavement Technology – Part 4F: Bituminous Binders* (Austroads 2008c) and (Austroads 2006c). A summary of the guidelines for the use of PMBs in HSS, SAM and SAMI applications is provided in Table 4.1. This lists possible applications without necessarily identifying the optimum material for each case.

Table 4.1: Selection of PMB and multigrade bitumen

Application	Service condition				Binder class					
	Cracking		Traffic							
	Activity	Width severity	Site severity	Loading	S10E	S20E	S25E	S35E	S45R S15RF	S18RF
HSS	NA	NA	Severe	All		✓		✓	✓	
			Moderate	Heavy		✓		✓	✓	
				Medium		✓		✓	✓	
SAM	Slow	All	NA	All	✓			✓	✓	
	Rapid	High	NA	All		✓	✓			✓
		Low	NA	All		✓	✓		✓	
SAMI	All	All	NA	All			✓			✓

✓ indicates suitable binder class
Source: Austroads (2006c)

4.3.3 Bitumen Emulsions

All sizes of seals and primerseals can be applied using bitumen emulsion binders.

Single application (single/single) seals using large aggregates must be combined with high bitumen content emulsions (67% or greater) to avoid drainage of the binder from the surface while still fluid. Such seals also commonly use a scatter coat of smaller size aggregate to assist in anchoring aggregate particles while curing of the binder takes place (see also Section 4.6.3).

Bitumen emulsions can also be modified with PMBs to improve both initial aggregate retention and the long term performance of the sprayed seal.

Care should be taken to ensure that sufficient time is allowed for the emulsion primerseal to cure before being opened to traffic at normal speed.

4.4 Prime

A prime is a temporary surfacing used as a preliminary treatment to the application of a sprayed seal or asphalt surface. It is a sprayed layer of primer (bitumen and cutter oil mixture or a formulated bitumen emulsion primer) without cover aggregate. Primes are placed on prepared granular surfaces, concrete bridge decks or timber surfaces. They are used to:

- bind and penetrate the surface of an unbound granular layer
- provide a bond onto which a bituminous surfacing can adhere
- provide a surface which retards the absorption of bitumen from the bituminous surfacing into the pavement
- assist in waterproofing and protecting the pavement during construction
- assist with the curing of stabilised pavement materials.

The use of a prime or primerseal is always recommended for unbound and stabilised granular pavements, particularly where the following surfacing is a sprayed seal or asphalt with a total thickness of no more than 50 mm.

If the pavement is not primed correctly, then the binder in the following seal could:

- be affected by the fine dust materials present on the surface of the pavement and 'ball' (i.e. it may not be uniformly spread across the pavement), resulting in poor adhesion to the underlying primed surface
- be absorbed into the pavement surface, resulting in insufficient binder being available to hold the cover aggregate in position
- flush or bleed, which is often the result of the addition of too much primer, the use of a primer with too high a viscosity, priming on a wet pavement (which prevents the prime from soaking into the pavement and results in too much binder around the aggregate) or excess primer as an outcome of poor penetration into a heavily bound base.

4.5 Primerseal

A primerseal is an initial treatment where a primerbinder is sprayed onto a prepared, but unprimed pavement surface and then covered with a layer of aggregate. It allows both immediate trafficking and a temporary pavement surfacing until a more substantial surfacing treatment is applied.

A cutback primerbinder is manufactured with between 12–18% cutter oil, usually with the addition of 1% of adhesion agent. The role of the cutter oil and adhesion agent is to assist in surface wetting to ensure a uniform coverage of binder as well as a degree of penetration into the surface of the pavement. If the bitumen in the primerbinder is not cut back sufficiently, it could 'ball' and/or it may not bond to the underlying surface.

A bitumen emulsion primerbinder may also be used. It must uniformly 'wet' the surface of the pavement if it is to bond to the underlying layers. Emulsion primerbinders can be specially formulated for this purpose.

When using either cutback or emulsion binders, the pavement surface should normally be damp (not wet) to assist in the binder 'wetting' process.

Failure to primerseal properly can result in similar problems to those described previously for incorrectly primed pavements.

Primerseals constructed with cutback bitumen binders should not be resealed until after a reasonable period of curing as any residual volatile cutter oil can affect the subsequent treatment. The rate at which the volatiles escape depends upon the primerbinder grade, application rate and temperature. The minimum time period for curing can vary from three months in warm conditions to up to 12 months in cooler conditions.

Minimum curing times do not apply to bitumen emulsion primerbinders that may be resurfaced immediately after initial curing has taken place.

A guide to the life expectancy of a primerseal is shown in Table 4.2.

Table 4.2: Life expectancy of primerseals

Type of primerbinder	Grade	Life expectancy (months)
Bitumen emulsion	All	12–36
Cutback bitumen	Medium	3–18
	Heavy	12–36

4.6 Seals and Reseals

4.6.1 General

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

In some jurisdictions, the term 'seal' is used specifically for the first seal applied over a primed or primersealed surface, but use of the term 'seal' as the generic description for all sprayed seal treatments, including reseals, is more common. The term 'initial seal' is also sometimes used to describe the first seal applied over a primed, or primersealed surface but is defined in the *Glossary of Austroads Terms* (Austroads 2008a) as a seal that has been placed on a basecourse that has not been primed. Application of a sprayed seal to a basecourse without priming is considered poor practice unless placed as a primerseal (Section 4.5). In New Zealand, the application of a 'first coat seal' to a prepared base course is synonymous with the practice of primersealing in Australia.

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).

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.

The most common type of sprayed seal is a single application of binder and single application of aggregate (single/single seal). Multiple application seals (Section 4.6.3) are generally described in sequence of application of binder and aggregate.

Further variations to sprayed seals for specific circumstances include high stress seal, strain alleviating membrane, strain alleviating membrane interlayer, fibre reinforced seal, geotextile reinforced seal and cape seal (Section 6.4).

4.6.2 Single/Single Seals

Sprayed seals are generally assumed to be single/single unless otherwise stated but can encompass a large range of aggregate and binder types

Choice of aggregate size, binder type and the design of aggregate and binder application rates are important factors in the selection of single/single seals for a particular application.

4.6.3 Multiple Application Seals

Double/double seals

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

A double/double seal is applied by spraying a layer of binder, spreading the large-sized aggregate and, after trafficking and/or suitable rolling, spraying another low 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.

Double/double seals are used:

- when additional waterproofing must be ensured
- when the traffic noise from a single application (single/single) is unacceptable
- when a fine texture is required (parking areas, residential streets, footpaths, etc.)
- in areas subject to high shear loading compared to single application (single/single) seals.

Double/double seals are also commonly used in geotextile reinforced seals as they provide a more robust treatment with better resistance to turning traffic than single/single seals.

In remote areas the second application of a double/double seal has been used to protect the binder in the bottom layer from extreme climatic conditions and dust, resulting in an increase in seal life.

Normal combinations of aggregate for double/double seals include:

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

Single/double seal (racked-in seal)

A single/double is a variation of the double/double application seal. It is constructed by spraying a single layer of bitumen, spreading the large-sized aggregate at less than the normal spread rate and, after suitable rolling, 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’ 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 and the second aggregate application, or scatter coat, is used to provide temporary mechanical interlock between the larger particles to prevent traffic overturning and dislodging the coarse aggregate particles during the initial curing and compaction of the seal.

A scatter coat is particularly applicable when using emulsions as described in Section 4.3.3.

A scatter coat differs from a single/double or racked-in seal in that the second aggregate is not applied until after initial rolling of the first application of aggregate 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 that 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 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.

Inverted seal

An inverted seal 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 is similar to the dry matting technique referred to above, except that a light application of binder is used to hold the first application of aggregate in place, and has similar applications such as treatment of bleeding seals or surfaces with a large variation in transverse surface texture. It may also be used to reduce risk of embedment of the larger aggregate into soft pavement materials.

4.6.4 High Stress Seals (HSS)

A high stress seal (HSS) is a bituminous seal or reseal treatment which is used in applications subject to heavier than normal traffic loading due to braking, accelerating or turning vehicles. The binder in an HSS normally contains medium levels of polymer modifiers.

4.6.5 Strain Alleviating Membrane (SAM)

A strain alleviating membrane (SAM) is a sprayed seal consisting of a binder containing a relatively large amount of crumb rubber or polymer modifier. It is used to absorb strains that occur in a road pavement and thereby reduce reflection cracking.

SAM applications may also be met by the use of fibre reinforced seals and geotextile reinforced seals (see below).

4.6.6 Strain Alleviating Membrane Interlayer (SAMI)

A strain alleviating membrane interlayer (SAMI) is similar to a SAM; however, it is placed as an interlayer. SAMIs should only use aggregates of size 10 mm or larger. The binder in a SAMI is usually heavier in application rate and more heavily modified than a SAM binder.

SAMI applications may also be met by the use of fibre reinforced seals and geotextile reinforced seals (see below).

4.6.7 Fibre Reinforced Seal (FRS)

A fibre reinforced seal (FRS) uses a polymer modified bitumen emulsion binder and chopped glass fibre as reinforcement. The process uses a purpose-built sprayer (Figure 4.1) which, in a single pass:

- sprays binder onto the pavement
- cuts the required amount of fibre glass 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.

The applications of an FRS are as a SAM or a SAMI, and FRS properties are somewhere between those of a SAM seal with PMB binder and a geotextile reinforced seal (GRS).

Figure 4.1: Application of fibre reinforced seal

Source: Pioneer Road Services

4.6.8 Geotextile Reinforced Seal (GRS)

Geotextile reinforced seals (GRS) 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 (Figure 4.2). A single/single or double/double seal is then applied over the geotextile.

GRSs are currently the most effective sprayed sealing technique in SAM and SAMI applications used for treating badly cracked and distressed bound and unbound pavements, particularly when crack movements are slow.

It must, however, be recognised that the potential life of the geotextile treatment may be influenced by premature distress in the underlying layers, the poor condition of the original pavement or periodic inundation.

Aggregate sizes for double application seals are commonly 14/7. For single application seals, size 10 aggregates provide the most suitable compromise between excessive embedment into the fabric by smaller aggregate sizes or potential puncturing of the fabric by larger aggregates.

Single/single seals are generally only used in SAMI applications. Double/double seals are preferred in SAM applications as they provide a more robust treatment with better resistance to turning traffic.

Both conventional bitumen and bitumen emulsions can be used in the construction of GRSs including PMBs. The use of PMBs in the bond coat or second application of a double/double seal is, however, not recommended.

Figure 4.2: Application of geotextile for geotextile reinforced seal

Source: VicRoads

A further application for GRS is as a surfacing treatment on pavements constructed with poor quality clay materials. This treatment has been successfully used in remote areas where reasonable quality granular pavement materials are unavailable and pavements must be constructed using local clay soils (Johnson-Clarke, Sharp and Walter 1993; RTA NSW 1992; 1998). These materials can provide adequate bearing capacity provided surface cracking is avoided in dry periods and moisture entry is prevented in wet periods. The use of GRS under these conditions has proven to be an economical means of providing low cost, all weather roads in remote areas (Figure 4.3).

Figure 4.3: Geotextile reinforced seal on a clay pavement

Source: RTA NSW

4.7 Surface Enrichment/Rejuvenation

Surface enrichment of a sprayed seal surface involves the spraying of a light application of a light 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 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 where traffic volumes are low and traffic can be diverted onto another lane or road, or for 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.

4.8 High Friction Surface Treatment

For specialty sealing applications, thermosetting resin binders, including epoxy and polyurethane modified materials and other forms of polyester and resin esters can be used. These binders have been particularly 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 4.4).

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 3-5 mm although larger sizes can be used. The high relative cost compared to conventional binders confines their use to specialised applications.

Figure 4.4: High friction surface treatment

Source: Roadcor

4.9 Coloured Surface Treatments

Coloured surface coatings used for delineation (Section 3.3.7) generally involve the application of suitably coloured materials applied as either a slurry of fine aggregate and binder or as a specialty binder and synthetic aggregate. The highest levels of colour intensity, surface friction and durability are generally obtained by the use of synthetic materials.

Figure 4.5: Coloured surface treatments using composite slurry (left) and epoxy resin binder with synthetic aggregate (right)

Source: Roadcor

5. Asphalt

5.1 General

Prior to the 1970s, most of the asphalt used in Australia and New Zealand was of the dense graded asphalt type or, occasionally, fine gap graded asphalt for surfacing lightly trafficked pavements and limited use of large nominal size mixes (macadam) for base course.

The 1970s saw a rapid growth in the use of open graded asphalt as a wearing course on freeways and other major roads for improved surface texture, increased safety and reduced surface noise. More recently, other wearing course asphalt types have been introduced to provide varying surface characteristics, including innovative materials for thin and ultra-thin surfacings as well as various proprietary surfacings.

Dense graded asphalt remains the primary choice of asphalt for base courses and it is still commonly used as a wearing course in general applications. Other wearing course asphalt types described in this Guide include open graded asphalt, stone mastic asphalt, fine gap graded asphalt as well as variations used in thin and ultra-thin surfacings and other specialty mix types.

An outline of the principal asphalt mix types and applications is provided below. Detailed guides to the selection, design of asphalt mixes and construction of asphalt pavements are provided in the *Guide to Pavement Technology – Part 4B: Asphalt* (Austroads 2007d) and AS 2150–2005.

5.1.1 Asphalt Mix Types

Asphalt mix types are broadly classified by grading type with further variations in selection of binder type as well as types and proportions of component materials for particular applications and traffic loadings.

The principal mix types are:

- dense graded asphalt
- open graded asphalt
- stone mastic asphalt
- fine gap graded asphalt.

5.2 Binders

5.2.1 Bitumen, Multigrade Bitumen and Polymer Modified Binder

Classes of binder used include:

- Australian Standard AS 2008–1997 bitumen Classes 170, 320 and 600
- multigrade bitumen
- polymer modified binders (including crumb rubber).

Class 320 bitumen is most commonly used for asphalt in Australia. Class 170 may be used in cooler areas and for lighter-traffic applications. The main use of Class 600 bitumen is in asphalt base layers for improved structural stiffness. In some specific locations bitumen can be supplied as a non-standard grade with a nominal designation of Class 450 for use as an alternative to Class 320 bitumen for increased asphalt mix stiffness in wearing course and base course asphalt mixes.

In New Zealand, penetration bitumen grade 80–100 (TNZ M/1) is used for general asphalt work and 60–70 for heavier duty applications. A heavier grade (40–50 penetration) may also be used in specific applications where increased asphalt stiffness is required.

Asphalts containing polymer modified binders and multigrade bitumen have improved properties compared with asphalts composed of conventional binders. In combination with an adequate aggregate skeletal structure, the choice of binder will affect the modulus, fatigue life, rut resistance and cost of the asphalt.

A guide to the selection of PMB and multigrade bitumen types is shown in Table 5.1. This lists possible applications without necessarily identifying the optimum material for each case. Detailed guides to the selection of the most appropriate bitumen, polymer modified binder or multigrade bitumen for a given situation is provided in the *Guide to Pavement Technology – Part 4B: Asphalt* (Austroads 2007d) and *Part 4F: Bituminous binders* (Austroads 2008c).

Table 5.1: Guide to the selection of asphalt PMBs and multigrade bitumens

Application	Service condition		Binder class							
	Traffic	Temperature	M500/ 170	M1000/ 320	A27RF[1]	A35P	A25E	A20E	A15E	A10E
Rutting resistance	Very heavy	All		✓		✓				✓
	Heavy	High or medium	✓	✓		✓			✓	✓
Fatigue resistance (marginal pavement)	Very heavy to heavy	All			✓				✓	✓
Rutting and fatigue (marginal pavement)	Very heavy to heavy	All							✓	✓
	Medium							✓	✓	✓
Rutting and fatigue (adequate pavement)	Very heavy to heavy	High or medium		✓				✓	✓	✓
		Low	✓	✓	✓			✓	✓	✓
Open graded asphalt	Very heavy to heavy	High				✓			✓	✓
		Medium or low				✓	✓	✓	✓	
	< Heavy	All				✓	✓	✓	✓	
Stone mastic asphalt	Heavy	All		✓			✓	✓	✓	✓

Notes:
✓ indicates suitable binder class
Crumb rubber modified asphalt (dry mix to A27RF Class) has provided excellent performance over cracked pavements in road trials along with good rutting resistance.
Source: Austroads (2006c)

5.2.2 Epoxy Resin and Polyurethane Modified Binders

Epoxy resin and polyurethane modified binders provide surfacing materials with exceptional bond strength, toughness, flexibility and resistance to solvents.

The high cost of these materials confines their use to specialised applications such as the surfacing of steel bridge decks or applications subject to very high traffic stresses.

Asphalt mixes with epoxy resin and polyurethane modified binders also have potential use as long life surfacings on strong bound pavements.

5.3 Dense Graded Asphalt

The most common type of asphalt is a dense graded mixture of continuously graded aggregate, sand, filler and bitumen which is mixed and placed hot. By varying the aggregate combination to provide a range of different air voids, and using different grades of binder, asphalt properties can be adapted to suit applications ranging from lightly trafficked applications such as residential streets to heavily trafficked applications such as freeways, and heavy duty applications such as airports and container storage areas.

In lightly trafficked applications, long term deterioration is usually manifest as ravelling due to oxidation of the binder. To minimise this, a soft grade of binder may be used and the air voids reduced through the use of a high binder content and/or fine aggregate grading. Durable asphalt mixes for lightly trafficked applications can also be achieved with fine gap graded mixes (Section 5.6).

On more heavily trafficked pavements it is important that the asphalt does not flush, deform or fatigue under the action of traffic. Resistance to flushing and deformation is improved through the use of coarser gradings and stiffer binders. Polymer modified binders can be used to enhance both rutting resistance and the fatigue properties.

Generally, dense graded asphalt is manufactured in nominal sizes of 5, 7, 10, 14, 20 and 28 mm, though some 40 mm mixes are also manufactured. Mix sizes 20 mm and above are normally used as structural layers in the pavement rather than as wearing surfaces.

A guide to the selection of the nominal size of asphalt is provided in Table 5.2. A detailed guide to the selection and design of asphalt mixes is provided in the *Guide to Pavement Technology – Part 4B: Asphalt* (Austroads 2007d). Further detailed advice on the application of polymer modified binders and multigrade bitumen for asphalt is contained in the *Guide to Pavement Technology – Part 4F: Bituminous binders* (Austroads 2008c).

Table 5.2: Selection of nominal size of dense graded asphalt mix

Nominal size (mm)	Typical layer thickness (mm)[1]	Typical use
5	15–20	Available in limited locations for use as very thin surfacing layer with fine surface texture
7	20–25	Commonly used for surfacing residential streets and pedestrian areas where thin layers and fine surface texture required
10	25–35	General purpose wearing course mix suitable for both light and moderate traffic applications
14	35–45	Wearing course mix for heavier traffic applications; also intermediate course to suit layer thickness
20	> 50	General purpose base and intermediate course mix for wide range of uses
28	>60	Less commonly used than 20 mm for base and intermediate course; control of segregation can sometimes be an issue
40	>100	Occasionally used as a heavy duty base; control of segregation can be a significant problem

Notes:
To ensure adequate compaction of asphalt mixes containing heavily modified polymer modified binders, a minimum layer thickness of 3.5 times the nominal size is generally recommended.
Source: Austroads (2006b)

5.4 Open Graded Asphalt

Open graded asphalt is manufactured with a large proportion of coarse aggregate and only a small amount of fine aggregate, resulting in a high void content. For wearing surface applications the size of the aggregate is usually 10 mm or 14 mm. Larger aggregate sizes (20 mm and 28 mm) are also occasionally used where open graded asphalt is used as a drainage blanket in the lower layers of a pavement.

Open graded asphalt contains 18–25% air voids and is porous by design. It is used for the rapid removal of water from the surfacing to improve safety. The use of open graded asphalt contributes to:

- improved skid resistance associated with a reduction in surface water
- a reduction in tyre road noise generation
- a reduction in water spray for visibility and road safety.

Considerations in the use of open graded asphalt surfacings include the following:

- Water retained in open graded asphalt may increase the volume of water entering the underlying layers. A waterproofing seal or a uniform, heavy tack coat should be placed prior to the placement of the open graded asphalt surfacing.
- It is very important that an outlet be provided for the water that enters an open graded asphalt. Otherwise the layer deteriorates and dust and debris build up. For this reason, open graded asphalt must have a free-draining edge and be placed above the lip level of any adjacent kerb and channel. As this raised edge may be a hazard to cyclists it may be necessary to minimise its height and consider where the edge is located.
- As performance may be poor in areas of high surface shearing forces and oil droppings, open graded asphalt is generally not suitable for applications such as heavily trafficked intersections.
- Some of the noise and drainage benefits can reduce over time due to wear, densification, ravelling and the clogging of voids.
- Open graded asphalt has a shorter life expectancy than dense graded asphalt.

Open graded asphalt can be manufactured using standard bitumen or lightly modified PMBs. The usual method of failure is by ravelling of the surface aggregate as the binder hardens. The durability of open graded asphalt with PMBs can be significantly greater than that of mixes with unmodified binders.

The choice between the use of modified and unmodified binders is dependent upon traffic stresses and volumes. PMBs are particularly suitable for heavier traffic applications. The durability of the PMB increases due to increased binder cohesion, especially if thicker binder films are used. PMBs also reduce binder ‘drain down’ effects during construction.

5.5 Stone Mastic Asphalt

Stone mastic asphalt (SMA) is designed to have a large percentage of coarse aggregate with predominantly stone-on-stone contact, with the remaining voids partially filled with a mastic comprising fines, filler and bituminous binder. The combination of stone-on-stone contact of the coarse aggregate and stiffening of the binder mastic with fine aggregate and filler provide a mix with good deformation resistance.

The larger proportion of coarse aggregate can also result in a surface texture somewhere between dense graded asphalt and open graded asphalt but with lower air voids than open graded asphalt and hence good durability.

Particular care is required in the design, manufacture and placing of SMA mixes. Inadequate compacted density can result in high air voids, and hence increased permeability and risk of moisture damage to the SMA or the underlying pavement. Alternatively, overfilling of the coarse aggregate structure with the fine aggregate/filler/binder mastic can lead to flushing, reduction in surface texture and, in severe circumstances, surface rutting.

Small percentages of cellulose or mineral fibres are commonly used to minimise the risk of drainage of the relatively high binder content during transport and placing. PMBs may also be used to reduce the risk of 'drain down' as well as reduce the risk of bleeding under severe performance conditions and/or to enhance rutting resistance and flexural performance. SMA mixes are inherently more flexible due to the high binder contents.

SMA is usually used as a surfacing material in 7, 10 and 14 mm nominal sizes.

5.6 Fine Gap Graded Asphalt

Fine gap graded asphalt was developed to have good durability in locations such as residential streets and lightly trafficked roads. It is a variation of dense graded asphalt, but with some aggregate fractions reduced or omitted.

Fine gap graded mixes have a relatively larger proportion of fine aggregate for improved workability and ease of compaction. When combined with relatively high binder content, they can achieve exceptional durability.

Ease of placement and the fine surface texture makes these mixes suitable for residential streets and other light traffic applications.

Detailed procedures for the design of durable asphalt surfacing for lightly trafficked streets are available in Austroads (2006c).

5.7 Thin Asphalt Surfacings

The terms thin and ultra-thin asphalt could be interpreted as applicable to any asphalt surfacing designed to be placed in layers of less than 25 mm in thickness. In practice, the terms are taken as associated with particular mix types that have been specifically designed as thin surface retreatments to restore surface characteristics with a minimum thickness of asphalt.

These types of asphalt mixes originated in Europe, generally as proprietary products, and are usually variations of open graded or stone mastic asphalt mix types. Most of these mixes are designed to provide good texture depth and low noise characteristics for use on major roads.

Thin open graded asphalt mix types generally comprise a more graded product than standard open graded asphalt, as well as a polymer modified binder to ensure adequate resistance to heavy traffic shearing forces. They also require a heavy application of a bitumen emulsion polymer modified binder tack coat for waterproofing and adequate bond to the underlying surface which, in turn, involves the use of a modified asphalt paver to place the binder layer immediately ahead of the asphalt. The surface characteristics of thin open graded asphalt are similar to normal open graded asphalt but without the same level of water spray reduction due to the reduced porosity.

Use of the term 'thin open graded asphalt' in Australia ('ultra thin asphalt' in Victoria) is generally taken to refer to the particular variant of thin surfacing referred to above. The selection tables in Section 9 are based on this particular mix type.

A variation to thin open graded asphalt is 'low noise asphalt' that adds crumb rubber to the mixture for improved noise attenuation.

Further variations of ultra thin asphalt specialty mixes follow the concept of SMA with a large proportion of coarse aggregate to provide a stable mixture with good texture depth, but with sufficient fine aggregate, filler and binder to achieve air void levels associated with dense graded asphalt mixes. Although not greatly different to SMA, some of these mixes have been given particular names such as 'regulation gap graded asphalt' (Victoria) and 'thin high textured asphalt surfacing' (NSW).

Specialty thin surfacing mix types may also be supplied as proprietary products. Proprietary surfacings should generally be used only after a structured process of verification of performance.

Other types of thin asphalt surfacings include small nominal sizes of dense graded and fine gap graded asphalt mixes. These mix types are generally associated with light duty applications only.

5.8 Recycled Asphalt

Asphalt reclaimed from existing pavements can be recycled primarily in two ways:

- plant mixed using reclaimed asphalt pavement (RAP) that is milled from existing asphalt layers and used:
  - as a component in the manufacture of new asphalt
  - as a cold plant mixed material using a small amount of rejuvenating oil, bitumen emulsion binder or foamed bitumen binder
- in situ recycling of asphalt:
  - cold-in-place recycling using similar processes to cold plant mixed material
  - hot-in-place recycling with or without new asphalt components added into the mixture or new asphalt added as an overlay.

Asphalt incorporating RAP is manufactured to meet the same performance requirements as mixes manufactured entirely from new materials. Mixes containing up to 15% RAP are regularly used while up to 40% RAP may be used in specific applications with appropriate mix design, manufacturing plant and process controls.

Cold recycling processes generally require some form of additional surfacing layer and are not usually considered as a surfacing.

Hot-in-place recycling requires special equipment and techniques but an end result can be achieved that is comparable to new materials if proper design systems are utilised. It can be used in shape correction, to address issues associated with ageing, or to improve the surface texture of an asphalt surfacing on an otherwise sound pavement. Where required, the recycled asphalt can also be overlaid with fresh asphalt in a single operation. Hot-in-place recycling is generally limited to pavements with significant depths of existing asphalt.

For further information, reference should be made to the *Guide to Pavement Technology – Part 4B: Asphalt* (Austroads 2007d).

5.9 Warm Mix Asphalt

The use of 'warm mix asphalt' is associated with a reduction in the temperatures of manufacture, paving and compaction of asphalt mixes. This lowering of temperature brings with it reductions in energy consumption, fume and odour emission, mix oxidation, and construction times where cooling of the asphalt layer prior to overlay or opening to traffic is a concern.

Currently, various processes for lowering the temperature of asphalt are being introduced for use in Australia and New Zealand, including:

- foamed bitumen

  - direct injection
  - two-component binder system
  - addition of synthetic zeolite
- addition of organic additives
- bitumen emulsions.

In its simplest form, foamed bitumen involves injection of water along with the hot bitumen binder to create a volume expansion of the bitumen that allows increased workability and coating of aggregates at a lower temperature.

In the two-stage foam process, an extremely soft binder is mixed with aggregate in the first stage at 100–120^{0}C to fully coat the aggregate. In the second stage of production, a much harder bitumen component is foamed into the pre-coated aggregate mixture. The presence of the foam provides the necessary workability for spreading and compaction while the combination of soft and hard bitumen binders provides the appropriate in-service properties. This process requires a modified asphalt mixing plant for adding the foamed bitumen component.

The synthetic zeolite additive is introduced as a powder of crystallised zeolite (sodium aluminium silicate) that incorporates around 21% water that is released on contact with hot bitumen to create a foaming effect that, like other foamed bitumen processes, allows increased workability and aggregate coating at lower temperatures.

Organic additives are supplied as a number of proprietary products, including wax based products that alter the flow characteristics of bitumen at the elevated temperatures used in asphalt manufacture or amine based products that allow coating of aggregates to be achieved at lower asphalt mixing temperatures.

The use of bitumen emulsions to produce warm mix asphalt is not new, but issues associated with curing and dispersal of the water phase have largely confined the use of bitumen emulsions to cold mix maintenance patching materials and open graded asphalt mixes. New forms of emulsion technology, however, are being introduced that enable asphalt mixes to be manufactured and placed in the same manner as conventional asphalt mixes, but at substantially reduced temperatures.

It could be noted that most warm mix asphalt technologies require some form of licensing, modified asphalt mixing plant or the use of proprietary products as additives.

5.10 Cement Grout Filled Macadam

Cement grout filled macadams are constructed with a layer of open graded asphalt that is penetrated with a special fluid cement mixture. The open graded asphalt provides a surfacing layer suitable for use on flexible pavements while the penetrated cement mixture produces a rut and abrasion resistant surface that is also resistant to the spillage of fuels and other solvents.

This surfacing is particularly suitable for industrial applications and transport terminals where resistance is required to static and slow moving loads, fuel or oil spillages, or surface abrasion.

This treatment is generally offered as a proprietary process and requires skilled installation. Expert advice should be sought before use.

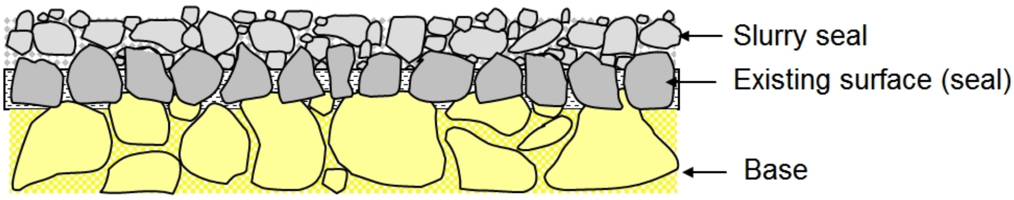
6. slurry surfacing

6.1 General

Slurry surfacing is a mixture of graded aggregates and bitumen emulsion produced as a slurry. There are two general types of slurry surfacing: a basic mixture known as a slurry seal and an enhanced mixture that is usually designated as microsurfacing. In practice, nearly all the slurry surfacing undertaken in Australia and New Zealand is microsurfacing.

Slurry surfacing is generally applied as a thin wearing course as either preventative maintenance on existing sound pavements or as corrective maintenance to restore surface texture, correct ravelling and loss of fines, and fill minor surface cracks (Figure 6.1).

Figure 6.1: Slurry surfacing



Source: Austroads (2006f)

Slurry surfacing used for shape correction and rut filling can result in variable surface texture due to uneven settlement of larger aggregate particles in deeper sections of the applied slurry. An additional wearing course of slurry surfacing, sprayed seal or asphalt may be required.

Slurry surfacings must be placed on a sound pavement due to the relative brittleness of the material and poor resistance to reflective cracking.

Additional guidelines and framework specifications for slurry surfacing are provided in Austroads (2003a).

6.2 Slurry Seals

The size of materials in a slurry seal varies from sand to 7 mm aggregate. These surfacings are composed of a graded mixture of sand and crushed rock containing filler, cement and bitumen emulsion. They tend to be very thin (<12 mm), have a fine surface texture and are relatively brittle compared with asphalt.

Due to their fine surface texture, slurry seals generally provide satisfactory skid resistance at low speeds (<70 km/h) but may be unsatisfactory at high speeds (>70 km/h). Careful consideration should therefore be given to the road environment when contemplating the use of slurry seals.

6.3 Microsurfacing

Microsurfacing is similar to the slurry sealing process except that PMB emulsions are used to provide faster setting for earlier trafficking, greater resistance to rutting, greater durability and improved flexibility. Larger sized aggregate and multiple applications are also feasible.

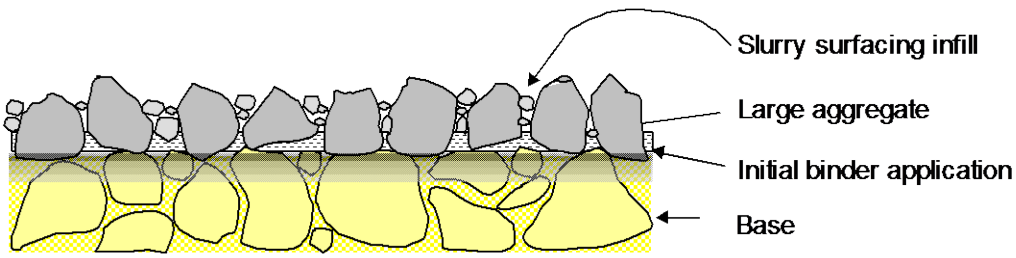
The nominal size of microsurfacing is usually in the range 4–10 mm and it is usually placed in layers one to three times the nominal mix size. Microsurfacing may be used for wearing course applications at nominal depths of about 18 mm, or it may be used for significant shape corrections such as repairs to wheelpath rutting. Polymers are an integral part of these systems, being used to optimise the mix design for the overlay product.

6.4 Cape Seals

Cape seals take their name from their origin in Cape Province, South Africa. They are constructed by initially spray sealing the pavement (usually using a size 20 mm aggregate) followed by a microsurfacing which can either partially fill the void space between the bitumen and the top of the aggregate or completely cover the top of the aggregate. This is achieved by either a single or double application of microsurfacing (Figure 6.2).

This type of treatment provides a very robust surfacing. The surface characteristics of cape seals are similar to those of slurry surfacing.

Figure 6.2: Cape seal



Source: Austroads (2006f)

7. Concrete

7.1 Concrete Surfaces

Concrete pavements may be finished with a variety of surface treatments tailored to suit anticipated traffic conditions.

Durability of a concrete surface depends primarily on concrete strength and the presence of quartz sand. To this end, the finishing and curing techniques are critical. Under ideal conditions, the surface may remain durable for the design life of the pavement. If construction techniques are relaxed, or if good quality sands are unavailable, retexturing treatments such as diamond grinding may be required after 15 to 25 years.

An outline of concrete surface finishes is provided below. Guides to the design and construction of concrete materials and pavements are provided in AS 3600–2001 and the *Guide to Pavement Technology – Part 8: Pavement construction* (Austroads 2009e).

7.1.1 Concrete Surface Finishes

A wide variety of surface finishes are available. Various colours and textures can be incorporated into the surface following placing and compaction, but prior to curing and hardening. The finish can be varied within the works.

Most concrete surface texturing is carried out during the construction phase although, in some instances, grinding techniques are used during rehabilitation.

The selection of the concrete finish type requires the consideration of a number of factors including surface texture, noise properties and aesthetics. Typical surface finishes used for concrete pavements are shown in Table 7.1.

Table 7.1: Concrete surfacing finish

Application	Surfacing finish
Freeways and highways	Tined Hessian drag and tined
Main roads	Tined Hessian drag and tined Hessian drag
Residential streets	Hessian drag Wood float Broomed Stencilled Stamped Exposed aggregate

Tining

Tining is achieved by dragging a steel comb over the surface of wet concrete (Figure 7.1). The tining may be longitudinal or transverse. In Australasia, the tining is conducted in the transverse direction whereas, in other countries, longitudinal tining is preferred. In some cases, longitudinal tining may be carried out with a very-long-weave pattern. If longitudinal tining is used, the shoulders are tined transversely to highlight the change to drivers wandering off the lane.

The tines are generally 2 to 3 mm in width and square in section. Tine spacing may be regular or randomised, such that average spacing is between 10 and 30 mm. The pattern recommended in Australia is a random pattern of 10, 14, 16, 11, 10, 13, 15, 16, 11, 10, 13 and 10 mm to produce an average tined space of 12.5 mm. The tine depth is generally 2 to 3 mm.

Figure 7.1: Tined concrete surface

Source: CCAA

Hessian drag

This is achieved by dragging a wet hessian cloth along the whole width of the paved area immediately after the concrete is at its final surface elevation. In some cases the hessian is given some horizontal movement to create a longitudinal wave form on the surface. It provides adequate skid resistance and aquaplaning performance for vehicle speeds below 80 km/h.

Figure 7.2: Hessian drag

Source: CCAA

Hessian drag and tine

This is achieved by dragging a wet hessian cloth longitudinally over the formed surface followed by longitudinal or transverse tining (Figure 7.3).

Figure 7.3: Hessian drag followed by transverse tine

Source: CCAA

Broomed

In this process, the surface is broomed by hand in one direction after the concrete is placed and initial finishing has taken place. Coarse textures, suitable for steep slopes or heavily trafficked areas, are produced by stiff-bristled brooms or tined rakes, while medium to fine textures are obtained using soft-bristled brooms (Figure 7.4).

Figure 7.4: Broomed finish

Source: CCAA

Exposed aggregate

This surface results from the removal of a portion of the mortar from the surface (Section 3.3.9).

Wood float

The surface is wood floated after initial finishing. It produces slightly raised lines in the surface paste which provide adequate skid resistance for low-speed traffic.

Stencilled

This technique has been used for many years. It involves a stencil (paper template) being placed over the concrete surface immediately after the concrete is placed. A coloured (or several colours in some instances for special patterns) dry shake powder is placed evenly over the surface and trowelled into the wet concrete. The stencil is raised and a sealer is placed on the concrete. This surface provides a wide variety of surface patterns and textures, whilst maintaining skid resistance for the appropriate traffic speed (Section 3.3.9).

Stamped (impressed)

This technique involves the stamping of a surface pattern onto the wet concrete to produce surface texture and pattern in the concrete. Simple grid patterns may be formed, such as bluestone pitchers (Section 3.3.9). These pavements are normally finished with a light brooming to provide adequate skid resistance. Alternatively, by using texture mats, the entire surface may be textured to produce slate, rock or cobble textures.

Coloured

All concrete surfaces may be coloured. The colouring can be used in combination with any form of concrete texturing. Whilst colouring can be achieved using a variety of methods, paints or stains are not recommended for roads due to the abrasion of traffic. Concrete is often coloured by the addition of a mineral oxide to the mix design. Additionally, if the coarse aggregate is exposed, its colour will play a role.

The use of coloured and decorative concrete surface finishes is discussed in Section 3.3.9.

Guides to decorative surface finishes are obtainable from the Cement & Concrete Aggregates Association (CCAA 2007a; 2007b).

7.2 Concrete Segmental Pavers

Concrete segmental pavers, by virtue of their shape and depth, form the wearing surface. The surface texture is a combination of the paver finish and the paver layout. Pavers can also be manufactured with an off-mould, honed, polished, or shot blast surfacing finish. They have been used for roads in industrial subdivisions for their surface toughness and abrasion resistance, whilst in residential subdivisions and shopping precincts, their variety of colours, textures and shape have led to their wide adoption on the basis of appearance (Section 3.3.9).

Paving units are categorised according to breaking load, abrasion resistance, colour and shape. Designers are advised to consult manufacturers, or guidelines produced by industry bodies such as the Cement & Concrete Aggregates Association and the Concrete Masonry Association of Australia, especially when products are identified only by trade names.

8. Selection of Surfacings for New Pavements

8.1 General

The selection of a surfacing type for a new pavement is a function of the need to meet structural and economic parameters as well as the necessary surface characteristics required by road users and the community. The major structural and economic factors are:

- traffic volume, composition and mass
- pavement materials
- subgrade soil conditions
- climatic conditions
- construction and maintenance practices and constraints
- whole-of-life costs including delay costs associated with traffic disruption during maintenance and rehabilitation and potential recycling.

The major surface characteristics important to road users and the community are:

- shape, including roughness
- skid resistance
- surface texture
- noise
- delineation and appearance
- water spray
- resistance to traffic stresses (shear forces, deformation and fatigue).

Generally, the first step is to select a pavement structural type, which then leads to a generic surfacing type. Preferably, a detailed process should be undertaken that takes into account the structural and economic factors and the major surface characteristics required.

The following sub-sections provide a guide to the most common surfacings (and types of pavement) used in Australia and New Zealand. This should be used as a general guide only and does not substitute for proper whole-of-life costing analyses. Detailed guides to comparison of pavement types are provided in the *Guide to Pavement Technology – Part 2: Pavement structural design* (Austroads 2008b) and AAPA (2003). Further guidance is provided in QDMR (1998).

8.2 Road Class

In broad terms, the Australian road system consists of national highways, arterial roads (variously known as state highways, state roads, main roads, etc) and local roads, while the New Zealand road system consists of state highways and local roads. These administrative classifications indicate the level of government with primary responsibility. In practice, the higher levels of government provide limited funding support for roads in the lower classifications.

To improve the effectiveness of asset management decisions, a number of road agencies have allocated their roads to categories or sub-networks. In this way, roads with similar purposes are treated consistently with respect to decisions on standards and levels of service, regardless of legal or administrative classification.

Roads are allocated to a category or sub-network on the basis of indicators such as traffic volume, numbers of heavy vehicles, travel speed and strategic significance.

Location, whether urban or rural, can be the major factor in influencing the choice between lower-cost sprayed seal and thin asphalt surfacings and more expensive pavements (thick asphalt or concrete).

AAPA (2002) provides a summary of road classes grouped into the broad categories of rural and urban as shown in Table 8.1.

Table 8.1: Road classes

Road class [2]	Description of function	Perceived importance	Project reliability [1]	Design ESAs range
Rural classes				
1	Principal links between major regions and capital cities	Very important	Very high	10^6–10^8
2	Linking capitals and key towns, capitals and major regions	Important	High	10^5–10^7
3	Linking important centres, Class 1 and 2 roads and rural arterials	Less important	Medium	10^5–10^6
4	Provides access to abutting property.	Low importance	Low	10^4–10^5
5	One type of activity and not Class 1, 2, 3 or 4	Not important	Very low	$<10^4$
Urban classes				
6	Main link that performs massive traffic movements.	Very important	Very high	10^7–10^9
7	Supplements Class 6 by distributing to local streets	Important	High	10^5–10^7
8	Provide access to abutting property	Less important	Medium	10^4–10^5
9	One type of activity and not Class 6, 7 or 8	Low importance	Low	$< 10^5$

Notes:

1. *The desired project reliability is the chance that the pavement being considered will carry its design traffic before reaching a terminal level of serviceability, given that:*
   - *the pavement is designed in accordance with established procedures*
   - *the pavement is constructed and maintained in accordance with industry standard specifications*
   - *materials used meet the industry standard specification requirements*
   - *the desired project reliability is chosen by the designer.*
2. *The classifications provided in the table are indicative only and do not necessarily relate to SRA Network Rankings. By rationally assessing the risks associated with any type of pavement type and road class, the level of project reliability can be varied to suit individual needs.*

Source: AAPA (2002).

8.3 Pavement Types

8.3.1 Suitability

The general suitability of the various pavement types with respect to road class and typical equivalent standard axles (ESAs) is shown in Table 8.2, where ✓✓ regions are the best-perceived application for the pavement type and the ✓ regions indicate adequate performance. ✗ regions indicate applications that are generally not recommended. In this general overview, there is no discernment based on environmental or other regional factors.

Table 8.2: Suitability of pavement types

	Situation	Rural[a]					Urban[a]			
	Road class	1	2	3	4	5	6	7	8	9
	Design traffic (ESAs)	$10^6 – 10^8$	$10^5 – 10^7$	$10^5 – 10^6$	$10^4 – 10^5$	$<10^4$	$10^7 – 10^9$	$10^5 – 10^7$	$10^4 – 10^5$	$<10^5$
Pavement type	Granular/sprayed seal	✓[b]	✓	✓✓	✓✓	✓✓	✗[c]	✗[c]	✗[c]	✓
	Granular/thin asphalt	✓[b]	✓[b]	✓	✓	✓	✗[c,e]	✓[b,c]	✓✓	✓✓
	Granular/thick asphalt	✓	✓	✓	✗[d]	✗[d]	✗[c,e]	✓	✓✓	✓✓
	Deep strength asphalt	✓✓	✓✓	✗[d]	✗[d]	✗[d]	✓✓	✓✓	✓	✓
	Full depth asphalt	✓✓	✓✓	✗[d]	✗[d]	✗[d]	✓✓	✓✓	✓	✓
	Concrete	✓✓	✓	✗[d]	✗[d]	✗[d]	✓✓	✓✓	✓	✓
	Concrete segmental pavers	✗[d]	✗[d]	✗[d]	✗[d]	✓	✗[d]	✗[d]	✓	✓

✓✓ Most suitable ✓ Adequate performance ✗ Not recommended

Notes:

a. Pavement types recommended are based on design for free-flowing traffic. For high stress conditions such as turning traffic, accelerating and braking traffic and on steep grades, other considerations may govern.

b. This type of pavement can be used successfully in this road class but very good quality control of materials and construction processes, together with good maintenance, are required.

c. Generally require high maintenance.

d. Usually uneconomic when considered on whole-of-life cost basis.

e. May be difficult to achieve satisfactory structural design.

Source: adapted from APPA (2002).

As a guide, the common surfacings applied to each of the major types of pavement constructed in Australia and New Zealand is described below.

8.3.2 Granular Pavements with Sprayed Seal Surfacings

Unbound granular pavements

Unbound granular pavements with sprayed seal surfacings are the major pavement type in rural Australia, comprising some 90% of the length of all surfaced roads. They comprise the majority of Classes 3, 4 and 5 and are even successfully used on roads of Classes 1 and 2, subject to suitable materials and construction and maintenance standards.

The wearing surface on light and medium trafficked roads usually comprises a single application spray seal, while double application seals are used for heavier traffic applications and areas of greater traffic stress such as intersections and roundabouts. For minor and low traffic road treatments, 10 mm and 7 mm aggregates are normally used. For major roads 10 mm and 14 mm are the most common sizes

A prime and seal is considered to be a better surfacing treatment than a primerseal; however, a prime and seal can only be carried out on a dry pavement which is generally free from traffic (e.g. a new road) or under minimal traffic. On the other hand, a primerseal can be placed on a damp pavement and allows for immediate trafficking.

A particular form of initial treatment sprayed seal used when extremely poor pavement materials and/or subgrade conditions prevail is the geotextile reinforced seal (GRS) (Section 3).

Details of all spray seal types are provided in Section 4.

Cemented granular base with sprayed seal surfacing

The use of cemented bases with sprayed seal surfacings is more commonly associated with rehabilitation treatments of granular pavements than new construction. Surfacing performance requirements are generally the same as for unbound granular pavements other than the need to consider the possibility of shrinkage cracking. Incorporation of polymer modified binders is appropriate in such circumstances, e.g. SAM, GRS and FRS.

The use of slow-setting cementitious binders in these types of pavements has the benefit of producing more closely spaced, finer cracks than traditional faster setting binders. This facilitates the control of reflection cracking through the surfacing (Austroads 2006b) and also allows more time for placement, compaction and trimming.

8.3.3 Granular Pavements with Thin Asphalt Surfacing (Asphalt ≤ 40 mm)

Unbound granular base

Unbound granular pavements with thin asphalt surfacings are identical structurally to sprayed seal pavements except that asphalt surfacing is used in place of, or in addition to, the sprayed seal. In this case the asphalt surface makes little contribution to the overall strength of the pavement but provides greater resistance to minor traffic damage as well as a smoother and more durable surface. These attributes make it particularly suited to residential streets and other light traffic urban applications (urban road Classes 8 and 9).

With suitable quality of materials and construction standards, these pavements are sometimes used for urban Class 7 pavements, although they may not provide the same serviceability as more heavily bound pavements. They are not generally recommended for urban Class 6 applications.

Thin asphalt surfacing can also be used on rural road pavements (Classes 1–5), where sprayed seals do not provide adequate serviceability, e.g. intersections and other areas of turning traffic, or to provide improved ride quality.

It is important that these types of pavements have a primed, primer sealed or sprayed seal surface beneath the asphalt surface to provide a waterproofing membrane.

The most common surfacing types are dense graded asphalt 7 mm or 10 mm in size for lightly trafficked pavements or lower speed environments, and 10 mm or 14 mm aggregate for more heavily trafficked applications. Detailed asphalt selection criteria are provided in Section 5.

Care needs to be taken with the construction of thin asphalt layers to ensure that a uniform thickness is obtained and also that adequate compaction is attained.

Cemented granular base

This type of construction can be associated with the rehabilitation of existing pavements as well as new construction. Careful consideration must be given to the resulting reflection cracking. Control measures include the use of deep strength asphalt (Section 8.3.5) and the use of SAMI treatments (Section 4.6.6).

8.3.4 Granular Pavements with Thick Asphalt Surfacing (Asphalt >40 mm, ≤ 75 mm)

A *thick asphalt surfacing* is defined as an asphalt layer greater than 40 mm, but generally not more than 75 mm in thickness, placed on a granular base and sub-base. In these pavements the primary purpose of the asphalt is to provide a wearing surface and make a small contribution to the structural capacity of the pavement. The granular base layer(s) provides a substantial proportion of the load carrying capacity and both a deformation and fatigue failure mechanism are possible and, therefore, both the asphalt and granular base material must be of high quality.

The main application for asphalt on granular pavement is on medium to high traffic urban roads (Class 7). It may also be suitable for rural Classes 1 and 2 depending on actual traffic loads.

The most common surfacing type is 14 mm dense graded asphalt except where open graded asphalt is needed due to operational requirements. Binder type and mix design requirements will vary according to traffic loading (refer Section 5).

Moisture retained in open graded asphalt can increase the risk of moisture damage to the underlying asphalt. Thick asphalt pavements with open graded asphalt surfacings usually incorporate 10 mm or 14 mm dense graded asphalt under the open graded asphalt surfacing. This dense graded asphalt must be well compacted. Trafficking of the dense graded asphalt surface before placing the open graded asphalt surfacing can also assist in decreasing surface permeability. Alternatively, a heavy tack coat or sprayed seal (depending on local practice) may be used before the open graded asphalt is placed to ensure adequate waterproofing.

8.3.5 Deep Strength and Full Depth Asphalt Pavements (Asphalt > 75 mm)

In this case asphalt is used in both the surface and base layers to provide a significant proportion of the load carrying capacity. Deep strength asphalt pavements may also incorporate a cemented or lean mix concrete subbase, especially where low strength subgrades exist or for use in heavy duty pavements.

These pavements are suited to moderate to heavily trafficked roads, including urban Classes 6 and 7, and rural Classes 1 and 2.

Surfacing requirements for deep strength and full depth asphalt pavements are the same as that described for thick asphalt pavements above.

8.3.6 Concrete Pavements

Concrete pavements may be used in all urban classes of road pavement and rural Classes 1 and 2. For heavy duty pavements, concrete pavements are particularly resistant to the effects of slow-moving and heavily loaded vehicles, as well as fuel spillages. Concrete pavements may also be used to achieve specific traffic calming, landscape and architectural effects through their ability to display a variety of colours, textures and forms.

Surface finish forms part of the construction process. The selection of the concrete finish types requires the consideration of a number of factors including surface texture, noise properties and aesthetics. Typical surface finishes used for concrete pavements are described in Section 7.1.

Concrete pavement with asphalt surface

Concrete pavements may be surfaced with asphalt to meet particular operational requirements. Typical applications include surfacing of concrete bridge decks or use of open graded asphalt for reduced noise levels.

Concrete surfaces should be primed with a very light bituminous primer before placing asphalt. Open graded asphalt will not generally bond adequately directly to concrete surfaces and is usually combined with a sprayed seal pre-treatment.

8.3.7 Concrete Segmental Pavers

Segmental pavers can be used where a special aesthetic effect is required, or where heavy vehicles are slowing, accelerating or standing. For high-speed traffic the resultant noise levels would normally be considered too high for urban conditions. Surface finish is determined by the selection of paver shape, colour and type.

9. Selection of Surfacings for Retreatment

9.1 General

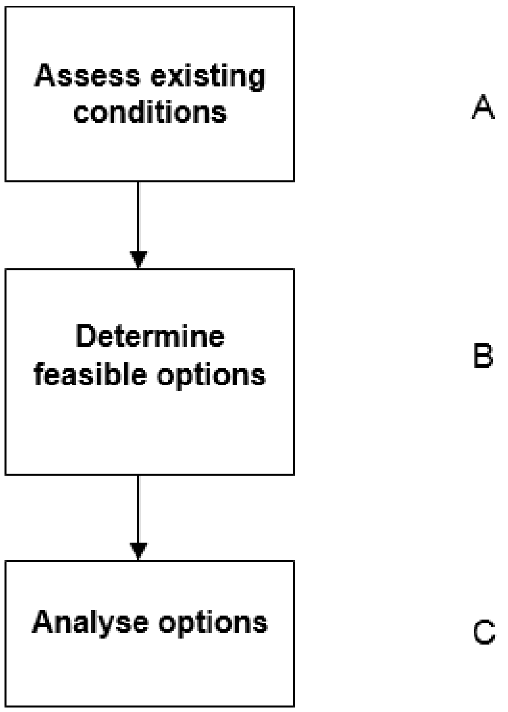
In selecting a surfacing retreatment the practitioner/asset manager is offered a wide array of choice. As well as the relatively straightforward options applicable to new surfaces, there are further options depending on whether the need is merely to restore surface condition, improve shape or ride quality, or compensate for more serious pavement deficiencies. The challenge is to select the most suitable treatment that satisfies technical performance criteria in the most cost-effective manner.

The purpose of this section is to provide a methodology, which may be used to match the deficiencies in the existing surface with a surfacing type that will meet the desired performance characteristics of the retreated surface. This process may still leave a choice of treatment types that will require further economic analysis.

9.2 Selection Process

The three basic steps are outlined in Figure 9.1. The level of detail used in the selection process will, however, vary substantially depending on the complexity and importance of the job and the experience used in the selection process.

Figure 9.1: Selection of surfacings for retreatment



Source: Austroads

A. Assess existing conditions

A guide to identifying and correcting deficiencies in existing pavement surfacings is provided in the *Guide to Pavement Technology – Part 5: Pavement Evaluation and Treatment Design* (Austroads 2008e). Reference to performance characteristics discussed in Section 3 may also be required.

In general terms, assessment comprises three parts:

- visual inspection and/or road database records
- testing, if required (e.g. skid resistance, deflection)
- defining the required performance characteristics of the new surfacing.

B. Determine feasible options

A general guide to treatment type relevant to the correction of particular surfacing deficiencies is provided in the following subsections. A more detailed guide to the identification and treatment of surfacing deficiencies is provided in the *Guide to Pavement Technology – Part 5 Pavement evaluation and treatment design* (Austroads 2008e).

C. Analyse options

Generally, the cheapest satisfactory solution should be considered first, taking into account limitations imposed by such parameters as deflection, curvature, roughness and permeability. For example, a thin layer of asphalt (say 25 to 30 mm thick) used as a surfacing on a weak granular base may be more expensive, and have a shorter life, than a single or double application sprayed seal. This is due to the limited ability of the thin asphalt layer to tolerate pavement deflections and curvatures, and adequately waterproof the base.

Life-cycle costing should be considered to refine the choice.

9.3 Effect of Resurfacing Treatments on Existing Road Surface Condition

Table 9.1 and Table 9.2 provide a guide to the effect that a properly designed bituminous surfacing treatment will have, if any, on the surface characteristics of the pavement.

The tables provide a generic description of the effect of surfacing treatments. The properties presented are for newly placed surfacings after a settling-in period. For example:

- The skid resistance of new surfacings will increase after application when the surface coating of bitumen has been worn off the aggregate in an asphalt mix or precoating material worn or washed off the aggregate in a sprayed seal.
- New seals may be tender until they are bedded down, some of the cutter removed or, for emulsions, until the emulsion has cured.
- Asphalt surfaces may be tender until cooled sufficiently or tightened by the action of traffic.

Table 9.1: Effect of asphalt resurfacing treatment on existing surfacing characteristics

Parameter requiring improvement	Asphalt treatment				
	Dense graded asphalt)	**Fine gap graded asphalt)**	**Stone mastic asphalt**	**Open graded asphalt**	**Thin open graded asphalt**
Bitumen ageing/oxidation[1]	Covers oxidised surface			Covers oxidised surface, requires a seal or heavy tack coat on existing surface to minimise moisture infiltration into the pavement	
Roughness	All asphalt treatments reduce surface roughness. Improvements to the shape of existing surfaces may require additional use of correction/regulation layers (generally using dense graded asphalt)				
Waterproofing properties	Good if compacted adequately and the layer is thick enough			Surfacing is permeable but usually combined with heavy tack coat or seal for waterproofing	
Skid resistance	Good at low speeds; reduces as speed increases	Suitable for low speeds only	Good, particularly for high speed freeways		
Structural strength	Improves strength depending on layer thickness	Some minor improvement but normally a surfacing only	Improves strength depending on layer thickness	Minimal	None
Robustness/shear resistance (relating to sharp turning traffic)	Excellent	Fair	Excellent	Generally fair to poor. improves when PMBs are used	
Water spray	Poor	Very poor	Good	Excellent	Very good
Permeability of surface	Low	Low	Low	The surface is designed to be permeable	
Flexibility (strain tolerance)	Relatively stiff but influenced by binder type	Greater flexibility than dense graded mixes	Relatively flexible	Flexible	
Surface reflection cracking	Limited ability to resist reflection cracking in thin layers		Some ability to resist reflection cracking	Fair ability to resist reflection cracking	Some ability to resist reflection cracking
Likely life of treatment	8 to 20 years	15 to 25 years	10 to 20 years	7 to 15 years	7 to 12 years

Note: Hot-in-place recycling can also be an option for aged asphalt surfaces.

Table 9.2: Effect of sprayed seal, slurry surfacing and combined resurfacing treatments on existing surfacing characteristics

Property requiring improvement	Sprayed seal treatments				Slurry surfacing		Combined treatments	
	Surface enrichment	Single application sprayed seal (single/ single)	Multiple application sprayed seal	Geotextile reinforced sprayed seal	Micro-surfacing	Slurry seal	Correction or regulation course plus SAM/SAMI	Correction or regulation course plus SAM/SAMI with asphalt surface
Bitumen ageing/ oxidation	Delays further oxidation							
Roughness	No effect				Some improvement, more with multiple layers		Good	Very good
Waterproofing properties	Reasonable	Good	Very good	Excellent	Minor improvement		Excellent	
Skid resistance	May reduce	Excellent			Fine texture good at low speeds but may reduce at high speeds		Excellent	As for asphalt
Structural strength	No effect					Minimal to 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	No effect	Remains the same as for existing surface			Poor		Good	
Shape correction ability	No effect				Some improvement more with multiple layers.		Good	Very good
Surface reflection cracking	Little effect	Good	Very good	Excellent	Poor		Excellent	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.*

9.4 Surfacing Retreatment Types

A summary of surfacing retreatment types follows. For more detail refer to Sections 4 to 7 of this Guide.

9.4.1 Sprayed Seals

Sprayed seals and other thin surfacing options (including slurry surfacing and asphalt) tend to form a progression in terms of cost which can then be related to the particular performance levels required. Sprayed seal options (Section 4) include:

- reseal
- high stress seal

- strain alleviating membrane and strain alleviating membrane interlayer
- fibre reinforced seal
- geotextile reinforced seal.

9.4.2 Slurry Surfacing

A slurry surfacing is a thin bituminous surfacing treatment which provides a uniform surface and minor shape correction. Slurry surfacing options (Section 6) include:

- slurry seal
- microsurfacing
- cape seal.

9.4.3 Asphalt

Asphalt options (Section 5) include:

- dense graded asphalt
- stone mastic asphalt
- open graded asphalt
- thin open graded asphalt
- fine gap graded asphalt.

9.4.4 Concrete Overlays

Concrete overlays may be used for strengthening concrete or flexible pavements. They require specialist design advice.

9.4.5 Combination Treatments

A number of these treatments can be combined, resulting in innovative rehabilitation treatments which provide a combination of surface texture, flexibility and shape correction which cannot practically be achieved with the individual surfacing treatments. Examples of combination treatments are:

- use of a SAMI treatment under dense graded or open graded asphalt to waterproof the surface and resist reflection cracking
- regulation and shape correction of a rough surface with a thin asphalt layer or slurry surfacing followed by a sprayed seal (standard or polymer modified binder depending on the degree of crack resistance and waterproofing required)
- treatment of a rough, weak and badly cracked surface by regulating or correcting the shape with a thin, flexible layer of asphalt, then applying a geotextile reinforced sprayed seal membrane to waterproof the pavement and reduce the effect of reflective cracking. This treatment may be used:
  - alone as a SAM in appropriate conditions
  - as a SAMI followed by an open graded asphalt or ultra thin asphalt to provide a smooth quiet surface, or by a dense graded or stone mastic asphalt.

9.4.6 Miscellaneous Surface Correction Treatments

In addition to the surface retreatments described above, a number of other techniques can be applied to surfaces to improve texture or reduce the effects of ageing of bituminous surfaces. These include the following:

- Surface enrichment and rejuvenation
  - Surface enrichment and rejuvenation refer to the application of a bituminous binder or proprietary rejuvenation agent to extend the life of a spray seal. Rejuvenation using proprietary rejuvenating agents may also be applied to asphalt surfaces to slow down the rate of oxidation and arrest ravelling or to seal an asphalt surface to prevent moisture entry and stripping.
  - Local surface enrichment refers to treatment of coarse textured areas of a sprayed seal pavement only, for example, areas outside wheelpaths. It may also be used as a preliminary treatment to applying a reseal to the full width of the pavement.
- Hot aggregate treatment
  - Heating of aggregate can improve the chances of the corrective aggregate, applied to a flushed bitumen surface, binding to the excess bitumen.
- Solvent treatment
  - A suitable solvent, or proprietary solution of gilsonite in a volatile solvent, is sprayed onto a flushed bituminous surface to soften the existing bitumen prior to applying and rolling a small sized, precoated aggregate.
- Asphalt grooving
  - Grooving, using specially designed sawing equipment, can be used to provide local correction of surface texture on sound asphalt surfaces, particularly where additional vehicle control is required on tight curves. Transverse grooving is also used on airfield pavements to provide the texture required at high speeds on wet surfaces.
- High pressure water retexturing
  - Surface retexturing by removal of excess bitumen from the surface of asphalt and sprayed seals can be undertaken with purpose built machines. Precise control of pressure, water volume and cutting speed allow effective removal of excess bitumen and surface contamination with minimal damage to the surface or dislodgment of coarse aggregate particles in the surfacing (Figure 9.2). Suction heads are used to collect water and detritus from the surface for later disposal.

Figure 9.2: Flushed sprayed seal surface (left) treated with high pressure water (right)

Source: RTA NSW

- Dry matting (Section 4.6.3)
- High friction seal (Section 4.8)
- Concrete grooving or grinding
  - Grooving: specially designed sawing equipment can be used to correct surface texture of concrete surfaces. Grinding machines can be used to correct both surface texture and profile. Modern diamond grinding machines can achieve significant improvements in surface smoothness and ride quality as well as reduced tyre noise, (Figure 9.3) and (Figure 9.4).

Figure 9.3: Concrete surface texture correction with transverse grooving

Source: CCAA

Figure 9.4: Diamond grinding head for concrete surface texture correction

Source: RTA NSW

- Abrasive blasting
  - Abrasive blasting can be used on both concrete and asphalt surfaces to improve surface texture by removal of surface mortar or excess bitumen. Results can, however, be variable due to uneven removal of binder materials and aggressiveness of the process.

Further guidance on miscellaneous surface treatments are provided in the documents referenced in the *Guide to Pavement Technology – Part 9: Pavement Work Practices* (Austroads 2008f).

References

Australian Asphalt Pavement Association 2002, *Selection and design of flexible pavements*, AAPA, Melbourne, Vic.

Australian Asphalt Pavement Association 2003, *Comparison of pavement alternatives*, AAPA, Melbourne, Vic.

Austroads 2003a, *Guidelines and specification for bituminous slurry surfacing,* AP-T26/03, Austroads, Sydney, NSW.

Austroads 2003b, *Guide to the Selection of Road Surfacings,* 2nd edn, AP-G63/03, Austroads, Sydney, NSW.

Austroads 2005, *Guide to Pavement Technology: Part 1: Introduction to Pavement Technology*, by K Sharp, AGPT01/05, Austroads, Sydney, NSW

Austroads 2006a, *Guide to Asset Management: Part 5E: Cracking*, by M Moffatt & R Hassan, AGAM05E/06, Austroads, Sydney, NSW.

Austroads 2006b, *Guide to Pavement Technology: Part 4D: Stabilised Materials*, by B Andrews, AGPT04D/06, Austroads, Sydney, NSW.

Austroads 2006c, *Guide to the Selection and Use of Polymer Modified Binders and Multigrade Bitumens*, by P Tredrea, AP-T42/06, Austroads, Sydney, NSW.

Austroads 2006d, *Specification Framework for Polymer Modified Binders and Multigrade Bitumens*, by P Tredrea, AP-T41/06, Austroads, Sydney, NSW.

Austroads 2006e, *Update of the Austroads Sprayed Seal Design Method*, by A Alderson, AP-T68/06, Austroads Sydney, NSW.

Austroads 2007a, *Guide to Asset Management: Part 5B: Roughness,* 2nd edn, by M Moffatt, AGAM05B/07, Austroads, Sydney, NSW.

Austroads 2007b, *Guide to Asset Management: Part 5C: Rutting*, 2nd edn, by M Moffatt & R Hassan, AGAM05C/07, Austroads, Sydney, NSW.

Austroads 2007c, *Guide to Pavement Technology: Part 4: Pavement Materials*, by G Youdale & K Sharp, AGPT04/07, Austroads, Sydney, NSW.

Austroads 2007d, *Guide to Pavement Technology: Part 4B: Asphalt*, by J Rebbechi, AGPT04B/07, Austroads, Sydney, NSW.

Austroads 2008a, *Glossary of Austroads terms*, by K Sharp & P Milne, AP-C87/08, Austroads, Sydney, NSW.

Austroads 2008b, *Guide to Pavement Technology: Part 2: Pavement Structural Design*, by G Jameson, AGPT02/08, Austroads, Sydney, NSW.

Austroads 2008c, *Guide to Pavement Technology: Part 4F: Bituminous Binders*, by J Rebbechi, AGPT04F/08, Austroads, Sydney, NSW.

Austroads 2008d, *Guide to Pavement Technology: Part 4J: Aggregates and Source Rock*, by B Vuong, G Jameson & B Fielding, AGPT04/08, Austroads, Sydney, NSW.

Austroads 2008e, *Guide to Pavement Technology: Part 5: Pavement Evaluation and Treatment Design*, by G Jameson & M Shackleton, AGPT05/08, Austroads, Sydney, NSW.

Austroads 2008f, *Guide to Pavement Technology: Part 9: Pavement Work Practices*, by J Rebbechi, AGPT09/08, Austroads, Sydney, NSW.

Austroads 2009a, *Guide to Asset Management: Part 5: Pavement Performance*, Austroads, Sydney, NSW.

Austroads 2009b, *Guide to Asset Management: Part 5F: Skid Resistance*, Austroads, Sydney, NSW.

Austroads 2009c *Guide to Asset Management: Part 5G: Texture*, Austroads, Sydney, NSW

Austroads 2009d *Guide to Pavement Technology: Part 4K: Seals,* Austroads, Sydney, NSW

Austroads 2009e, *Guide to Pavement Technology: Part 8: Pavement Construction,* Austroads, Sydney, NSW.

Austroads 2009f *Guide to Traffic Management: Part 10: Traffic Control and Communication Devices*, Austroads, Sydney, NSW.

Cement & Concrete Aggregates Association 2007a, *Colouring, stencilling and stamping concrete flatwork*, briefing 01, CCAA, Sydney, NSW.

Cement & Concrete Aggregates Association 2007b, *Exposed aggregate finishes for concrete flatwork*, briefing 02, CCAA, Sydney, NSW.

Descornet, G 1989,'A criterion for the optimisation of surface characteristics', *Transportation Research Record*, no. 1215, pp. 173-7.

Johnson-Clarke, JR, Sharp, KG & Walter, PD 1993, *The performance of pavements with geotextile reinforced seals: the Brewarrina, New South Wales, ALF trial*, ARR 241, Australian Road Research Board, Vermont South, Vic.

Queensland Department of Main Roads 1998, *A guide to whole-of-life costing of heavy duty pavements*, QDMR, Brisbane, Qld.

Roads and Traffic Authority New South Wales 1992, *Guide to the design, construction, maintenance and management of clay pavements with geotextile reinforced seals*, RTA, Sydney, NSW.

Roads and Traffic Authority New South Wales 1998, *Maintenance of geotextile reinforced seals on clay pavements*, TP-GDL-013, RTA, Sydney, NSW.

Transit New Zealand, Road Controlling Authorities & Roading New Zealand 2005, *Chipsealing in New Zealand*, Transit New Zealand, Wellington, NZ.

Transit New Zealand 2007, *Roading bitumens, standard specification*, TNZ M/01, NZ Transport Agency, Wellington, NZ.

Australian Standards

AS 2008-1997, *Residual bitumen for pavements*.

AS 3600-2001, *Concrete structures.*

AS 2150-2005, *Hot mix asphalt: a guide to good practice.*

Austroads' **Guide to Pavement Technology Part 3: Pavement Surfacings** addresses the selection of the most appropriate pavement surfacing. The guide identifies the significant factors that need to be considered in the selection of the most appropriate surfacing, their inter-relationships and the rationale for assessing the surfacing options available.

Guide to Pavement Technology Part 3

Austroads

Austroads is the association of Australasian road and transport agencies.

www.austroads.com.au