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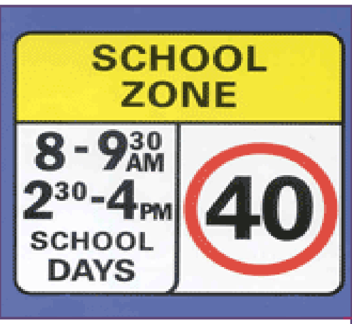
AUSTROADS TECHNICAL REPORT

# Review of Primes and Primerseal Design




Austroads

# Review of Primes and Primerseal Design

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# Review of Primes and Primerseal Design

Austroads
Sydney 2011

## Austroads profile

Austroads' purpose is to contribute to improved Australian and New Zealand transport outcomes by:

- providing expert advice to SCOT and ATC on road and road transport issues
- facilitating collaboration between road agencies
- promoting harmonisation, consistency and uniformity in road and related operations
- undertaking strategic research on behalf of road agencies and communicating outcomes
- promoting improved and consistent practice by road agencies.

## Austroads membership

Austroads membership comprises the six state and two territory road transport and traffic authorities, the Commonwealth Department of Infrastructure and Transport, the Australian Local Government Association, and New Zealand Transport Agency.  Austroads is governed by a Board consisting of the chief executive officer (or an alternative senior executive officer) of each of its 11 member organisations:

- Roads and Traffic Authority New South Wales
- Roads Corporation Victoria
- Department of Transport and Main Roads Queensland
- Main Roads Western Australia
- Department for Transport, Energy and Infrastructure South Australia
- Department of Infrastructure, Energy and Resources Tasmania
- Department of Lands and Planning Northern Territory
- Department of Territory and Municipal Services Australian Capital Territory
- Commonwealth Department of Infrastructure and Transport
- Australian Local Government Association
- New Zealand Transport Agency.

The success of Austroads is derived from the collaboration of member organisations and others in the road industry.  It aims to be the Australasian leader in providing high quality information, advice and fostering research in the road sector.

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# SUMMARY


Primes and primerseals play an important role in achieving a successful surfacing as they form the basis for the performance of future treatments. Any defect in the prime or primerseal can quickly impact on the serviceability of the entire pavement.

The fact that poor performing primes and primerseals are increasingly being reported is cause for concern. A review of current design and application practices for primes and primerseals was commissioned by the Bituminous Surfacings Research Reference Group (BSRRG). The scope of this investigation included recommendations regarding future work associated with the design and selection of primes and primerseals.

Pavement compaction, moisture content and surface hardness directly affect the success of a prime or primerseal. Poor surface hardness, as measured by the Ball Embedment Test, is known to result in an under-performing seal. Maximum hardness values for new construction are specified by only one state road authority.

An additional factor that must also be considered is the effect of moisture content on surface hardness. While values of 70% of OMC are generally specified before a pavement can be sealed this value relates to achieving a minimum level of stiffness in the pavement and does not necessarily translate to acceptable levels of hardness. Moisture-sensitive materials may require lower moisture levels, in the range of 40–50%, before the desired hardness is reached. At this stage further work is required to determine what level of surface hardness is achievable and the corresponding moisture content for a range of materials around Australia so that reasonable limits can be introduced.

No design method, either in Australia or overseas, for primes was identified in the review. The selection of the type of prime, and application rate, is based heavily on experience. This seems to be a function of the many variables at play which necessitates the application of some degree of judgement in assessing the pavement. The range of rates provided in the current Austroads *Sprayed Seal Design* method would seem to be the most comprehensive published guide to prime selection. Several sources place emphasis on undertaking small field trials to determine the most appropriate rate and product for the pavement. The development of a primer field trial procedure may assist inexperienced personnel to choose the most appropriate primer material and application rate in a sound and methodical manner.

Guidance on the use of emulsion primes is limited with reference often being made to manufacturers' recommendations. Consideration should be given to providing additional information on the use of these products in future Austroads documents.

While a prime and seal are the preferred treatment on new work, primerseals are particularly useful where construction is being performed under traffic. This is likely to occur more often in the future with an increase in the number of roads that require major rehabilitation.

Traditionally, primerbinders with 12–25% cutter have been used in an effort to achieve some penetration into the base while providing enough binder to hold the aggregate. However, there are several problems that have been experienced with this approach, including:

- Higher levels of compaction and the use of bound bases have made it more difficult to achieve penetration.

- The use of such high percentages of cutter is in conflict with the need to maximise binder cohesion and produce a resilient surfacing resistant to flushing.
- High cutter levels also require extended curing of the primerseal.

Emulsion primerbinders cure far more rapidly than cutbacks and this allows the final surfacing treatment to be applied after several weeks rather than months. An issue with emulsions has always been the low early or green strength. High residue and modified emulsions provide improved properties that go some way to overcoming this issue. In addition, the use of larger aggregates scatter coats or double/double primerseals has been shown to assist with aggregate retention. At present, no recommendations on the use and design of double/double primerseals is provided. Further work is required to develop such guidelines.

It was noted that emulsions achieve very little penetration. Despite this, they have been used successfully on numerous projects. This suggests that adhesion, rather than penetration, should be targeted. If so, then the use of cutback primerbinders with 5–10% cutter may be warranted, particularly under heavy traffic where improved cohesion and resistance to flushing is needed. Several projects have been reported where primerseals with reduced cutter levels have performed well.

No specific primerseal design method was identified from a review of overseas literature. New Zealand practice on new construction is to apply a first coat seal where residual application rates are calculated using the standard reseal design method but with allowances added for absorption and embedment (based on experience). The binder consists of bitumen cutback to varying degrees depending on air temperature. At temperatures above 27.5 °C the equivalent of 8 parts of cutter is added.

The current Austroads primerseal selection and design process is based predominantly on VicRoads Guidelines. These have been continually developed over many years based on field experience and observations. While this system has worked well it fails to take into account heavy vehicle volumes and aggregate properties. With increasing traffic volumes there is a need to update the current system. A review of overseas practice, and a brief comparison of primerseal and seal rates, suggests there is scope for adapting the current reseal design method for primerseals. Such an approach needs further investigation based on case studies of the field performance of primerseals applied under a range of conditions.

# 1 INTRODUCTION

The use of granular pavements with thin surfacings is the cornerstone of the Australian sealed road network. While the length of granular pavements being constructed has reduced since the 1960s and 1970s, the need to produce high quality pavements is of even greater importance considering the challenges being faced by road authorities and asset managers to meet the demands of increasing traffic levels and the impacts of new-generation heavy vehicles.

Primes and primerseals play an important role in achieving a successful surfacing as they form the basis for the performance of future treatments. Any defect in the prime or primerseal can quickly impact on the serviceability of the entire pavement.

Considering this, the fact that poor-performing primes and primerseals are increasingly being reported is cause for concern. In order to understand and address the issues involved, a review of Australian and international prime and primerseal design practice was undertaken to determine what further work was required to improve current design and selection procedures.

## 1.1 Background

Several high profile failures prompted the Roads and Traffic Authority, NSW (RTA NSW) to conduct a workshop in March 2007 on the performance of primes and primerseals. This was attended not only by personnel from the RTA but also representatives from the bituminous surfacing industry and other state road authorities (SRA).

Issues identified at the workshop that were considered to be contributing to the poor performance observed included:

- increasing traffic volumes and heavy vehicle densities
- inadequate or inappropriate base preparation
- timing of works during cold and wet weather
- limited design procedures for initial treatments.

Questions were also raised regarding the need to achieve minimum levels of binder penetration into the base. This has historically been cited as one of the reasons for using primerbinders with 15–20 parts of cutter.

A review of current design and application practices for primes and primerseals, endorsed by the Bituminous Surfacings Research Reference Group (BSRRG), is outlined in this report. The scope of this investigation includes:

- recommendations regarding required future work to improve the design and selection of primes and primerseals, including requirements for minimum levels of pavement hardness and dryback
- a consideration of current cutback and emulsion primes and primerbinders and emerging materials (e.g. emulsion primes).

It was agreed that the approach of using basic rates for primerseals needed to be re-examined to determine whether a more precise means of determining primerbinder rates could be identified which took into account aggregate properties, e.g. Average Least Dimension (ALD), Flakiness Index (FI), embedment, road geometry and heavy vehicle volumes (Fenton 2008).

# 2 METHODOLOGY

The project involved the following steps:

- examine current Austroads prime and primerseal design methods and gather information related to their original development
- conduct a literature review of the historical background of current recommendations, alternative design methods, any published work related to prime and primerseal design performance, and comparison of SRA specifications
- gather case study information on prime and primerseal performance from SRAs
- determine whether any alternative design methods exist within Australia or overseas including the applicability of the update of the Austroads *Sprayed Seal Design Method* (Austroads 2004a) to primerseals
- conduct a desktop comparison of current Austroads recommendations regarding primerseal designs and alternative methods
- make recommendations for further work.

# 3 EFFECT OF PAVEMENT-RELATED ISSUES ON PERFORMANCE OF PRIMES AND PRIMERSEALS

## 3.1 Introduction

By definition, primes and primerseals are initial treatments that are applied to a prepared base. As such, their performance is highly dependent on pavement-related factors, including the following:

- Compaction – increasing traffic volumes, higher tyre pressures and the introduction of freight efficient vehicles have demanded that higher levels of compaction are achieved. Tightly-bound, well-compacted materials will have lower levels of absorption and hence allow less penetration.
- Surface hardness – poor surface hardness will often result in aggregate embedment and flushing in the primerseal or prime and seal. Inadequate compaction or slurrying of the surface can produce a soft surface crust that may lead to this situation. The Ball Embedment Test (Austroads 2006a) will give an indication of the level of embedment that can be expected and whether the surface is fit to seal.
- Moisture content – excess moisture can affect the performance of a prime and primerseal in two ways. Firstly, surface hardness is reduced, leading to aggregate embedment. Secondly penetration of the prime or primerbinder is inhibited, leading to excess bitumen on the surface (Austroads 2004b). Scheduling work for the warmer part of the year will greatly assist in achieving a successful outcome by allowing the pavement to dry back.
- Material type – pavements can be constructed from a wide range of materials with very disparate properties. This is particularly the case in remote locations where marginal sources may behave very differently compared to a standard crushed rock. For example, sandstone and limestone bases are known to be highly absorptive and hence must be treated to minimise the drain-down of binder in future seals.

## 3.2 Pavement Properties Prior to Treatment

Before applying an initial bituminous treatment it is essential that the pavement is assessed to confirm that it is fit for sealing. This should include a visual check for (Austroads 1997):

- soft, ravelling and boney areas
- a uniform surface texture with larger stone particles visible.

Most SRA specifications provide a general description of the desired surface properties. For example, the following is an extract from Section 310 of the VicRoads specification (VicRoads 2006):

> The pavement surface shall be prepared to produce a hard dense surface capable of being swept with a rotary broom to leave a tight surface free of loose and foreign materials.
>
> The surface so prepared shall be free of tearing and shall be uniform in texture with no lamination within 75 mm of the finished surface …

Descriptions of a 'hard tight surface' are rather subjective. Traditionally, the acceptance of a pavement for sealing has been based on the judgement of experienced supervisors and the 'ringing' heard when the base is struck with a hammer.

Applying this to a specification is almost impossible and so some other means of assessing a pavement surface is required. Fenton (2008) and Midgley (2008) suggest that the Ball Embedment Test could be employed as an acceptance tool. Midgley (2008) recommends that a pavement with Ball Penetration values greater than 4 mm should not be sealed but allowed to dryback further. Austroads (2006c) suggests qualified limits of 3 mm, with pre-preparation of the pavement for primerseals when Ball Penetration values are greater than 4 mm.

Pavement hardness values are generally not included in specifications. The Department for Transport, Energy and Infrastructure, South Australia (DTEI) is the only SRA that stipulates maximum ball embedment numbers, these being 2.5 mm for national highways and 3.0 mm for other roads (DTEI 2007).

An alternative means of assessing a base prior to sealing is the Clegg Impact hammer. This is a relatively simple device that allows many tests to be undertaken quickly. Queensland Department of Main Roads[1] (QDMR 1988) suggests that Clegg Impact Values (IV) of 60 to 70 are acceptable; however, this may vary depending on the type of material. A potential issue is that Ball Penetration values are currently used in the Austroads sprayed seal design procedure to adjust binder application rates for aggregate embedment (Austroads 2006c). If the Clegg hammer was to replace the Ball Penetration Test then a correlation would need to be developed which related Impact Values with aggregate embedment.

As reported by Choi (2009), it is widely recognised that moisture content will affect surface hardness and that allowing a pavement to dryback will in most cases lower ball embedment values (apart from zero PI materials where hardness can actually decrease as the pavement dries). It should be noted that Ball Embedment Test results are influenced by only the top section of a pavement, perhaps a depth of only approximately 20 mm (DTEI 2007). A moisture gradient through the pavement may give a false impression of the future performance of the pavement. Delayed embedment could occur as excess moisture moves to the pavement surface after sealing (Fenton 2008).

A maximum moisture content of 70% of optimum moisture content (OMC) is commonly required in SRA specifications. Main Roads WA (MRWA) Specification 501 (MRWA 2008) is somewhat different in that it has a range of dryback levels for various material types (Table 3.1), while TMR (2009a) requires that the degree of saturation does not exceed 65%. Whilst dryback values are derived from the need to achieve minimum levels of stiffness and bearing capacity, they should not be relied upon to produce an acceptable level of surface hardness. Part 226 of the DTEI specification (DTEI 2007) is the only document that stipulates a moisture content (60% of OMC) prior to priming but this only relates to the top 20 mm of the base.

Choi (2009) examined Ball Embedment values of several materials in Victoria over a range of moisture contents. It was found that, in order to achieve the suggested 4 mm embedment value, moisture contents (based on average moisture readings taken to a depth of 100 mm) between 15-50% of OMC would be required.

Another factor to consider is the effect that moisture will have on the level of penetration of primes and primerbinders. A laboratory investigation conducted by Gaughan (1996) showed that unacceptably low levels of penetration were achieved for most of the base materials studied where moisture contents exceeded 40% of OMC.

1 Now Department of Transport and Main Roads, Queensland (TMR).

Table 3.1: MRWA basecourse dryback requirements

| Material type | Dryback characteristic moisture content (%) |
|---|---|
| Gravel | 85 |
| Crushed rock base | 60 |
| Ferricrete | 85 |
| Bitumen-stabilised crushed limestone | 85 |
| Cement-stabilised basecourse | 85 |
| Crushed recycled concrete | 85 |
| Hydrated cement-treated crushed rock base (asphalt surface) | 70 |
| Hydrated cement-treated crushed rock base (spray seal surface) | 85 |

Source: MRWA (2008).

It is well known that the best performance from prime and seal and primerseals is achieved when they are applied in warm conditions. This is due in part to the pavement being allowed to dry back throughout its depth and for the surface to harden or ‘bake’. This observation, together with work by Choi (2009) and Gaughan (1996), suggests that moisture contents considerably lower than the commonly used 70% of OMC may be required to produce a successful seal.

A number of authors have indicated that information needs to be gathered on Ball Penetration values of different materials. This data collection exercise should also encompass the collection of moisture contents and Clegg Impact Values, as well as the methods used to achieve the results. The inclusion of specification requirements to supply this information as part of a contract may be the most efficient means of sourcing this information. Procedures for the collection and presentation of the data will need to be drafted to ensure that results are reported in a consistent manner.

# 4 PRIME

## 4.1 Historical Background

During the 1960s and 1970s primes based on coal and petroleum tar were readily available and they tended to perform well. The health risks associated with such materials prompted the wholesale move to cutback primes in the late 1970s.

NAASRA guidelines (NAASRA 1965 and 1975) provided an indicative range of rates for primes depending on surface finish or basecourse. These appear to have been based on Victorian Country Roads Board (CRB) practices and procedures developed through experience gained in the field and refined over many years. Rates and guidance published in Country Roads Board (1982) are similar to those recommended in current Austroads publications.

## 4.2 Expected Performance

The main aims of a prime are to:

- provide a surface for subsequent treatments to bond to
- minimise the drain-down of binder from overlying spray seals into the base.

To achieve these goals, it is generally accepted that some penetration of the prime should occur. Whilst values of 5–10 mm are commonly referenced, the level of penetration will depend on the type of base to be treated, its surface finish and moisture content.

Once cured, the primed surface should be hard, dry and have a black to dark brown appearance. The presence of free bitumen, resulting in a fatty and sticky surface, suggests that the application rates or the grade of prime were too heavy (RTA NSW 2004). Such a situation is not desirable as this can result in extended curing times and the pick-up of the base by construction traffic. This may contribute to bleeding in the final seal.

## 4.3 Austroads Guidelines

The selection of prime grades and application rates is referred to in a number of Austroads guides, the most recent of these being the update of the Austroads sprayed seal design method (Austroads 2006c). Rather than a formal design method, general guidance for cutback primes is provided for a range of surface conditions and material types as presented in Table 4.1.

Proprietary emulsion primes may be used, however guidance on their use and application rates must be sought from the manufacturer.

Otherwise, primes are chosen based on experience, taking into account several variables including prevailing weather conditions and the properties of local materials.

## 4.4 Road Authority Guides and Specifications

RTA NSW and VicRoads have published guides and manuals that provide indicative rates for priming of various base materials. The values in these documents are very similar to those presented in Austroads (2006c) which are reproduced in Table 4.1.

These rates have been adopted by most SRAs apart from MRWA and DIER Tas., which stipulate generic rates of 0.6 L/m$^2$ and 0.9 L/m$^2$ respectively. In the case of DIER, the rate indicated is a nominal value only as the responsibility for adjusting the prime rate lies with the contractor.

Table 4.1: Austroads suggested priming rates

| Pavement | Primer | |
|---|---|---|
| | Grade | Rate of application ($L/m^2$) |
| Tightly bonded | light | 0.6–1.1 |
| Medium porosity | medium | 0.8–1.1 |
| Porous | heavy to very heavy | 0.9–1.3 |
| Limestone | heavy to very heavy | 2 applications<br>1st @ 0.7–0.9<br>2nd @ 0.5–0.7 |
| Sandstone | heavy to very heavy | 2 applications<br>1st @ 0.7–0.9<br>2nd @ 0.5–0.7 |
| Hill gravels, granitic sands | light | 0.8–1.1 |
| Stabilised | very light to light | 0.5–0.8 |
| Concrete | very light | 0.2–0.4 |

Source: Austroads (2006c).

The RTA (2004) *Spray Sealing Guide* places particular emphasis on achieving 5–10 mm of penetration. However, these requirements were based on older types of unbound pit gravels and are not relevant for heavily-bound bases. The main reason for penetration depth was to help satisfy continuing binder demand of such porous bases (absorption) and, secondly, to strengthen them (Cunningham personal correspondence via e-mail, 7 April 2009).

The design sequence for primes suggested by RTA (2004) involves:

- consideration of previous experience with the particular pavement material
- where no such information is available, a laboratory investigation based on RTA Test Method T126 (February 2001)
- field trials over a small area to validate the laboratory results (also recommended by VicRoads).

For cutback primes the usefulness of performing a laboratory simulation is questionable considering that a field validation to determine the most appropriate product and rate of application is a quick and simple method that is applied to the as-constructed pavement. If needed, a change to the grade of cutback prime to suit field conditions is a relatively easy task to perform.

What may be of use to inexperienced personnel is the development of a step-by-step procedure to perform such a field trial in a consistent and methodical manner. This should also include guidance on the inspection and review of the primed surface.

All SRAs specify the use of cutback primes according to AS 2157 (1997). MRWA stipulates one cutback prime containing 40% Class 170 and 60% medium curing cutter oil.

The curing period for a prime will depend to a large degree on the grade of prime and the prevailing weather conditions. Minimum curing periods specified by various SRAs are presented in Table 4.2.

Table 4.2: Cutback primer curing periods required by various road authorities

| Prime type | RTA NSW | VicRoads | TMR | MRWA | DTEI SA | DIER Tas |
|---|---|---|---|---|---|---|
| Specification No. | R106(1) | BSSM*(2) | MRT 11S(3) | 501(4) | Part 226(5) | R51(6) |
| AMC 00, AMC 0* | 2 days (7 days)# | 7 days | 3 days | 3–7 days | 3 days | - |
| AMC 1 | 2 days (14 days)# | 14 days | 3 days | - | - | - |

1 RTA NSW 2006.
2 VicRoads 2004.
3 QTMR 2009b.
4 MRWA 2008.
5 DTEI SA 2009.
6 DIER Tas 2009.

* AS 2157-1997; # RTA NSW 2004.

A minimum curing time of three days is suggested for cutback primes (Austroads 2006c) and one to two days for specialty emulsion primes; however, longer periods may be required in cold conditions.

Curing is particularly important to allow any volatiles to evaporate that would otherwise soften the subsequent seal. There is also the fact that the prime itself can initially soften the base; applying a seal too early can lead to aggregate embedment and flushing. It may be advantageous to apply the longer curing periods suggested by RTA NSW and VicRoads to pavements that are moisture sensitive (based on PI) or subject to heavy traffic where embedment can be significant.

It would seem, then, that no design method, as such, exists for primes. This seems to be a function of the many variables at play which necessitates the application of judgement and experience in assessing the pavement. The range of rates provided in Austroads (2006c) would seem to be the most comprehensive guide to prime selection. The development of a primer field trial procedure may assist inexperienced personnel to choose the most appropriate material and application rate.

## 4.5 Emulsion Primes

Gaughan (1995) suggested that conventional emulsions were not suitable for priming. Since that time specialised emulsion primes have been developed. They contain between 20% to 40% of bitumen and some cutter, but at much lower levels than equivalent cutback primes. Formulations are available for a range of base types, including concrete decks.

No SRA specifies properties for emulsion primes. Despite this, they have been in use for several years, with most SRAs contacted having had positive experience with them. Trials of emulsion primes have shown that they have similar penetration to cutback primes and have performed equally well in the field (Dinakis, Cuttler & Maccarrone 2000). Their main advantages over cutback primes are:

- shorter curing periods, which is particularly important when works must be completed within a single day
- minimal use of cutters, thus lowering the risk of flushing in the subsequent seal. They have also been used in tunnels where a build-up of flammable fumes that could occur with cutback primes would pose a safety risk.

The selection of application rates is generally based on past experience and manufacturers' recommendations. Alternatively, it is suggested that Test Method AGPT/T252 (Austroads 2002a) be used as the basis to select the most appropriate type and application rate for emulsion primes. Undertaking such a laboratory investigation would also allow any compatibility issues to be identified. As the product may need to be ordered weeks in advance any potential problems need to be addressed as early as possible.

Consideration should be given to developing specification limits for these products to provide purchasers with some degree of reassurance that materials ordered will be consistent and achieve certain minimum standards.

## 4.6 Overseas Procedures

### *4.6.1 New Zealand*

The use of cutback primes in New Zealand is generally discouraged due to perceived health and safety issues (Transit NZ, Road Controlling Authorities and Roading NZ 2005). Whilst emulsion primes are available, it would appear that the use of a prime is not considered to be essential provided that a good aggregate mosaic is visible on the pavement surface.

It is recognised that the use of a prime allows a harder and more resilient binder to be used in the subsequent seal. Despite this, first coat seals, bitumen (130/150 or 80/100 pen) with six to eight parts of cutter are widely adopted as initial treatments applied directly to the base.

### *4.6.2 South Africa*

The approach to priming in South Africa appears to be similar to that in Australia, in that it is recognised that the use of a prime reduces the risk of failure in the seal. Despite this, however, primes are not always used. This tends to be acceptable on crushed rock bases with a good aggregate mosaic, particularly where double/double seals are employed (National Institute for Transport and Road Research (NITRR) 1986).

Until recently, tar primes were recommended but the health risks associated with these products have resulted in a move to cutback bitumen and emulsion alternatives. Typical properties of these products are presented in Table 4.3. A comparison with primes in AS 2157 shows that MC 30 and MC 70 have similar properties to an AMC 0 and AMC 1 respectively.

Detailed requirements for cutback and emulsion primes are published in SANS 308:2009 and 1260:2004.

Table 4.3: Typical properties of primes in South Africa

| Product | Density at 20 °C (kg/l) | Viscosity at 60 °C (Pa.s) | | Spray temperature (°C) | Residual binder (%) | |
|---|---|---|---|---|---|---|
| | | Min. | Max. | | SANS# | Typical* |
| MC30 | 0.93 | 0.025 | 0.06 | 55 | 50 | 55 |
| MC70 | 0.95 | 0.065 | 0.13 | 70 | 55 | 64 |
| Inverted | 0.92 | | | 60 | | 41 |

Source: * SABITA (2006); # South African National Standards 308:2009 and 1260:2004.

A summary of construction and application issues related to primes in South Africa is as follows:

- Prime application rates are not designed but rather based on the premise that a residual binder rate of 0.35 L/m$^2$ is required which equates to 0.7 L/m$^2$ for MC30, 0.6 L/m$^2$ for MC70 and 0.95 L/m$^2$ for an inverted emulsion (SABITA 2006).
- Open and coarse bases may require an increase of 15% in application rates while fine and dense bases may require a decrease of 15%.
- A small field trial or ‘paint test’ is advocated to determine the most appropriate product and application rate for the prepared pavement.
- Drying back of the top 10–25 mm of the surface to approximately 50% of OMC is recommended (NITRR 1986).

Guidance on the selection of primes for a range of conditions provided by SABITA (2006) is reproduced in Table 4.4.

Inverted emulsions and MC30 primes are most commonly used while high viscosity primes such as MC70 are rarely, if ever, selected (Muller 2007). Muller also suggested that poor penetration and extended drying times have been known to occur with MC30 primes. For dense crushed rock bases improved penetration requires MC30 primes to be cut back by an additional 10–15% (SABITA 2006). Muller proposed the introduction of an MC10 prime (similar to an AMC 00). It is noted that inverted emulsions have also provided good performance and are gaining wider acceptance.

Table 4.4: Prime selection matrix

| Type of base | MC30 | MC70 | Inverted emulsion |
|---|---|---|---|
| Graded natural gravel, e.g. weathered G2+ | 1 | 2 | 1 |
| Crushed stone, e.g. unweathered G1/G2 | 2* | – | 1 |
| Lime or cement stabilised | 1 | 2 | 1 |
| Bituminous stabilised | – | – | 2 |
| Calcrete | 1 | 2 | 1 |
| Containing soluble salts | – | 2 | – |
| Absorptive properties of base material | | | |
| High moisture content | – | – | – |
| Low moisture content | 1 | 2 | 1 |
| High degree of densification | – | – | 2 |
| Low degree of densification | 1 | 2 | 1 |
| High porosity | 2 | 1 | 2 |
| Low porosity | – | – | 2 |
| Plasticity Index > 7 | – | – | – |
| Plasticity Index < 7 | 1 | 1 | 1 |
| Open graded | 2 | 1 | 2 |
| Climatic conditions | | | |
| High humidity | 1 | 2 | – |
| Wet | – | – | 2 |
| Road temperature > 25 °C | 1 | 1 | 2 |
| Road temperature < 25 °C | 2 | – | 1 |

1 Primary recommendation.
2 Secondary recommendation.

– not suitable.

* lower viscosity by cutting back with illuminating paraffin.

Source: SABITA (2006).

# 5 PRIMERSEAL

## 5.1 Historical Background

Primerseals were initially developed out of the need to construct roads under traffic where vehicle volumes were present that would damage a prime. Primersealing also allowed authorities to avoid the problem of traffic control with priming on busier roads, and to maintain a road over the winter if conditions became unsuited for priming.

Penetration of the primerbinder into the base by 2–5 mm was targeted as it was thought that this was needed to provide a bond with the pavement. This necessitated the use of high cutter levels. However, like primes, values for penetration depth were based on older unbound materials that tended to have higher levels of absorbency than the bound materials in use today (Cunningham personal correspondence via e-mail, 7 April 2009).

## 5.2 Expected Performance

Primerseals are temporary treatments which have been used in the following situations:

- construction of pavements under traffic
- holding sections on large construction jobs
- maintaining the pavement over winter months
- on porous pavements
- allowing traffic to find defects in the pavement that can be rectified before the application of the final surfacing.

They have life spans ranging from several months to two years (Austroads 1997).

They must provide a waterproof, skid resistant wearing surface for long enough to allow the final treatment to be applied in warm weather. Primerseals are often expected to perform when placed in cold and damp conditions when pavement hardness and dryback are not at optimal levels.

The temporary nature of primerseals means that regular monitoring of their performance should be programmed. Where needed, maintenance of the surface should be undertaken in a timely manner.

## 5.3 Austroads Procedures

At present no design method for primerseals exists. Austroads (2006c) provides tables (reproduced here as Table 5.1 and Table 5.2) to select a primerbinder type and base application rate. These values are then adjusted based on site specific conditions which include:

- increased binder absorption on porous materials such as limestone and sandstone where, based on experience, an additional 0.1 to 0.2 L/$m^2$ is required
- reduced binder absorption requiring a lowering of base rates on cement-treated bases (-0.1 L/$m^2$) and bitumen stabilised materials (-0.1 to -0.2 L/$m^2$)
- pavement hardness requiring a reduction in base rates to allow for aggregate embedment as per the allowances (Table 5.3).

In the context of AS 2157 grades, it is considered that a light to medium grade refers to an AMC 4 while a heavy grade is an AMC 5 cutback bitumen.

Table 5.1: Primerbinder selection guide

| Primerbinder | Recommended use |
|---|---|
| Light to medium grade of cutback bitumen | Cool and/or damp conditions. tightly bonded or medium porosity pavements. |
| Heavy grade of cutback bitumen | Warmer and/or drier conditions. Porous type pavements. |
| Bitumen emulsion (60% or 70% residual bitumen content) | All year, but most suited to cool and/or damp conditions. Porous type pavements. When final surfacing is to be applied immediately or before adequate curing of a cutback bitumen. |

Source: Austroads (2006c).

Table 5.2: Base primerbinder application rates (total volume of binder)

| Traffic (veh/day) | Aggregate size (mm) | Total primebinder application rate (L/m$^2$ at 15 °C) | | |
|---|---|---|---|---|
| | | Cutback bitumen | Bitumen emulsion | |
| | | | 60% | 67% |
| ≤ 150 | 5 or 7 | 1.3 | 1.6 | 1.4 |
| | 10 | 1.4 | 1.8 | 1.6 |
| 151 to 1200 | 5 or 7 | 1.2 | 1.5 | 1.3 |
| | 10 | 1.3 | 1.6 | 1.4 |
| 1201 to 2500 | 5 or 7 | 1.1 | 1.4 | 1.2 |
| | 10 | 1.2 | 1.5 | 1.3 |
| > 2500 | primersealing is not recommended | | | |

Source: Austroads (2006c).

Table 5.3: Embedment allowance for primerseals

| Ball penetration value (mm) | Traffic (veh/lane/day) | | |
|---|---|---|---|
| | ≤ 150 | 151–1200 | 1201–2500 |
| < 1.0 | nil | nil | nil |
| 1.0 to 2.0 | nil | -0.1 | -0.1 |
| 2.1 to 3.0 | nil | -0.1 | -0.2 |
| 3.1 to 4.0 | nil (see Note 1) | see Note 1 | see Note 1 |
| > 4.0 | see Note 2 | see Note 2 | see Note 2 |

Note 1: For ball penetration values exceeding 3 mm, maximum aggregate grading size should be limited to 7 mm.

Note 2: For ball penetration values exceeding 4 mm, primersealing is not generally recommended, particularly at higher traffic volumes (> 1200 veh/lane/day). Alternative treatments, or re-preparation of the pavement, should be considered.

Source: Austroads (2006c).

The selection of aggregate size is dependent on traffic and climatic conditions. Factors that must be considered are summarised in Table 5.4.

Table 5.4: Aggregate size for primerseals

| Traffic (veh/lane/day) | Aggregate size (mm) | Climatic conditions |
|---|---|---|
| < 200 | 5 or 7 | |
| ≥ 200 | 7 or 10 | |
| ≥ 600 | 10 | hot or wet |

Source: Austroads (2004b).

The values in Table 5.4 must be considered in light of the pavement condition and operating environment. For this reason, several situations have been raised where primerseals are not recommended, namely under heavy traffic (>2,500 veh/lane/day) and where the ball embedment value exceeds 4 mm, as may occur on a damp pavement.

From discussions with several users the following deficiencies with the current approach have been raised:

- inability to consider heavy vehicle volumes
- inability to consider double/double primerseals
- texture allowances do not consider potential reorientation and meshing of the primerseal and final seal aggregate.

## 5.4 Road Authority Guides and Specifications

### *5.4.1 Primerbinder Grade*

AS 2157-1997 classifies AMC 2 to AMC 4 cutback bitumens as primerbinders, though it is known that AMC 5 and AMC 6 cutback bitumens are also used, particularly on heavily-trafficked roads where it is considered that penetration is unlikely to occur. As a result, adhesion and resistance to flushing are desired.

Apart from MRWA and DTEI SA, all road authorities specify AS 2157 grades for primer sealing, albeit with some minor alterations. DTEI SA has a single primerbinder, the properties of which are provided in Table 5.5. This material is based on Class 320 binder and mineral turpentine. The reason for this combination is to provide a binder that cures rapidly, leaving a stiffer bitumen that would resist flushing. However, it is understood that availability and storage issues with mineral turpentine in South Australia is forcing a revision of this requirement.

Table 5.5: AS 2157 and DTEI primerbinder properties

| Test | Primerbinder | | AMC 4 | | AMC 5 | | AMC 6 | |
|---|---|---|---|---|---|---|---|---|
| | Min | Max | Min | Max | Min | Max | Min | Max |
| Viscosity @ 60 °C (Pa.s) | 1.5 | 2.5 | 2.0 | 4.0 | 5.5 | 11.0 | 13.0 | 26.0 |
| Residue from distillation to 360 °C (%) | 80 | – | 79 | – | 88 | – | 92 | – |

Source: AS 2157 (1997) and DTEI (2009).

Rather than detailing primerbinder properties, MRWA typically specifies the desired combination of Class 170 binder and cutter; for example, Class 170 with 5% or 10% cutter is commonly used for 10 mm primerseals (MRWA 2004).

For primerseals using sand or quarry fines, MRWA has developed a design method where the application rate and percentage of cutter (slow or medium curing) is calculated based on the need to achieve a desired viscosity level that is dependent on traffic level, expected pavement temperature and aggregate grading. The intention of the MRWA requirements is not to achieve penetration but rather to produce a stable aggregate mat that is well bonded to the base (MRWA 1985).

For emulsion primerseals all road authorities specify cationic rapid set (CRS) emulsions as outlined in AS 1160-1996. Properties for specialty products such as high binder content (> 70% residual) and latex-modified emulsions are not stipulated in any specification. Reference is often made to manufacturers' recommendations where these products are being considered.

### *5.4.2 Primerbinder Selection*

RTA NSW and VicRoads, in their respective sealing manuals, provide guidance on the selection of primerbinders. The RTA procedures are based predominantly on pavement temperature (Table 5.6) while VicRoads suggests grades considering the time of use (Table 5.7) and pavement properties. These are essentially the same as those suggested in Austroads (2006c) and shown in Table 5.1.

Table 5.6: RTA primerbinder selection criteria

| Pavement temperature | Primerbinder |
|---|---|
| > 20 °C in summer | AMC 4 or 13–16% cutter |
| > 20 °C outside of summer | AMC 4 or 16% cutter |
| 10 °C to 20 °C | AMC 3, AMC 4 or 16–21% cutter |
| 5 °C to 10 °C | Bitumen cutback with fast curing cutter or special grade cationic emulsion |
| 5 °C to 10 °C and/or damp conditions | Seek specialist advice |

Source: RTA NSW (2004).

Table 5.7: VicRoads primerbinder selection criteria

| Grade | Time of use |
|---|---|
| Light – medium (AMC 4) | May to November |
| Heavy (AMC 5) | December to April |
| CRS emulsion (60% or 67%) | All year but more suited to cool and damp conditions |

Source: VicRoads (2004).

Table 5.8: Selection of type and grade of primerbinder

| Primerbinder | Recommended use |
|---|---|
| Light-medium grade of cutback bitumen | Cool and/or damp conditions<br>Tightly bonded or medium porosity type pavements |
| Heavy grade of cutback bitumen | Warmer and/or dry conditions<br>Porous type pavements |
| Bitumen emulsion<br>(60% or 67% bitumen content) | All year, but more suited to cool and/or damp conditions<br>Porous type pavements<br>When final surfacing is to be applied immediately or before adequate curing of a cutback bitumen |

Source: Austroads (2006c).

As with the Austroads procedures, there is no information provided by any SRA relating to the selection of heavy vehicle volumes. It would be expected that the rapid loss of voids in the primerseal under heavy traffic would allow the use of a heavier grade of cutback primerbinder. Such a concept is similar to that for the cutting back of Class 170 binder proposed in Austroads (1998) where cutter levels are reduced as traffic volumes increase.

The high percentages of cutter in primerbinders that were adopted to reduce viscosity to the point that some degree of penetration would occur is in conflict with the need to maximise binder cohesion and produce a resilient surfacing resistant to flushing.

High cutter levels also require extended curing of the primerseal. Where short curing periods are needed, emulsions are generally accepted. MRWA regularly specifies a 10/5 double/double CRS170–60 emulsion primerseal based on the standard binder application rates presented in Table 5.9.

Table 5.9: MRWA double/double emulsion primerseal binder application rates

| Primerseal coat | Binder application rate @ 15 °C (L/m$^2$) |
|---|---|
| 1$^{st}$ coat–10 mm | 0.9 |
| 2$^{nd}$ coat–5 mm | 1.1 |

Source: MRWA (2009).

An issue with emulsions has been their poor green strength which has made them susceptible to damage for several days after application. Modified and high residue emulsions have been developed that attempt to overcome this problem but limited guidance is provided with respect to their use. Bligh (1994 and 1995) reported that high binder content and polymer modified emulsions performed well, even when applied in poor weather conditions. Such products would seem to be more applicable than the AS1160 grades to heavy traffic situations due to their faster curing and improved adhesion and cohesion characteristics.

Bligh (1995) also reported that a scatter coat proved useful in protecting single/single emulsion seals from damage due to traffic. As a consequence, RTA NSW now recommends the use of scatter coats for seals using 10 mm or larger aggregate (RTA NSW 2006).

Scatter coats or double/double primerseals would appear to assist in overcoming the low early strength associated with emulsion binders. Including such a recommendation and providing guidance on the design of double/double primerseals should be considered for future Austroads guides.

### *5.4.3 Curing*

It is universally recognised that the curing of cutback primerseals is required to allow volatiles to escape. The curing times recommended by each SRA are presented in Table 5.10. VicRoads and MRWA suggest two periods; the first is based on curing in hot conditions while the second is based on cool weather.

Table 5.10: Primerseal curing periods required by each road authority

| Treatment | RTA NSW(1) | VicRoads(2) | QTMR(3) | MRWA(4) | DTEI SA(5) | DIER Tas(6) |
|---|---|---|---|---|---|---|
| Primerseal (cutback) | 12 months | 3 months<br>6 months | 3 months<br>6 months | 3 months<br>12 months | 6 months | – |
| Primerseal (emulsion) | – | – | – | – | 1 month | – |

1 RTA NSW (2006)
2 VicRoads (2004)
3 QTMR (2009b)
4 MRWA (2004)
5 DTEI (2009)
6 Austroads (2009)

– Not specified.

Curing for emulsions is required to allow them to set, which may take up to several days. It is suggested that minimum curing periods do not apply to emulsion primerseals and that they may be resealed once the initial curing has taken place (Austroads 2004a). While this is true with respect to volatile concentration it does not take into account a period for trafficking to allow the primerseal aggregate to bed in so that a uniform texture level is achieved.

If an asphalt overlay is the final surfacing this is not an issue but where a spray seal is to be applied an excessive texture allowance may be used that could contribute to bleeding. Consideration may need to be given to recommending a minimum curing period for emulsion primerseals. For emulsion skin patching a desirable minimum period of one month before resealing is suggested (Austroads 2004b). It would seem reasonable that this could also apply to primerseals.

It has also been suggested that some modification to the surface texture allowances in Austroads (2006c) is required when sealing over a primerseal where the primerbinder is still soft and lively. This may take the form of the 20–30% reduction suggested for double/double seals where the second application is delayed.

## 5.5 Overseas Procedures

### *5.5.1 New Zealand*

Primerseals in New Zealand are referred to as first coat seals. They consist of 180/200 grade bitumen with between 6 to 15 parts of diluent added, depending on the shade air temperature as outlined in Table 5.11. Recently, 130/150 and 80/100 grades have also been used to minimise the risk of bleeding (TNZ et al. 2005).

Table 5.11: New Zealand first coat seal cutter levels

| Shade air temperature (°C) | Total diluents including cutter and adhesion agent (parts at 15 °C) |
|---|---|
| 12.5 | 15 |
| 15.0 | 14 |
| 17.5 | 13 |
| 20.0 | 11 |
| 22.5 | 9 |
| 25.0 | 7 |
| ≥ 27.5 | 6 |

Source: Transit New Zealand 1995.

The values presented in Table 5.11 show that, for temperatures below 20 °C, first-coat seals have similar cutter contents to AS 2157 primerbinders. A 180/200 pen grade being similar to a Class 50 bitumen means, for the same volume of cutter, a first coat seal binder will be softer than a AS2157 cutback. Therefore the minimum six parts diluent content would produce a binder almost equivalent to an AMC 6 cutback. This level of cutter is considered necessary to wet and bond with the base course (Transit New Zealand et al. 2005). First coat seals are commonly resealed after a year to allow the cutter to evaporate out.

Commonly used first-coat seals include (Transit New Zealand et al. 2005):

- Grade 4 chip (10 mm) followed by a Grade 3 (14 mm) reseal: traditionally used on highways with high traffic levels; however, care must be taken as texture on the Grade 4 seal may be too coarse for a reseal
- Grade 3 chip (14 mm) followed by a Grade 5 or 6 (7 mm or 5 mm) reseal: reserved for roads with medium to heavy traffic and where texture of Grade 4 chip may be too coarse
- Grade 3/5 (14/7) double/double seal: used in areas of high stress
- Grade 3 (14 mm): used on roads with low traffic and low shear stresses.

The design of first-coat seals (single/single and double/double) is performed using the same method employed for reseals. A residual binder application rate is calculated to which the required cutter levels are applied. Adjustments for absorption and embedment are made based on experience (Transit New Zealand et al. 2005) while a visual assessment of the base is performed to determine if any texture allowance is needed.

### *5.5.2 South Africa*

Primerseals are not mentioned in the South African literature and it is understood that they are not commonly used. SABITA (2006) recommends the use of a prime; however, in the event that this is omitted it is suggested that the spray seal application rate be increased by 0.15 L/m$^2$ to allow for adsorption.

SANS 308 (SANS 2009) does, however, include two grades of cutback bitumen that could be classified as primerbinders: MC-800 and MC-3000 (Table 5.12). SANS (2009) suggests that one of the applications for these materials is for surface treatments on new construction.

Table 5.12: SANS 308 cutback bitumen primerbinder grades

| Property | MC-800 | | MC-3000 | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| Viscosity @ 60 °C (Pa.s) | 0.8 | 1.6 | 3.0 | 6.0 |
| Residue from distillation to 360 °C (%). | 75 | | 80 | |

Source: SANS (2009).

## 5.6 Discussion

### *5.6.1 Penetration Versus Adhesion*

Achieving penetration into the base has been cited as the main reason for adopting cutter levels between 12–27%. While under some circumstances this will assist in achieving a bond between the primerseal and the base it comes at the cost of binder cohesion and stiffness. In addition, higher levels of compaction mean that lighter fractions from the primerbinder are not being absorbed into the pavement, resulting in a primerbinder that remains softer for longer.

Fenton (2008) reported several projects where poorly-performing primerseals encouraged the use of primerbinders with cutter levels between 3% and 10%. At these concentrations virtually no penetration occurred, which is not surprising considering that, in reality, these treatments were simply seals without a prime. Despite this these primerseals, which mostly operated under heavy traffic, performed well. New Zealand practice also suggests that relatively low cutter levels (6–8 parts) may be successfully adopted.

Difficulty in achieving penetration on stabilised materials prompted RTA NSW to conduct a review of surfacing practice on bound pavements (Herben 2005). It was found that many Regions within RTA NSW believed that adhesion was more important and realistic than penetration. This approach has led to the use of a mix of different primerseals as outlined in Table 5.13. The performance of these treatments has generally been good with lives of 6 to 12 months reported.

Table 5.13: Primerseals used on stabilised pavements in NSW

| Seal size (mm) | Base binder | Cutter content (%) |
|---|---|---|
| 10 or 7 single/single | C170 | 10 |
| 10 single/single & 5 mm scatter | C320 | 5 |
| 10 single/single | C320 | 4 |
| 10 or 7 single/single | C320 | 5–10 |

Source: Herben (2005).

Emulsions are a generally accepted alternative to cutback primerbinders that have provided excellent performance, particularly under very heavy traffic. Fenton (2008) reported that sections of the Pacific Highway at Blackmans Point, Port Macquarie were successfully primersealed using high binder content emulsion (70% binder content). In this case the base had been stabilised with 3% cement over which a 10 mm primerseal with a 5 mm scatter coat was applied.

Such performance occurs in spite of the fact that the degree of penetration of emulsions into bases is generally quite poor (MRWA 2004). This, together with the performance of the low cutter primerbinders, raises the question whether adhesion rather than penetration should be targeted.

It is acknowledged that a prime and seal should be adopted wherever possible. However some practitioners have suggested that primes may not be required where the base presents a clean stone mosaic and the pavement is dried back. This is not to suggest that primes should be omitted, rather it indicates that penetration may not be absolutely necessary in all situations.

It could be argued that this presents a risk of delamination or shoving occurring to the primerseal in high-stress areas. However, this has always been a problem with primerseals as penetration (where it does occur) is not immediate and cohesion of the bitumen with 15–20% cutter oil is relatively poor, resulting in the binder being less capable of holding the aggregate (Fenton 2008).

The use of traditional primerbinders would still be applicable to roads with low traffic volumes or where fine grained materials (sandstone, limestone) are used. However, in most other cases, particularly under heavy traffic, cutter levels of the order of 5–10% may be warranted.

It has been proposed that Class 320 should replace Class 170 as the base bitumen for cutback primerbinders in order to produce a primerseal more resistant to flushing and pickup. It is considered that this does warrant further investigation, particularly for heavy traffic applications in warm weather. However, before any such work commences the issue of minimum levels of penetration will need to be clarified. It may be defeating the purpose of using harder bitumen if the same viscosity as current primerbinders is targeted.

### *5.6.2 Emulsions*

Whilst emulsions have been used for primersealing for some time, their acceptance has been limited. While 60% emulsions are user-friendly in terms of stability and handling they do have several disadvantages, including:

- They cannot be applied at high rates of application due to their tendency to run off the pavement.
- This limits their use to small size and double/double primerseals.
- The high water content adds to binder transportation costs.
- Low early strength or green strength makes them susceptible to damage from traffic.

High binder content emulsions (HBCE) with residual binder levels in excess of 67% have been developed for use in resealing and primersealing applications. These products provide the following advantages (Remtulla & Swanston 2000):

- higher binder viscosities that allow high rates of application without the risk of runoff
- lower transportation costs than 60% emulsion
- quicker breaking and curing.

Increasing binder viscosity can, however, have a disadvantage in terms of reduced ‘sprayability’, i.e. not being able to achieve a uniform binder distribution, often seen as streaking or tram lining. While adjustments can be made to the formulation and particle size distribution of the emulsion to minimise this problem it is still known to occur. In some cases this uneven binder distribution has resulted in stripping in straight, uniformly-spaced lines as shown in Figure 5.1.

Source: DTEI (2010).

Figure 5.1: Stripping due to high emulsion binder viscosity

Modified HBCEs have been developed to overcome the issue of low early strength associated with conventional emulsions and to provide improved aggregate adhesion. Initially, emulsions were modified by the addition of latex, either by post-addition of latex to a Cationic Rapid Set (CRS) emulsion or by addition to the bitumen during the milling process (Remtulla & Swanston 2000). Recently, emulsions using polymer modified binders (PMBs) complying with Austroads (2006b) have been developed to deliver the elastic properties of a PMB while overcoming the issue of poor adhesion and aggregate wetting that can occur with a hot product.

While they have improved properties compared to conventional emulsions they still need time to set up and cure. Curing is affected by numerous factors including weather, emulsion chemistry and aggregate chemistry. Therefore it is important that the conditions under which the emulsion will be applied be communicated to the supplier to enable the optimum formulation to be used. An example of the importance of this process occurred in trials undertaken in NSW where prolonged curing in cool conditions led to extensive aggregate stripping (Bligh 1995). One of the outcomes of this trial was the need to confirm the setting times with the manufacturer to take into account the forecast weather conditions.

In terms of performance, numerous trials (Parfitt 1999; RTA NSW 2000) have shown that emulsions can be successfully applied with some alteration to existing construction practice including:

- Rolling, particularly under cool conditions, needs to commence at slow speeds and without drag brooming (Austroads 2002b; Parfitt 1999).
- Where pick-up of aggregate is occurring, watering of the tyres of multi-wheeled rollers may be necessary (Austroads 2002b).
- Sweeping may need to be delayed
  - it is advisable to check whether the aggregate has adhered to the binder and even conduct a short trial run to make sure that aggregate is not going to be dislodged
  - it may be necessary to have a roller follow the broom to allow any disturbed aggregate to be rolled back into the binder.
- The speed of traffic on the seal must be controlled until the binder has gained sufficient strength to retain the aggregate:

— as this can take several hours, enough time at the end of the day must be allowed for trafficking at 40 km/h; this may necessitate the use of pilot vehicles to escort traffic through the site.

Caution needs to be exercised when using single/single emulsion seals as stripping due to the low early strength of the binder (this includes HBCEs) can occur. To reduce this risk, particularly in heavily-trafficked situations, a rack-in coat or a double/double primerseal should be employed. Double/double primerseals also reduce the risk of binder runoff as the binder application can be apportioned between two layers.

Austroads (2002b) recommends the use of a scatter with 10 mm or larger seals. This, however, has not translated to the Austroads (2009) or pavement work tips. In addition, the current primerseal design method does not cater for double/double primerseals for either emulsion or cutback binders. Guidance on the design of double/double primerseals is therefore needed.

Emulsion primerseals have also been used on salt-affected pavements with good results. While the bitumen becomes brittle very quickly the emulsion does not tend to blister as a cutback primerseal would. The use of emulsion also allows a final seal to be applied quickly, further reducing the risk of salt damage.

It should be noted that present standards do not cover modified emulsions. This poses a risk to purchasers and makes comparison between products difficult. Consideration must be given to developing specification limits for these products to provide purchasers with some degree of reassurance that materials ordered will meet certain minimum standards.

## 5.7 Seal Design

The application of a seal design methodology to primerseals seems to have occurred overseas and has also been reported in one RTA district in NSW (Fenton 2008). To test this approach, a series of designs have been undertaken for the following range of traffic levels, aggregate sizes and binder types for seals (with and without prime) and primerseals:

- traffic (veh/lane/day): 100, 250, 1000, 1500, 2500
- heavy vehicles (%): 10
- seal size: 10 mm single/single, 10/5 double/double
- binder types: AMC 5, CRS67-170, Class 170.

Calculations are based on the following assumptions:

- two-way road that is flat and straight
- ball embedment of 2.0 mm
- well-constructed, smooth and uniform granular unbound pavement
- crushed angular sealing aggregate
- ALD of 5.5 mm for 10 mm aggregate
- absorption allowance for seals with no prime based on values presented in Austroads (2006c)
- emulsion factor of 1.1 for high bitumen content emulsions (≥67%)
- AMC 5 contains 90% bitumen.

A summary of the application rates calculated is presented in Table 5.14. For ease of comparison residual rates are provided, together with rates for the total volume of product (in brackets). The following points can be observed from the data:

- Residual rates for cutback primerbinder are generally 0.2 L/m$^2$ higher than those for emulsion. This may be a reflection of the poor penetration achieved by emulsions which means the majority of the binder is available on the surface to hold aggregate.
- Single/single residual rates for emulsion seals (no prime) are significantly higher than those for emulsion primerseals. Seal rates without a prime include a 0.2 L/m$^2$ absorption allowance. Whether this allowance is necessary for high binder content and modified emulsions is debatable, particularly where penetration into the base could be limited. Application rates for single/single emulsion seals with a prime (hence no absorption allowance) are closer to the emulsion primerseal rates and appear to offer more reasonable values apart from the rate at 2500 veh/lane/day.
- At 2500 veh/lane/day, cutback and emulsion single/single seal rates (with prime) are considered to be too low and present a significant risk of stripping. Single/single and double/double emulsion rates with no prime appear more reasonable.
- In the 250–1500 veh/lane/day range residual primerseal and single/single seal rates (no prime) for cutback binders are similar. With traffic at 2500 veh/lane/day, single/single seal rates are 0.5 L/m$^2$, 0.2 L/m$^2$ lower than those for a primerseal. This was to be expected as the primerbinder method does not change above 1200 veh/lane/day. Primersealing is not recommended for traffic volumes exceeding 1200 veh/lane/day; however, embedment allowances are still provided for traffic levels above 2500 veh/lane/day.
- Cutback double/double residual seal rates are higher than single primerseal residual rates but these tend to converge at higher traffic levels.

While primerseals are not recommended where traffic exceeds 1200 veh/lane/day (due to budget restrictions) the reconstruction of major highways using granular pavements and spray seals is likely to increase. Some means of calculating rates taking into account high volumes of traffic is necessary.

Table 5.14: Binder application rates for 10 mm seals and primerseals

| Traffic (veh/lane/day) | Binder application rate (L/m$^2$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 mm primerseal | | 10 mm single/single (no prime) | | 10 mm single/single (with prime) | | 10/5 double/double (no prime) | | 10/5 double/double (with prime) | |
| | AMC 5 | CRS 67 | C170 | CRS 67 | C170 | CRS 67 | C170 | CRS 67 | C170 | CRS 67 |
| 100 | 1.2 (1.4) | 1.1 (1.6) | 1.4 | 1.5 (2.2) | 1.2 | 1.3 (1.9) | 1.6 | 1.7 (2.5) | 1.4 | 1.5 (2.2) |
| 250 | 1.1 (1.2) | 0.9 (1.4) | 1.2 | 1.3 (1.9) | 1.0 | 1.1 (1.6) | 1.4 | 1.6 (2.4) | 1.3 | 1.4 (2.0) |
| 1000 | 1.1 (1.2) | 0.9 (1.4) | 1.0 | 1.1 (1.6) | 0.8 | 0.9 (1.3) | 1.2 | 1.3 (1.9) | 1.0 | 1.1 (1.6) |
| 1500 | 1.0 (1.1) | 0.8 (1.2) | 1.0 | 1.0 (1.5) | 0.8 | 0.8 (1.2) | 1.2 | 1.3 (1.9) | 1.0 | 1.1 (1.6) |
| 2500 | 0.9 (1.0) | 0.7 (1.1) | 0.7 | 0.8 (1.2) | 0.5 | 0.6 (0.9) | 1.0 | 1.1 (1.6) | 0.8 | 0.9 (1.3) |

These observations suggest that there are similarities between the outputs of the primerseal and seal design methods. It is recommended that data on primerseals applied over a range of traffic levels be gathered by SRAs to allow a more in-depth comparison of actual field performance with the current primerseal and seal design methods. Information that would need to be sourced should include:

- basecourse properties, density, hardness, moisture content, grading, Atterberg limits
- primerbinder properties
- primerseal application records including design binder and aggregate application rates, actual binder and aggregate application rates
- assessment of performance over the life of the primerseal
- final seal records.

# 6 CONCLUSIONS

The use of granular pavements with thin surfacings is the cornerstone of the Australian sealed road network. While the length of granular pavements being constructed has reduced since the 1960s and 1970s, the need to produce high quality pavements is of even greater importance considering the challenges being faced by road authorities and asset managers to meet the demands of increasing traffic levels and the impacts of new-generation heavy vehicles.

Primes and primerseals play an important role in achieving a successful surfacing as they form the basis for the performance of future treatments. Any defect in the prime or primerseal can quickly impact on the serviceability of the entire pavement.

Considering this, the fact that poor-performing primes and primerseals are increasingly being reported is cause for concern. In order to understand and address the issues involved, a review of Australian and international prime and primerseal design practice was undertaken to determine what further work is required to improve current design and selection procedures.

The main findings of this review and recommendations for further work, are as follows:

- Design methods currently in place for primes appear adequate. However, the development of a procedure to provide guidance to inexperienced personnel undertaking field assessments of prime performance should be considered.
- Moisture contents prior to priming and sealing may need to be revised to consider not only pavement stiffness but also surface hardness.
- The need for consensus on curing times for primes should be discussed.
- There may be scope to have longer curing periods and lower moisture contents for roads with high traffic levels.
- Heavier grades of cutback primerbinder may need to be considered, particularly where the proportion of heavy vehicles is high, in order to improve binder cohesion and minimise risk of flushing. AMC 5 and AMC 6 could be adopted at low traffic and high traffic primerbinders.
- Good performance has been reported with high binder content emulsions where penetration has been minimal. The fact that good adhesion is achieved suggests that adhesion, rather than penetration, should be aimed for.
- The need for minimum curing periods for emulsion primerseals should be considered.
- As expected, double/double primerseals or scatter coats assist in maintaining the integrity of the primerseal during initial trafficking. However, recommendations regarding their most appropriate use are lacking.
- Additional guidance is needed regarding the most appropriate grade of primerbinder to be used in different seasons.
- The need to prepare the base to produce a clean aggregate mosaic on the surface to allow the pavement to dry back is a fundamental requirement if a bond between the pavement and the primerseal is to be achieved.
- Information related to the design and application of primerseals subject to a range of traffic levels must be gathered to allow a thorough comparison between current and potential methods and actual field performance.

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**Keywords:**

Primes, primerseals, state-of-the-art review, Australia, New Zealand, South Africa.

**Abstract:**

A review of Australian and international prime and primerseal design practice was undertaken to determine what further work is required to improve current design and selection procedures. It was found that design methods currently in place for primes appear adequate. However, a number of recommendations are made regarding current practice and the need for further research.