DESIGN OF RATES OF APPLICATION

INTRODUCTION

The development of the *Austroads provisional sprayed seal design method: Revision 2000* (Austroads AP-T09) represented the outcome of a large national trial and substantial review of sprayed seal design procedures in Australia and New Zealand. The method is provisional because the procedures developed need to undergo a period of validation, and may require some adjustment before being accepted in the final design method. A companion publication with the title of *Practitioners guide to design of sprayed seals* (Austroads AP-T17) provides the same design information but in a more convenient summary format.

Austroads "AP-T68/06: Update of the Austroads Sprayed Seal Design Method" has since been published'

The design procedures are supported by a number of Austroads test methods (SDT) which are published on the Austroads website and can be downloaded free of charge from https://www.onlinepublications.austroads.com.au/collections/agpt/research-technical

The design method is divided into three main design sections:

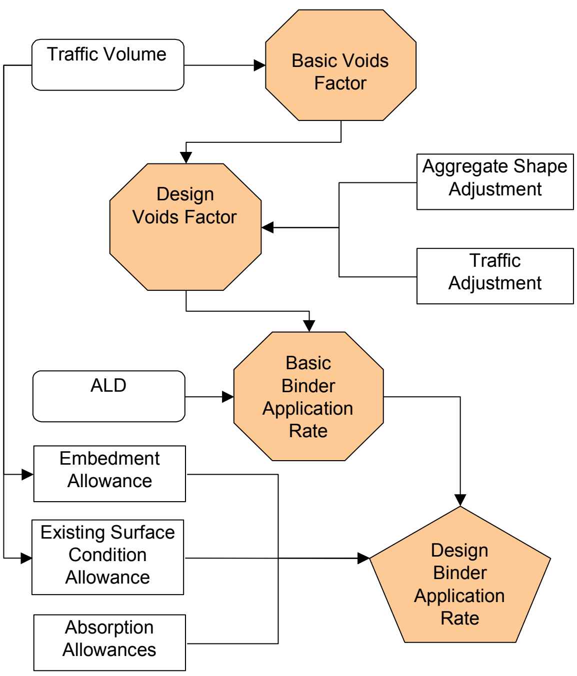
Part I size 10mm and larger aggregates

Part II size 7mm and smaller aggregates

Part III double/double seals.

The following description provides an outline of the Austroads "Revision 2000" procedures for the design of rates of application for sprayed seals. Tables and charts required are not included in these notes but are in the course presentation. Users undertaking sprayed seal design work should refer to the Practitioner's Guide for the most current design information. The design concepts are based on the following assumptions:

- Use of sound, single sized aggregate.
- Aggregate is spread in a uniform layer of one stone thickness (some seals may require more than one layer).
- Aggregate particles form a continuous, partly interlocked contact resulting in a shoulder-to-shoulder mosaic.
- The aggregate least dimension is near vertical.
- The surface layer has typically 40–60% voids.
- Binder should be 50–60% up the height of the aggregate.



Rates of application of binder and aggregate are determined as a function of the average least dimension (ALD) of the aggregate. The preferred method for the determination of ALD is Austroads Test Method SDT 01.

The design procedure is summarised in the following steps:

1. Derive a Basic Voids Factor appropriate to the design traffic level.
2. Adjust the Basic Voids Factor to cater for non-typical traffic and/or non-typical aggregate to derive the Design Voids Factor.
3. Multiply the Design Voids Factor by the ALD of the aggregate to derive a Basic Binder Application Rate.

4. Determine what Allowances are appropriate for absorption, existing surface condition and texture, embedment.
5. Determine Design Binder Rate by adding Basic Binder Rate and Allowances
6. Determine the Aggregate Spread Rate based on the ALD and traffic.

PART I – SIZE 10MM AND LARGER AGGREGATES

BINDER APPLICATION RATE

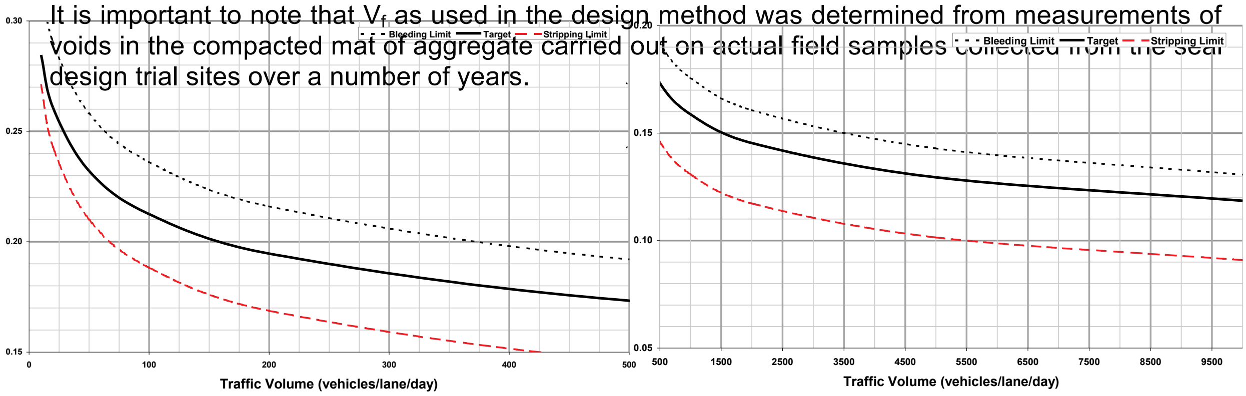
General

The binder application rate will depend upon the size of the proposed aggregate and the traffic it is expected to carry. The determination of the traffic for each lane (and sealed shoulder and/or sealed median) is very important. The apportioning of traffic volumes and its composition to various lanes is discussed in detail in Appendix 5A of Revision 2000. To this there are some adjustments and allowances to cater for situations that differ from the assumptions made for typical traffic mix and aggregate characteristics.

Basic Voids Factor (V_f)

The Basic Voids Factor (V_f) is represented as a relationship between traffic volume and the voids in the aggregate to be filled with binder to achieve a binder height of between one half to two-thirds the height up the aggregate after rolling and up to 2 years of trafficking. V_f is expressed in L/m^2/mm and may vary from 0.12 L/m^2/mm for roads with high traffic volumes (low voids), up to 0.25 L/m^2/mm for very low traffic volumes (high voids).

It is important to note that V_f as used in the design method was determined from measurements of voids in the compacted mat of aggregate carried out on actual field samples collected from the seal design trial sites over a number of years.



Adjustment for Aggregate Shape (V_a)

Aggregates may be crushed rocks, partly crushed natural gravel or uncrushed (screened only) natural gravel. The Austroads design process assumes that crushed rock aggregates of angular shape, with a flakiness index between 20 to 30, are commonly used. When these aggregates are spread and rolled at the correct spread rate they will have a particular void volume. Aggregates of different shapes will have a different void volume, and when they are used an adjustment to the basic voids factor is necessary to compensate for the difference.

The adjustments can be positive (e.g. natural gravel which is usually very cubical) which increase the basic binder application rate or negative (i.e. flaky/flat, crushed particles), which reduce the basic binder application rate. The adjustment for aggregate shape is added to the basic voids factor to determine the design voids factor.

Adjustment for Traffic (V_t)

The Austroads design assumes that traffic is free flowing with less than 15% heavy vehicles. Where there are more heavy vehicles or the traffic flow is constrained, then adjustments to the basic voids factor are essential. Where there is more traffic compaction than normal taking place, the voids to be filled with bitumen are reduced. Adjustments may vary from a reduction of up to 0.04 L/m^2/mm for severe loading conditions to an addition of 0.02 L/m^2/mm for areas with little or no traffic.

This adjustment is also added to the basic voids factor to determine the design voids factor.

Design Voids Factor (VF)

The design voids factor (VF) is calculated from:

$$\mathbf{VF = (V_f) + (V_a) + (V_t).}$$

The design voids factor (VF) is in litres per square metre per millimetre (L/m^2/mm), reported to two decimal places.

Basic Binder Application Rate (B_B)

The basic binder application rate is determined from:

$$\mathbf{B_B\ (L/m^2) = VF \times ALD}$$

Allowances

The condition of the existing pavement and/or surfacing, and/or any aggregate or pavement allowances, needs to be made to determine the allowances that may be required to be made to the basic binder rate to determine the design binder rate. Allowances may be positive (increase in binder rate) or negative (decrease in binder rate).

Existing Surface Allowances (A_S)

Surface texture should be assessed using Austroads SDT 02 – Modified Surface Texture Depth (Pestle Method), which is often referred to as the sand patch test. The test is applicable to surfaces where the texture depth is in excess of 0.3mm. It is difficult to use the test correctly on depths of less than 0.3mm, and at this low texture the allowance to be made to the basic binder rate of application will either be very small or nil.

Allowance for texture can be substantial for surfaces with high textures (e.g. large aggregate seal), and may require a degree of judgement by the designer. Existing seals generally require additional binder to fill in spaces between the existing seal and the new seal.

Low textured seal surfaces often exhibit some bleeding or flushing and the ball penetration test should be used to determine if an allowance for embedment may also need to be considered. On fatty surfaces the surface texture allowance will be negative.

Where the existing surface comprises asphalt, slurry surfacing, concrete or timber, it is necessary to always provide some additional binder to fill the underneath voids in the proposed seal that would normally be occupied by the texture in an existing seal.

Absorption Allowances (A_A)

Absorption allowances are to offset binder lost from the seal due to absorption into either the aggregate or the underlying pavement. These allowances are always positive – that is, additional binder is added to the basic binder application rate.

The quantity of binder likely to be absorbed into aggregate can be estimated using Austroads Test Method SDT 03 – Absorption of bituminous binder into aggregate. Generally, the allowance for binder absorption by aggregate does not exceed +0.1 L/m^2. Aggregates requiring absorption allowance greater than +0.3 L/m^2 should not be used unless their performance is proven.

Absorption of binder by existing pavements can be due to loss of binder to fill pavement voids not adequately filled by priming or primersealing. This is most likely to occur in sandy or silty-rubble base courses (sandstone, limestone or silty gravel) and hot dry climates. There are no direct methods to estimate an allowance, but local knowledge may provide some indication of the allowance required, generally in the range +0.1 to +0.2 L/m^2.

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

Embedment Allowance (A_E)

Embedment can be expected if the underlying pavement is:

- granular soft pavement (may be a primed or primersealed surface) or "green" surface soft due to moisture and not allowed to dry-back prior to treatment;
- flushed or bleeding seal with free binder;
- new or soft asphalt pavement or patches.

Where there is greater compaction (more heavy traffic), there will be a greater likelihood of embedment into the underlying pavement.

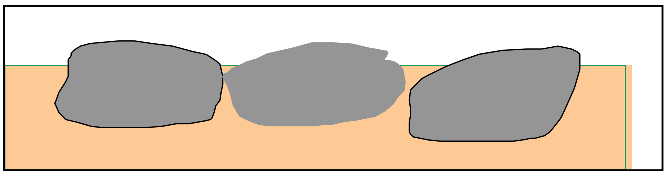


Figure 17: Embedment of aggregate particles

Where embedment is likely, an allowance can be estimated by performing the Austroads Test Method SDT 04 – Ball penetration test. The penetration depth is related to traffic volume to derive an embedment allowance.

Figure 18: Ball embedment testing

Where embedment allowances of minus 0.3 L/m^2 or more are indicated, consideration should be given to alternative treatments, such as armour coating with better quality materials, or adopting a prime and seal/primerseal with small aggregate followed about 12 months later with a larger aggregate seal.

Design Binder Application Rate (B_D)

The design binder application rate is calculated from:

$$B_D \text{ (L/m}^2\text{)} = \text{Basic Binder Application Rate (L/m}^2\text{)} + \text{Allowances (L/m}^2\text{)}$$

Some of the allowances may be negative and this could mean that the design binder application rate is lower than the basic binder application rate.

The design binder application rate is expressed at the standard temperature of 15°C, and the hot volume sprayed on the road will need to be adjusted for thermal expansion at the spraying temperature.

AGGREGATE SPREAD RATE

Aggregate spread rates are generally expressed as m^2/m^3 of loose aggregate as spread from the truck/spreader. The design method provides for a range of aggregate spread rates for single/single seals that may vary from 750/ALD to 900/ALD. Note: No allowance for whip-off is to be added to the spread rate as was the case in previous methods.

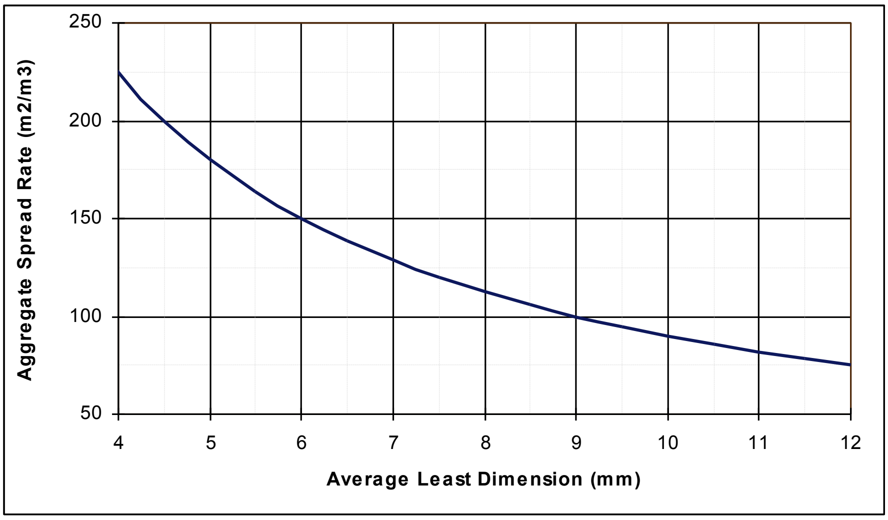


Figure 19: Loose aggregate spread rate for single/single seals

The lighter rates of spread (900/ALD) are used when using conventional bitumen and traffic is medium to heavy. The spread rate is heavier when traffic is below 200 v/l/d to compensate for reduced reorientation of aggregate by the low traffic.

Heavier rates of spread of aggregate (up to 750/ALD) may also be required when using polymer modified binders, particularly on roads with low traffic volumes. Heavier aggregate spread rates may also be required when using bitumen emulsion binders to provide greater support between adjoining aggregate particles while the binder sets up and cures.

Reductions to the aggregate spread rate are applied in the design of double/double seals, or when a second layer of small aggregate is used as a scatter coat as in the case of emulsion binder seals.

When determining quantities for the establishment of stockpile sites, about 5–10% should be added to the quantity calculated from the design spread rates, to allow for handling and wastage on the stockpile site.

PART II – SIZE 7mm AND SMALLER AGGREGATES

The design philosophy is similar to the larger aggregates except that:

- the ALD is generally not determined
- they are often used as correction seals
- they are used in situations that can tolerate reduced surfacing life, or as temporary surfacing.

The same design process as in Part I may be used if an ALD is available. If not, a table of Basic Binder Application rates is provided to cover most situations. The Basic Binder Rate varies from about 1.0 L/m² at low traffic (<100 v/l/d) to 0.5 L/m² for high traffic (>2500 v/l/d).

The normal allowances for surface texture and absorption apply. Embedment is less of an issue with the smaller aggregates as they are often used to minimise potential embedment problems.

The aggregate spread rate for size 7mm or smaller aggregate seals varies depending on the objective of the seal. If the intention is to provide a correction seal, an aggregate spread rate of about 250 m^2/m^3 will be appropriate. If a completely interlocked mosaic is required, the aggregate spread rate will be about 200 m^2/m^3.

PART III – DESIGN OF DOUBLE/DOUBLE SEALS

General

A double/double seal consists of two applications of binder, each followed by an application of aggregate. Double/double seals may be laid in two ways:

- both applications placed on the same day (or within 24 hours), or
- second application, delayed up to 3 or 4 months.

It must be decided at the outset if the second application is to be delayed or not.

Both Applications on the Same Day

When a both applications of a double/double seal are applied on the same day, the design voids factor for the first application is firstly determined as for a single/single seal, taking into account adjustments for aggregate shape, terrain and traffic. The design voids factor (VF) is reduced by between 10% and 25% depending on traffic volume. The greater reduction is required for lower traffic volumes, where the second layer has the greatest influence on the voids in the aggregate. Allowances for surface condition and texture, absorption and embedment apply as normal for the design of the first layer.

The design of the second binder application rate is the same as the design for a basic application rate for single/single seal, ***but without any allowances.***

The aggregate spread rate for the first application is reduced by 10% to provide an open mosaic which will allow the second aggregate application greater potential for interlock.

The second aggregate spread rate is reduced to around 70% of that required for a single/single seal in order to be just sufficient to fill the voids in the first aggregate application.

Second Application Delayed

The first application is designed as if it were a single/single seal.

The design of the second binder application rate is the same as the design of a basic application rate for single/single seal, but without any further allowances for surface texture, surface condition or embedment.

The second aggregate spread rate is reduced to 70% of that required for a single/single seal. The aim of the second aggregate application is to interlock into the first application and not provide a complete shoulder-to-shoulder mosaic.

POLYMER MODIFIED BINDER SEALS

General

It must be noted that seal design procedures need to be modified when HSS, SAM, SAMI techniques are used. The binder application rates will generally be higher when PMB sprayed seals are used, particularly in the case of a SAM with a highly modified binder such as S25E, and a SAMI. If a SAMI is to be trafficked for more than 1 or 2 days prior to placing the asphalt overlay, it may need to be designed as a SAM to prevent potential problems such as loss of aggregate or pick-up of the binder.

Aggregate spread rates also need to be amended to accommodate the differences in aggregate packing with the more viscous and elastic binders, and different aims of the PMB treatments.

Design Procedure

To determine the PMB design binder and aggregate application rates, the standard rates are adjusted by a factor (PMB Factor) based on the traffic and type and grade of PMB.

Binder Application Rate

1. Determine the Basic Binder application rate ($\mathbf{B_B}$) as for a C170 seal.
2. Multiply the Basic Binder rate by the appropriate PMB factor for HSS, SAM or SAMI to determine the Modified Base Rate.
3. Add the normal allowances e.g. surface texture, absorption, embedment to the Modified Base rate to determine the Design PMB application rate to use.

Aggregate Spread Rate

1. HSS – no change is usually necessary.
2. SAM – the normal standard spread rate is increased by between 10 and 15%.
3. SAMI – similar to a SAM if trafficked for 1 or more days.

If covered with asphalt within 24 hours, the spread rate is as standard or slightly reduced to avoid the need to remove loose aggregate prior to placing the asphalt. This is influenced by location and traffic stresses, length of time before asphalt placement, the type and volume of traffic, and risk of pick-up of the binder by traffic or supply trucks and asphalt paving equipment.

PMB Factors to design the Binder Application Rate

The following provides an indication of typical PMB factors used to design the rates of application of binder for a HSS, SAM or SAMI seal, taking into account traffic and the common types of PMBs used.

HSS – PMB factor of 1.0 to 1.1
SAM – PMB factor of 1.2 to 1.5
SAMI – PMB factor of 1.5 to 2

Note:
The above factors apply for all traffic conditions as this is already taken into account in the basic design approach.
Crumb rubber based PMBs usually require the higher PMB factors.
Where polymer modified binder types other than those listed in the Austroads method are used, an appropriate factor should be obtained for the particular material.

GEOTEXTILE SEALS

General

To perform its required function, a geotextile reinforced seal (GRS) requires a significantly higher total binder content than a conventional bitumen seal.

Additional binder is required to:

- saturate the geotextile
- tack/bond it to the surface
- retain the aggregate under severe climatic/traffic conditions.

This may be achieved by either using a heavier application of conventional bitumen or using a PMB in the seal coat. The advantage of using a polymer modified binder is that they are less likely to soften during hot weather and bleed or lose aggregate.

DESIGN OF RATES OF APPLICATION

For initial treatments the pavement should be primed to achieve a good bond.
The procedure for applying a geotextile is:

1. Spray a tack/bond coat, which is designed to fill the geotextile and bond it to the pavement
2. Quickly place the geotextile on the tack coat, and lightly roll. Rolling with multi-wheel rollers is required to ensure the binder is pushed into the fabric.
3. Apply the first seal coat, using normal procedures
4. Apply the second seal coat (if any), using normal procedures.

The success of the sealing operation depends largely on using the correct bitumen application rate. This in turn is determined by the combination of application rates for the tack coat and the seal coat.

Initially, the geotextile should be fully saturated with bitumen. Experience has shown that if the geotextile is not fully saturated at the time of sealing, it will continue to absorb binder from the seal coat with time and trafficking.

An unsaturated geotextile seal that appears well filled with bitumen may become hungry after trafficking and require an enrichment to prevent loss of aggregate, particularly if a single/single seal is used. To avoid pick up problems, rolling should be stopped when the fabric starts to blacken with binder.

Application rates are determined by:

- The grade (thickness) of the geotextile
- The seal type, i.e. single/single or double/double
- The texture and type of existing pavement surface
- The nature and volume of traffic, and traffic stresses.

Due to the wide range of traffic, seal and formation combinations, a definitive list of application rates cannot be given. The following should be taken as a guide only.

Seal Coat Design

The binder may be C 170 or C 170 fluxed and/or cutback as normal, or a PMB.

The rates of application of binder are designed as follows:

1. Determine the standard Basic Binder rate, or modified base rate if a PMB is used
2. Add the saturation allowance, say 0.9 L/m², for Class 170. Add say 1.2 L/m² if using a PMB (for a typical PMB grade used for a SAM)
3. Add the Allowances as normal for surface texture, absorption, embedment etc to determine the Total Design Binder rate (1 + 2 + 3).

Tack/Bond Coat

The binder should be Class 170 bitumen, ideally without cutter oil.

If the tack coat design rate is too heavy and causes problems during placing and rolling, it may be reduced, but any reduction from the tack design total must be added to the seal coat binder application placed on top of the geotextile

Application of Binder

The Binder Rate to be sprayed on the geotextile is:
Total Design Binder rate less the tack/bond coat application.

Aggregate Spread Rates

The aggregates are as for a normal, or PMB, seal and the spread rates are designed accordingly.

SURFACE ENRICHMENT

MATERIALS

The choice of materials depends on the availability, type of plant and cost of material. The two materials commonly used are cutback bitumen and bitumen emulsion.

There is no formal design procedure and the rates are based on field experience and expected performance. Generally the residual binder rate of application is between 0.5 and 0.8 L/m^2 depending on existing texture, traffic and life expectancy of the treatment.

Figure 20: Hungry coarse seal coat before (left) and after applying a surface enrichment of 0.7 L/m^2 of cutback bitumen (100-0-20)

FIBRE REINFORCED SEALS

This is a proprietary system, and the Contractor generally designs the binder application rates and aggregate spread rates. The design is based on standard procedures modified to take into account factors and allowances developed for this process. The rates used are generally heavier than for a normal seal, along similar lines to a PMB seal design.

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

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

Aggregate size of proposed seal	Measured texture depth (mm)	Surface texture allowance (L/m^2)
Existing: 5 or 7 mm seal		
5 or 7 mm	0 to 0.3	Note 1
	0.4 to 0.9	+0.1
	1.0 to 1.5	+0.2
	1.6 to 2.2	+0.3
	2.3 to 3.2	+0.4
	>3.2	+0.5
10 mm	0 to 0.3	Note 1
	0.4 to 0.7	+0.1
	0.8 to 1.1	+0.2
	1.2 to 1.8	+0.3
	>1.8	Note 3
14 mm	0 to 0.2	Note 1
	0.3 to 0.6	+0.1
	0.7 to 0.9	+0.2
	1.0 to 1.4	+0.3
	1.5 to 2.0	+0.4
	>2.0	+0.5
Existing: asphalt/slurry surfacing		
All	0 to 0.1	0
	0.2 to 0.4	+0.1
	0.5 to 0.8	+0.2
	0.9 to 1.4	+0.3
	>1.4	+0.4

Notes:

1. Embedment considerations dominant
2. Specialised pre-treatments may be necessary
3. This treatment might not be advisable depending on the shape and interlock of aggregates so alternative treatments (surface enrichment, small size seal or others) should be considered
4. For application of aggregate sizes greater than 14 mm, adopt allowances applicable to 14 mm aggregate.