NZTA P18: 2025

Specification for the Design of Chip Seals

NZ TRANSPORT AGENCY
WAKA KOTAHI

Te Kāwanatanga o Aotearoa
New Zealand Government

1 Scope

This specification defines algorithms used to determine the binder application rates for method-based specifications used for the construction of chip seal surfacings.

2 Related Documents

2.1 Waka Kotahi New Zealand Transport Agency

(a)	NZTA M01	Specification for Bitumen
(b)	NZTA M02	Specification for Bitumen Emulsion
(c)	NZTA M06	Specification for Sealing Chip
(d)	NZTA M13	Specification for Adhesion Agents
(e)	NZTA P03	Specification for First Coat Sealing
(f)	NZTA P04	Specification for Resealing
(g)	NZTA P18 Notes	Notes to the Specification for the Design of Chip seals
(h)	NZTA T03	Procedure for the Determination of Road Surface Texture
(i)	Transit New Zealand	Bituminous Sealing Manual (1993)

2.2 Standards New Zealand

(a)	NZS 4407	Methods of Sampling and Testing Road Aggregates
(b)	AS/NZS ISO 17025	General Requirements for the Competence of Testing and Calibration Laboratories

2.3 ASTM International

(a)	ASTM D1655	Standard Specification for Aviation Turbine Fuels
(b)	ASTM D4311	Standard Practice for Determining Asphalt Volume Correction to a Base Temperature

2.4 Other

(a) New Zealand Government: Engine Fuel Specifications Regulations

(b) Chipsealing in New Zealand. Published by Transit New Zealand, Road Controlling Authorities & Roading New Zealand (2005).

3 Quality

All sampling and testing required by this specification shall be carried out by a laboratory accredited to AS/NZS ISO 17025.

4 Definitions

(a) Bitumen – a very viscous liquid or a solid, consisting essentially of hydrocarbons and their derivatives, which are soluble in carbon disulphide. It is substantially non-volatile and softens gradually when heated. It possesses waterproofing and adhesive properties. It is obtained from native asphalt or by processing the residue from the refining of naturally occurring crude petroleum. The properties of bitumen for chip sealing are specified by NZTA M01 specification.

(b) Binder – a bituminous material used for waterproofing pavements and holding an aggregate layer to the base. It may be applied as cutback bitumen or as a bitumen emulsion.

(c) Cutback bitumen – a blend of bitumen and diluents used as the binder in a chip seal applied hot.

(d) Diluent – a diluent is a diluting additive to bitumen. Diluents are normally used for temporary or permanent reduction in viscosity and for enhancing adhesion to chip aggregate in the presence of water.

(e) Cutter oil – cutter oil is a diluent used to temporarily reduce the viscosity of cutback bitumen for workability, aggregate wetting and adhesion.

(f) Flux oil – flux oil is a diluent used for longer term reduction of the viscosity of chip seal binder for resistance to brittle failure in cold conditions.

(g) Adhesion agent – A substance used for the purpose of improving the adhesion between a bituminous binder and the aggregate. The term generally refers to adhesion in the presence of water. Refer to NZTA M13.

(h) Bitumen emulsion – a bitumen emulsion is a dispersion of finely divided droplets of bitumen in water. The dispersion is rendered stable by the addition of surface-active chemicals (emulsifiers). The emulsion may contain diluents or other additives (such as polymers), which may be incorporated in the bitumen or separately dispersed in the water. Bitumen emulsion is specified by NZTA M02 specification.

(i) Polymer – a polymer is a long-chain hydrocarbon material that can be added to road binders to modify the rheology of the binder to enhance performance.

(j) Sealing chip – a crushed, single-sized aggregate compliant with NZTA M06 specification.

(k) Average Least Dimension (ALD) - the average height of the aggregate particles when they are spread as a single layer with their least dimensions vertical.

(l) Chip seal – a thin layer of binder sprayed onto a pavement surface with a layer of aggregate incorporated and which is impervious to water.

(m) First coat seal – a seal placed on a prepared basecourse which has not been primed.

(n) Single coat seal – a seal coat made up of one application of binder followed by a single application of sealing chip aggregate.

(o) Reseal – A sprayed seal applied to a surface which has an existinfg seal.

(p) Racked-in seal – a seal consisting of a single application of binder, followed by two applications of aggregate applied in the following sequence:

   i. A single application of binder is applied, followed by the application of a large chip which is widely spaced (with “windows” between the chips). This is rolled to reorient the chips and embed them in the binder.

   ii. This is followed by a second application of smaller chip. The smaller chips fall into the windows between the large chips of the first application and adhere to the layer of binder below. The seal is rolled to embed the chip in the binder.

(q) Two coat seal – a seal with two applications of binder and two applications of chip applied in the following sequence:

   i. The first layer of binder is applied followed by an application of large size chip with moderately sized “windows” between the particles. This is rolled to reorient the chips and embed them in the binder.

   ii. The second application of sprayed binder is applied followed by second application of smaller chip. The smaller chips fall into the voids between the large chips and adhere to the binder on the large chip surface and below, creating a mechanical interlock.

   Two coat seals are constructed as a continuous process on the same day.

(r) Void fill seal – a seal coat consisting of a very light application of binder, applied as a low viscosity emulsion, followed by a single application of small chip designed to fit into the surface voids (macrotexture) of an existing chip seal surface. Excess chip that does not lodge into the substrate voids is normally lost. The resulting surface has reduced macrotexture but improved mechanical strength and waterproofness.

(s) Texturising seal – a seal coat consisting of an application of binder, followed by a single application of a small chip. A texturising seal is selected to add texture to low texture areas, such as asphalt patches and can be used to prepare a surface for a subsequent reseal.

(t) Wet lock seal – a wet lock seal is a seal coat applied to a relatively new chip seal and is intended to improve durability under traffic stress. It is a single coat seal that uses a light application of binder and a small chip that will fit into the substrate surface voids. Wet lock seals differ from the second coat of a two-coat seal in that:

   i. The wet lock seal is applied on to a newly completed chip seal that has been constructed and fully compacted (by rolling and sometimes trafficking) so an interlocked stone mosaic has been formed and the chips are lying on their greatest dimension.

   ii. They are not necessarily constructed immediately after the substrate seal and can use different binders.

(u) Geotextile seal - a geotextile seal incorporates a geotextile, which is a synthetic fabric composed of flexible polymeric materials. The seal is constructed by a light application of binder over which the geotextile is placed. The geotextile is then sprayed with binder to both saturate the fabric and construct a chip seal, which is normally a two-coat seal.

(v) Sandwich seal – a sandwich seal is the application of a layer of chip directly on to a pavement surface followed by a single application of binder. A smaller chip is then spread directly on to the sprayed binder and the surface is rolled to compact the seal. Sandwich seals are normally used over binder-rich chip seal surfacings to mitigate flushing.

(w) Combination seal – a combination seal uses a dry chip in the wheel paths and a single coat seal over the entire seal area.

5 Materials

5.1 Bituminous Binder

5.1.1 Bitumen

Bitumen used for the construction of chip seals shall be a grade compliant with NZTA M01 specification. The Principal shall nominate the base grade of bitumen for the site.

5.1.2 Diluents

The binder used for chip seals is bitumen that may contain diluents such as flux oil, cutter oil and adhesion agent.

Flux oil diluents must be low volatility, high boiling point oils that have negligible loss by evaporation from binders. Flux oil shall be Automotive Gas Oil (AGO, Diesel fuel) compliant with the New Zealand Government Engine Fuel Specifications or equivalent. The Contractor may nominate the flux oil used for the binder. The Principal shall nominate the dosage of flux oil to be used in the binder.

Acceptable cutter oil diluents include kerosene, usually supplied as “Jet A-1 aviation turbine fuel”, compliant with ASTM D1655 or equivalent.

Adhesion agents compliant with NZTA M13 shall be used with all cutback bitumen binders. Dosage rates shall not be less than 0.5pph v/v of the base bitumen.

Note: Adhesion agents are normally added to the cutback bitumen. Other systems, such as “interfacial adhesion agents” may be used by agreement with the Principal.

Adhesion agents shall be demonstrated to be compatible with the bitumen binder and the chip aggregate used for the seal. The dosage level for the adhesion agent and the specific chip aggregate used shall be determined by laboratory testing. Such testing shall not be more than three years old.

Note: Adhesion agents are not added to binders applied as bitumen emulsions. The emulsifier compounds used in bitumen emulsions generally provide the same functionality as adhesion agents.

5.1.3 Bitumen Emulsion

Bitumen emulsion used as a binder delivery medium for chip sealing shall comply with NZTA M02 specification. The dispersed phase shall be bitumen compliant with NZTA M01 specification which may be blended with diluents or other additives such as polymer modifiers.

5.1.4 Modified Bitumens

The use of bitumen modifiers, such as polymers or extenders such as bio-based materials may be used by agreement with the Principal. Such agreement must be based on the properties of the modified or extended binder, which shall include rheological properties and a logical basis for how the modification treats specific job site challenges and conditions.

5.2 Aggregate

The chip aggregate used for the chip seal shall comply with NZTA M06 specification.

6 Design Parameters

6.1 Aggregate

6.1.1 Chip Size

The Principal is responsible for the treatment selection and will nominate the NZTA M06 chip Grade, or Grades for multi-coat seals, for the job. The Average Least Dimension (ALD) shall be determined by measurement, using the method of NZS 4407 test 3.13, from samples drawn from site stockpiles for the calculation of the residual binder application rate R.

Note: The ALD is not normally determined for Grade 6 chip. If required it may be assumed to be 3.5mm.

6.1.2 Chip Size Compatibility

For multi-coat seals, such as racked-in or two-coat seals, determine the size compatibility of the two chip aggregates using the following formulae:

$$ALD_{fine} > 0.55 \times ALD_{coarse} - 1.24$$

and

$$ALD_{fine} < 0.72 \times ALD_{coarse} - 0.63$$

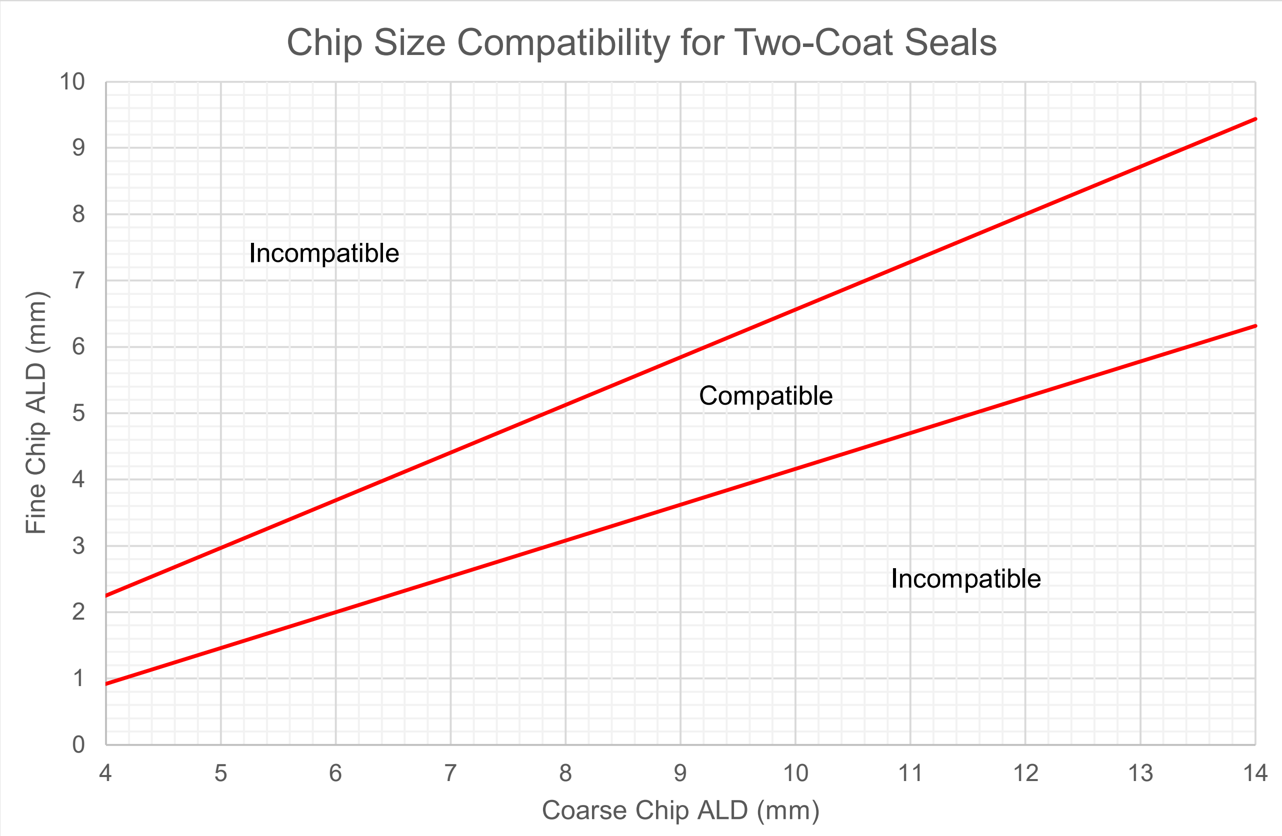
Where: ALD_{fine} = The ALD of the smaller chip used in the seal

ALD_{coarse} = The ALD of the larger chip used in the seal.

The ALD for the smaller chip shall fall within the limits calculated above. See Figure 1 for a graphical representation of the chip size compatibility requirements.

Note: Incompatible chip is less likely to form a durable interlocked stone mosaic which may lead to loss of the small chip from the surface of the chipseal ultimately leading to failure of the chipseal.

Figure 1: Chip Size Compatibility Chart



6.2 Binder for First Coat Seals

6.2.1 Base Bitumen and Flux Oil Content

The bitumen grade and flux oil content shall be nominated by the Principal based on the job site Winter climate conditions (see P18 Notes).

Flux oil content is in parts per hundred by volume of the bitumen at 15°C.

Note: The Contractor may select the binder delivery medium, i.e. as cutback bitumen or bitumen emulsion.

Base binder grade and flux oil content should be as recommended by Table 1 below.

Table 1: Recommended Flux Oil Content for First Coat Seal Binders

Winter Climate Category	Bitumen Grade	Flux Oil Content (pph v/v)
Very Cold	180/200	2
	130/150	4
Cold	180/200	0
	130/150	2
Cool	180/200	0
	130/150	2

6.2.2 Cutback Bitumen

If cutback bitumen is used as the delivery medium for the seal coat binder, cutter oil shall be added to the base bitumen.

Recommended cutter oil contents are as in Table 2. These cutter oil contents may be adjusted by the Principal following Contractor recommendations, depending on site conditions, climate (see P18 Notes), traffic and other criteria.

Cutter oil content is in parts per hundred by volume of the bitumen at 15°C.

Table 2: Recommended Cutter Oil Content

Winter Climate Category	Bitumen Grade	Cutter Oil Content (pph v/v at 15°C)		
		Early Season	Mid-Season	Late Season
Very Cold	180/200	Do not seal	6	Do not seal
Cold	180/200	6	4	6
	130/150	6	4	6
Cool	180/200	6	4	6
	130/150	6	4	6

Note: Where out of season sealing is required or for other anticipated adhesion difficulties such as experienced on heavily shaded sites, up to 4 parts extra diluent may be added, or heated or precoated chip used.

6.2.3 Adhesion Agent

Adhesion agent shall be added to all cutback bitumen seals as specified by NZTA M13.

6.2.4 Bitumen Emulsion

Where bitumen emulsion is used as the delivery medium for the seal coat binder, flux oil shall be added to the binder prior to emulsification as required by Table 1 above.

Note: Up to 3pph cutter oil may be added to the binder prior to emulsification, or "post-blended", as a workability aid at the discretion of the Contractor.

6.3 Binder for Reseals

6.3.1 Base Bitumen and Flux Oil Content

The bitumen grade and flux oil content shall be nominated by the Principal based on the job site Winter climate conditions (see P18 Notes) and local precedent.

Flux oil content is in parts per hundred by volume of the bitumen at 15°C.

Note: The Contractor may select the binder delivery medium, i.e. as cutback bitumen or bitumen emulsion.

Base bitumen grade and flux oil content should be as recommended by Table 3 below.

Table 3: Recommended Flux Oil Content for Resealing Binders

Winter Climate Category	Bitumen Grade	Flux Oil Content (pph v/v)
Very Cold	180/200	2
	130/150	4
Cold	180/200	0
	130/150	2
Cool	130/150	0
	80/100	2

6.3.2 Cutback Bitumen

If cutback bitumen is used as the delivery medium for the seal coat binder, cutter oil may be added to the base bitumen as required. Recommended cutter oil contents are as in Table 4. These cutter oil contents may be adjusted by the Principal following Contractor recommendations, depending on site conditions, climate, traffic and other criteria. See P18 Notes.

Cutter oil content is in parts per hundred by volume of the bitumen at 15°C.

Table 4: Recommended Binder Cutter Oil Content

Forecast Minimum Shade Air Temperature (°C)	Recommended Cutter Oil Content pph (v/v, 15°C)		
	180/200	130/150	80/100
10	6	Do not seal	Do not seal
15	4	6	Do not seal
20	2	4	6
25	0	2	4
30 and over	0	0	2

Notes: Where out of season sealing is required or for other anticipated adhesion difficulties, up to 4 parts extra diluent may be added, or heated or precoated chip considered for use.

Note also that the flux and cutter oil dosages are recommendations and are not mandatory. The seal designer must consider the site climatic conditions, loading, local practice and historical precedent when determining the diluent content for the chip seal.

6.3.3 Adhesion Agent

Adhesion agent shall be added to all cutback bitumen seals as specified by NZTA M13.

6.3.4 Bitumen Emulsion

If bitumen emulsion is used as the delivery medium for the seal coat binder, flux oil shall be added to the binder prior to emulsification as required by Table 1 and Table 3 above.

Note: Up to 3pph cutter oil may be added to the binder prior to emulsification, or “post-blended”, as a workability aid at the discretion of the Contractor.

6.3.5 Modified Binders

The Principal may specify, or agree with the Contractor’s recommendation that, a modified or extended binder is needed. Such agreement must be based on the rheological properties of the modified binder and how specifically identified issues are treated by the modification.

6.4 Traffic

The Principal will obtain the annual average daily traffic (AADT) loading for the site, including the percentage of heavy commercial vehicles (HCVs), m. Note that this loading may vary across lanes for multi-lane highways, hence binder application rates may differ across lanes. Determine the vehicles per lane per day for each lane on the site.

Calculate the Traffic Factor T_f for the site using the following formula:

$$T_f = 1 + 0.09m$$

Where: m = percentage heavy commercial vehicles (as percentage)

If the percentage HCVs is not known assume it to be 11%.

6.5 Texture

6.5.1 First Coat Seals

For the purposes of determining the binder application rate assume surface texture of the finished basecourse surface T_d = 1.3mm.

If necessary apply adjustments to the binder application rate if the surface texture is considered to be significantly different to the assumed texture on the day of sealing. Refer to clause 7.1 below.

6.5.2 Reseals

The Principal shall determine the texture of the site road surfacing using the method of NZTA T03.

Determine the difference between texture depth for the coarse textured areas Td_{coarse} and the average texture depth $Td_{average}$ and the difference between the texture depth between the fine textured areas Td_{fine} and the average texture depth.

$$Td_{c-a} = Td_{coarse} - Td_{average}$$

and

$$Td_{a-f} = Td_{average} - Td_{fine}$$

If $Td_{c\text{-}a}$ or if $Td_{a\text{-}f}$ is greater than the sealing chip Average Least Dimension divided by 16 (ALD/16) then targeted maintenance treatments must be completed before a reseal is designed and constructed.

7 Residual Binder Application Rate

7.1 First Coat Seals

7.1.1 Single Coat and Racked-In Seals

The following formula should be used to determine the basic binder application rate, V_b:

$$V_b = 0.2 + (ALD + 0.7 \times T_d) \times \left(0.291 - 0.025 \times log_{10}(T_f \times V_{l/d} \times 100)\right) \quad l/m^2 @ \, 15°C$$

Where: ALD = the measured Average Least Dimension of the sealing chip

T_d = texture depth (mm)

T_f = the traffic factor (clause 6.4)

$V_{l/d}$ = the vehicles per lane per day traffic loading for the site.

Notes: The binder is comprised of bitumen and non-volatile diluents including automotive gas oil and adhesion agents.

For racked-in seals, the ALD is for the coarser of the two chip aggregates.

Convert the basic binder application rate V_b to R, the final residual binder application rate by applying adjustments to compensate for specific site conditions, which include but are not limited to absorptive surfaces, soft substrates, steep grades, chip shape and urban and/or low traffic volumes.

$$R = V_b + A_s + S_s + G_s + C_s + U_s$$

Where: A_s = allowance for an absorptive surface

S_s = allowance for a soft substrate

G_s = allowance for a steep grade

C_s = allowance for chip shape

U_s = allowance for urban or low traffic volumes.

Refer to P18 Notes and *Chipsealing in New Zealand* section 9.4 for guidance in determining the need for adjustments. Such adjustments depend on engineering judgement and experience and may be recommended by the Contractor for approval by the Principal.

7.1.2 Two Coat Seals

Calculate the Equivalent Light Vehicles per lane per day ($ELV_{l/d}$) using the following formula:

$$ELV_{l/d} = V_{l/d} \times T_f$$

Where: m = percentage heavy commercial vehicles (as percentage)

$V_{l/d}$ = vehicles per lane per day (v/l/d)

Calculate the first coat two coat seal traffic factor using the following formula:

$$T_{f2coat} = 1.54 - 0.16 \times \log(ELV_{l/d})$$

Calculate the total residual binder content using the following formula:

$$V_b = \left(0.818 \times log(ALD_{coarse}) + 1.142 \times log_{10}(ALD_{fine}) + 0.247\right) \times T_{f2\ coat}$$

Where: ALD_{coarse} = the measured Average Least Dimension of the coarser sealing chip

ALD_{fine} = the measured Average Least Dimension of the finer sealing chip

Unless agreed with the Principal, the binder shall be applied in two passes, with 60% of Vb applied first and the remaining 40% of V_b applied as the second binder application. Note that V_b will be applied as CSR_{hot} or ESR_{hot} as determined in clause 9.

7.2 Reseals

7.2.1 Single Coat and Racked-In Seals

The following formula should be used to determine the residual binder application rate, V_b:

$$V_b = (ALD + 0.7 \times T_d) \times \left(0.291 - 0.025 \times log_{10}(T_f \times V_{l/d} \times 100)\right) \quad l/m^2 @ 15°C$$

Where: ALD = the measured Average Least Dimension of the sealing chip

T_d = texture depth (mm)

T_f = the traffic factor (clause 6.4)

$V_{l/d}$ = the vehicles per lane per day traffic loading for the site.

Note: The residual binder is comprised of bitumen and non-volatile diluents including automotive gas oil and adhesion agents.

For racked-in and two coat seals, the ALD is for the coarser of the two chip aggregates.

Convert the basic binder application rate V_b to R, the final residual binder application rate by applying adjustments to compensate for specific site conditions, which include but are not limited to absorptive surfaces, soft substrates, steep grades, chip shape and urban and/or low traffic volumes.

$$R = V_b + A_s + S_s + G_s + C_s + U_s$$

Where: A_s = allowance for an absorptive surface

S_s = allowance for a soft substrate

G_s = allowance for a steep grade

C_s = allowance for chip shape

U_s = allowance for urban or low traffic volumes.

Refer to P18 Notes for guidance in determining the need for adjustments. Such adjustments depend on engineering judgement and experience and may be recommended by the Contractor for approval by the Principal.

7.2.2 Two Coat Seals

Use the algorithm of 7.2.1 above to determine the final residual binder application rate R for two coat reseals. Ensure that the sealing chip grades selected comply with the size compatibility criteria of clause 6.1.2 above.

8 Maintenance Seals

8.1 Void Fill Seals

For Void Fill seals determine the residual binder application rate R by assessment. The residual binder application rate should be in the range 0.6L/m² to 0.8L/m² for Grade 6 chip and 0.8L/m² to 1.0L/m² for Grade 5 chip. The intention is for the binder to flow into the surface voids to bond the chip in the voids, hence a low viscosity emulsified binder is required.

8.2 Texturising Seals

For Texturising seals determine the residual binder application rate R determined using the formula in clause 7.2

8.3 Wet Lock Seals

For Wet Lock seals (which are similar to Void Fill seals) determine the residual binder application rate R by assessment. The residual binder application rate should be in the range 0.6L/m² to 0.8L/m² for Grade 6 chip and 0.8L/m² to 1.0L/m² for Grade 5 chip.

8.4 Geotextile Seals

For geotextile (or "fabric") seals instruct the Contractor to apply the first layer of binder at a rate sufficient to partially saturate the fabric mat as specified by the geotextile manufacturer. This depends on the fabric but is in the order of 0.5L/m² - 1L/m². The fabric is then applied on top of the first layer of binder and a conventional two-coat seal with application rates as calculated normally is placed over the fabric.

Note: A two-coat seal is required because the fabric substrate will not have sufficient texture to allow a single coat seal to "key in". The mechanical interlock of a two-coat seal is required for resistance to traffic damage.

8.5 "Holding" Seals

8.5.1 General

Holding seal treatments can be used for surfacings that are nearing the end of their service lives. Experienced judgement is needed for the design of these treatments and surfacing life can be limited depending on the condition of the substrate. Most seal types may be used as holding seals but in general specialised treatments may be selected as follows.

8.5.2 "Sandwich" Seals

For Sandwich Seals judgement by an experienced practitioner is used to determine the residual binder application rates. This is because sites requiring Sandwich Seals are often highly variable in texture. The application rate may be recommended to the Principal by the seal designer or the Contractor. Construction of the Sandwich Seal is subject to the Principal accepting the recommended binder application rate.

8.5.3 "Combination" Seals

For Combination Seals the residual binder application rate R is calculated using the formula in clause 7.2 above, using the Average Least Dimension of the smaller sealing chip used for the second coat. Use the texture value for the higher textured areas, outside of flushed or low texture areas, as the input to the seal design algorithm.

9 Binder Spray Rates

9.1 Cutback Bitumen

For binders containing cutter oil (either applied as cutback bitumen or as an emulsion), determine the total cutback spray rate CSR_{cold} at 15°C by using the following formula:

$$CSR_{cold} = R \times \left(1 + \frac{K}{100}\right) \quad l/m^2 \text{ @ } 15°C$$

Where: K = the cutter oil content in parts per hundred by volume of the bitumen

Determine the hot binder spray rate CSR_{hot} by correcting CSR_{cold} for spraying temperature T using the following formula:

$$CSR_{hot} = \frac{CSR_{cold}}{(1.00946841 - (6.33413411 \times 10^{-4} \times T) + (1.45710416 \times 10^{-7} \times T^2))} \quad l/m^2$$

Where: T = spraying temperature of the binder in °C.

Note: ASTM D4311 contains tables of volume correction factors versus bitumen temperatures which return the same volume change as the formula above.

9.2 Bitumen Emulsion

To calculate the hot spray rate for bitumen emulsions, convert the cold cutback spray rate CSR_{cold} to the hot cutback spray rate CSR_{hot} using the formula below.

$$CSR_{hot} = \frac{CSR_{cold}}{(1.00946841 - (6.33413411 \times 10^{-4} \times T) + (1.45710416 \times 10^{-7} \times T^2))} \quad l/m^2$$

Where: T = spraying temperature of the emulsion in °C.

Determine the emulsion spray rate, compensating for the water content of the emulsion, ESR by using the following formula:

$$ESR_{hot} = \frac{CSR_{hot} \times 100}{EBC}$$

Where: EBC = the total emulsion binder content (dispersed phase which includes added diluents) of the emulsion expressed as a percentage.