Surface dressing / chipseal

Asphalt applications

Nouryon

Surface dressing / chipseal overview

Surface dressing, also known as chipseal bituminous surface treatment, or seal coat, is a surface treatment comprised of an application of bitumen – in the form of emulsion, hot binder or cutback – to a pavement surface quickly followed by a layer of aggregate chippings. After application, the seal may be rolled to align and embed the aggregate into the binder.

A surface dressing / chipseal application is an economical and effective technique to waterproof a road's underlying structural layers and improve skid resistance. Surface dressing / chipseal applications provide many additional benefits. They seal the pavement surface, including cracks, minimize oxidative aging, enable minor reprofiling and improve appearance. They do not provide any structural improvement.

Surface dressing / chipseal can be used on roads of most traffic levels, or applied onto a base as a temporary or permanent riding surface. It comprises a 1-2 l/m^2 (0.2-0.5 gal/yd^2) sprayapplied bitumen layer typically covered with 6-12 mm (1/4-1/2 inch) one-size aggregate ("chip"), which is rolled in.

Excess aggregate is removed by sweeping after the surface treatment has cured. Double or triple applications of binder and chips can be made. Fog seal can be applied over chipseal to reduce raveling and provide a black surface.

There are several special types of surface dressing / chipseal:

Sand seal (fine aggregate seal)

Sand seal is a spray application of bitumen to a road surface followed by an application of sand or fine aggregate in a process similar to surface dressing / chipseal.

Scrube seal

Scrub seal is similar to surface dressing / chipseal except that after spraying, the binder is broomed into the road surface to better penetrate and seal cracks before application of the cover aggregate.

Graded aggregate seal (Otta seal)

Graded aggregate seal is a surface dressing for low-volume roads which uses an aggregate with a wider size range than conventional chipseal, and a softer binder. It provides a costeffective wearing course which after trafficking has a texture similar to dense hot or cold mix. It is less susceptible to snow plow damage than normal surface dressing / chipseal and has the flexibility to withstand movement in underlying unbound materials. Otta seal was designed for colder climates and is used in Northern USA, Canada, Scandinavia and in some developing countries.

Primer seal

The application of a surface dressing / chipseal on a gravel or stabilized base as a bond coat is called primer seal or "first coat" seal in some countries. It provides a temporary wearing course that may be covered with a new chipseal or other surfacing within a year. Surface dressing / chipseal is also sometimes used as bond coat on cement concrete roads if they are to be covered with a thin asphalt overlay or slurry. Similar products are used for stress absorbing interlayers (SAMI).

What can be achieved with surface dressing / chipseal?

- Prevent water penetration into asphalt surfaces
- Prevent water intrusion into gravel basis
- Improve skid resistance
- Improve surface texture / surface drainage
- Fill small cracks
- Correct flushed surfaces
- Wearing surface on stabilized bases
- Bond coat
- Delineate shoulders, rumble audible warning
- Reduce temperature of road surface (with reflective cover aggregate)
- Increase reflective surface for night driving (with reflective cover aggregate)
- Aesthetic surfaces in cultural areas, for example around old castles
- Aesthetic surfaces on highly patched roads

Surface dressing / chipseal primary uses

Type	Waterproofing	Skid resistance	Crack fill	Rejuvenation	Bond coat
Surface dressing / chipseal	√	√			√
Sand seal	√	√			
Scrub seal	√	√	√	√	
Graded aggregate seal (Otta seal)	√		√		
Primer seal	√				√

Otta seal after trafficking, soft binder has migrated to the seal surface

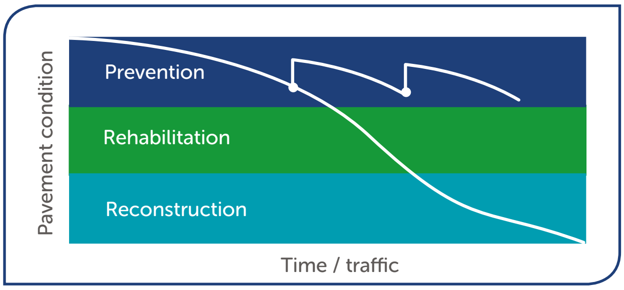
Scrub seal, broom dragged behind bitumen distributor pushes binder into cracks.

Surface dressing / chipseal

Pavement preservation

Asphalt and cement concrete roads deteriorate over time through the action of traffic, the elements and slow chemical changes in the binders themselves.

Early deterioration such as minor cracking, raveling, and polishing may be quickly and economically restored by maintenance treatments. Even earlier treatment can prevent significant deterioration by providing a barrier between the asphalt structural layers and the elements.



Early treatment of the road extends its life without expensive rehabilitation or reconstruction

The concept of Pavement Preservation or Preventive Maintenance is now widely accepted by highway engineers. The road should be treated while still in good or fair condition when a small investment of time and money will pay back the most in extended life. If left too long roads become severely damaged and are expensive and disruptive to repair or reconstruct. The Michigan Department of Transportation reports that for every dollar spent on Preventive Maintenance it saves six to ten dollars in future reconstruction or rehabilitation cost. According to several road authorities in Europe, surface dressing has a very favorable life cycle cost.

Surface dressing / chipseal and related applications provide a good combination of restorative and preventive maintenance for low cost, in a quick process which minimizes traffic delays and requires minimal adjustment to curbs and ironwork. The seals protect asphalt or cement structural layers from water intrusion, improve friction and ride quality, and seal minor cracks, but do not provide any structural improvement or correct major deformations. Potholes need to be filled before application of the seal. Compared to thin or ultra-thin hot mix overlays, the seal generally avoids the need for extensive milling and removal of old surfacing, and provide a surface with better wet skid resistance.

Surface dressings / chipseals are most widely used in suburban areas and low traffic rural roads but well-designed chipseals are also used on highways and may be applied to hard shoulders, airport roads and parking lots to restore and rejuvenate aged asphalt surfaces.

Surface dressings / chipseals based on bitumen emulsion provide particular benefits. Polymer (in the form of latex) can be easily incorporated either into the emulsion during production or soon afterwards to improve performance and durability. The result is an environmentally friendly product, without the fumes or fire risk associated with hot or cutback binders.

Emulsion, cutback and hot binder attributes for surface dressing / chipseal

Attributes	Emulsion	Cutback	Hot binder
Handling	Low fire hazard	Easy handling	Lower application rate
Fumes	Few fumes	VOCs	Fumes
Cure	Slow	Medium, solvent tunable	Fast
Season	Limited	Longer	Longer
Dust	Sensitive	Less sensitive	Clean or pre-coated chips
Adhesion	Damp chips okay	Needs anti-strip	May need pre-coated chips
Polymers	Can use latex or polymer	None	Can be polymer-modified

The process and types of seals

Before surface dressing / chipseal can be applied the existing road surface must be repaired as necessary. Crack seal and patch mix also must be fully cured. Cold lay patch materials which contain solvents may take several weeks to cure. The surface is swept before application begins.

Bitumen (hot, emulsion or cutback) is applied using a pressure distributor with nozzles arranged to provide full even coverage with no run off. With cutback and cationic emulsions, the aggregate is usually applied immediately. Some authorities suggest a delay of 5-15 minutes before applying cover aggregate to high float emulsions.

Aggregate is applied from a chip spreader and compaction begins immediately, typically with 4-5 passes or more with pneumatic tires rollers. Controlled speed traffic (less than 20-30 mph (30-50 km/h) depending on the region) may be allowed on immediately. Higher speed traffic must usually wait until any loose chippings are removed by sweeping. Light sweeping can usually be completed the morning following sealing. Fast curing systems may allow sweeping earlier.

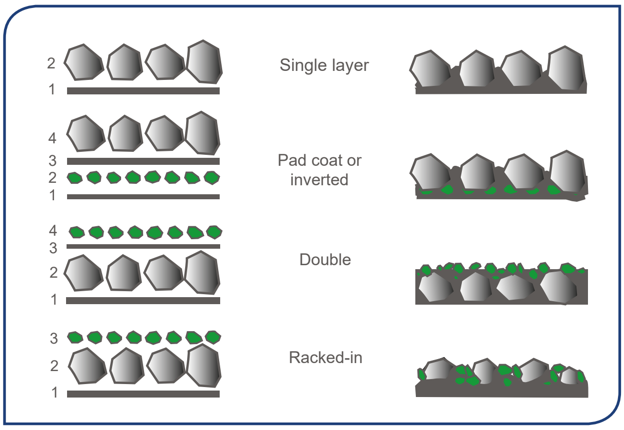
Double or multiple layers can be constructed using different sequences of binder and aggregate. In double chipseal, a second application of binder and smaller chip is applied to the first chipseal. Normally the application of cover aggregate is reduced in the first layer of a double chipseal compared to a single seal, to avoid the need for sweeping. The first layer may sometimes be compacted before the smaller chip is applied. The second material may be a coarse washed "choke" sand with an upper size of 3-5 mm or a regular single-sized chip, usually about half the size of the first chip. After the smaller chip is applied, the road is compacted again. Double seals are recommended for application on a gravel or stabilized base, or any high stress road surface. Some authorities wait several weeks before applying the second dressing to a granular base of gravel road to allow the first to fully embed. The lower texture of the double seal means a lower noise level. A third application with even finer chip can be applied to further reduce the texture and noise level in urban areas.

In "racked-in" systems a second layer of smaller chip is applied to the uncompacted or lightly compacted chipseal without a second binder application, then compacted. The coverage of the first layer of chips is reduced to allow space for the smaller stone. An advantage of the system is excess loose chips tend to be of the smaller size.

On cement concrete or where the asphalt road shows large variation in porosity (e.g. because of extensive crack fill, reinstatements or patching) a first pass using small chips can provide an even surface for a second regular surface dressing / chipseal. The process is sometimes called inverted seal or pad coat.

In yet another variation, "sandwich seal", coarse aggregate can be applied to the road surface with no prior application of binder. Binder is applied to the loose aggregate, and then a small aggregate is applied on top, followed by compaction. This treatment can be used to deal with fatted up areas in hot mix surfacing.

Surface dressing / chipseal types



Surface dressing / chipseal process


Application of binder


The chip spreader


Rolling of surface dressing / chipseal


Sweeping of surface dressing / chipseal

Design of single seals

Proper design can improve the useful lifetime of surface dressing / chipseal by determining the correct application rate of binder and cover aggregate for the particular traffic volume and existing road surface to ensure surface durability. Design methods start with size and packing properties of the cover aggregate.

Road designers first derive an aggregate application rate. Then they determine a binder application rate based on a certain embedment or voids filled with binder, adjusted for the condition of the old road surface and the traffic level.

The compatibility of the emulsion and cover aggregate may be checked by simple coating and adhesion tests. Performance tests on small scale seal samples may provide information on curing rates and final properties but are rarely included in the design process.

Single layer surface dressing, often referred to as single chipseal in the US, is a low cost process often applied to low trafficked roads. Many authorities will specify materials and apply guidelines for aggregate and binder application rates based on experience, with field adjustments, without following a full design procedure.

The aggregate

The quality of materials used depend on traffic level. While a pea gravel aggregate may be an acceptable and economical solution for a low trafficked farm-to-market road or cycleway, high quality cubical crushed rock with a low flakiness index, high abrasion value, and low polishing potential may be necessary for highways, or for roads subject to studded tires or snow-plow damage. Lightweight aggregate may be specified to avoid damage to cars from loose chippings.

Gradiation

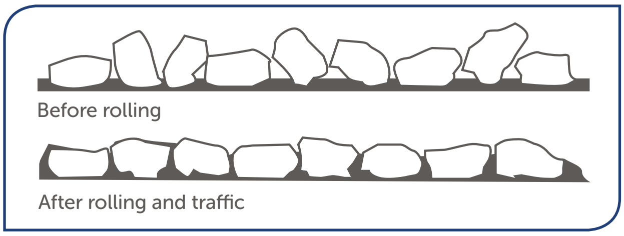
The top size of the cover aggregate ranges from 5 mm or (1/4 inch) to 25 mm (1 inch), although some development work with 2.4 mm (#8) chips has been performed in France. 9.5 mm (3/8 inch) top size is the most common chip used in single seals in the United States. Larger chips are more likely to cause damage if dislodged by traffic but design methods may demand coarser aggregate in higher traffic levels and with softer road surfaces to prevent full embedment. Better results are obtained with one sized aggregate and the tightness of the grading envelope may be specified in various ways.

Dust

Dust significantly impedes adhesion between the binder and stone surface and so should be minimized. Cover aggregate should be washed if possible. The material passing 200 mesh (75 micron) is typically specified to be less than 2% and often less than 1%.

Particle shape

After trafficking the chips tend to settle with their shortest dimension facing up. This is particularly true in the wheelpaths. Flat particles make it difficult to obtain texture and risk being submerged in the binder, so aggregate may need to meet a Flakiness Index value. Fractions from the sieve test are passed through appropriately sized slots and the percent flakiness determined.



Measurement of Flakiness index
Samples from the sieve test are passed through the slots

When considering embedment and coverage, design methods consider the average least dimension (ALD) which can be calculated from the median size and the flakiness index or determined on a sample of the aggregate by measurement. Average greatest dimension (AGD) or median dimension (MD) can be determined and specifications may set limits on the ratio of ALD to AGD or MD. Rounded particles do not interlock effectively and one, two or more crushed faces may be demanded especially for highly trafficked areas. Crushed faces are determined visually on plus 1/4 inch (greater than 5 mm) material.

Coverage and spread rate

The aggregate application rate can be simply calculated from the uncompacted bulk density or partially compacted bulk density and the top size, with an allowance for 5-10% waste (excess chips which are removed by traffic or sweeping). In the widely used McLeod design method the calculation uses the density of the stone and the voids in the uncompacted aggregate, but assumes compaction will reduce the voids in the aggregate to 40% of this value. This method tends to overestimate aggregate requirements with one-size cubic stone. In another widely used method the covering power of the aggregate is determined experimentally by spreading the aggregate out on a tray one stone deep and weighing. The more one sized the aggregate grading the higher the voids and the less aggregate will be required to cover the road.

Over application of small chips may help prevent initial bleeding. Over application of coarser chip may damage the sealcoat and increases the risk of vehicle damage. A 5-10% excess is built into some design methods.

Application rates are sometimes expressed or measured in volume of aggregate per area, because of the differences in aggregate density.
Typical application rates are 10-14 kg/m^2 (18-25 lbs/yd^2).

The binder

High binder content rapid set emulsions are the most common binder for surface dressing / chipseal, but cutback bitumen or hot bitumen are still used in some regions. Polymer-modified binders or emulsions may be specified for high traffic areas. Elastic Recovery, (Force) Ductility, MSCR or the Vialit Pendulum cohesion test may be specified as well as penetration. The Float test looks at the gel structure in certain binders. Gel structure is associated with reduced temperature susceptibility of the binder and is widely specified for chipseal emulsions in North America. The industry is developing a Surface Performance Grade system for spray applied binders using an approach analogous to PG grading of hot mix binders.

Binder options, bitumen emulsions

Anionic	Cationic
• RS-2	• CRS-2
• HFRS-2	• CRS-2P (SBS or latex) or CRS-2L (latex)
• RS-2H	• CRS-2H
• RS-2P (SBS or latex)	• CHFRS-2p
Hot bitumen (maybe polymer-modified)	
PG grade	**Penetration grade**
52-28	150-200
58-28	100-150
64-22	60-80

Application rate

Chip loss is reduced at higher binder application rates, but application rates are limited by the risk of bleeding and reduced texture. Design application rates are generally based on a certain target embedment of the chip into the binder or a certain filling of the voids content of the aggregate.

Many authorities use a mix design approach which targets 70% of voids filled with bitumen after compaction and traffic. An initial filling of the voids with binder to 50% after rolling may rise to 70-80% after trafficking. As mentioned above there is a risk that smaller chips or flaky material may be covered by binder over time and aggregates with high flakiness indices will need reduced binder application rates, while providing less texture depth than more cubical aggregate.

Because the seal outside the wheel-path is compacted less by traffic, there is a mismatch between the design binder application in the wheel-path and that outside. This can be directly addressed by reducing the application of binder in the wheel-paths with sophisticated distributors, or an average application rate can be used.

The application rate of emulsion and cutback binders needs to be adjusted according to their residue content. Because they are applied at a higher volume more of the chip is initially wetted and they may deliver a better bond at an application equivalent to a hot bitumen.

Corrections to the application rate depend on the absorptive capacity of the road surface to be treated. Higher binder application rate for dry open surfaces and lower for smooth rich surfaces. This can be a very significant adjustment (+/30% is possible) to the original design application rate. In some design methods the road surface is tested for texture using the sand patch test in an effort to get a quantitative correction factor. A portion of the embedment of the chip is a result of penetration into the underlying road surface.

Surface dressing / chipseal aggregate and emulsion application guidelines

		Primer or binder [1]			Aggregate		
Treatment	Aggregate	Grade	Range kg/m^2	Typical kg/m^2	Class	Range kg/m^2	Typical kg/m^2
Prime	Class 4	Primer	1.90+/-	1.9	4	10-12	12
Single surface treatment	Class 1	CRS-2 or RS-2	1.65-1.90	1.8	1	14-17	16
	Class 2 [2, 6]	HF-150S	1.35-1.55	1.45	2	16.5-19	19
	Class 4 [3]	CRS-2, HF-150S	1.20-1.40	1.3	4	8-11	11
	Class 5	CRS-2 or RS-2	1.15-1.45	1.3	5	11-13	13
	Class 6	HFMS-2(ON) or HFMS-2P (ON)	1.50-1.80	1.7	6	16-20	17
Double surface treatment	Class 2 [6]	HF-150S [4]	1.60-1.80	1.65	2	16-18	18
		HF-150S [5]	1.45-1.65	1.5	2	16.5-19	19
	Class 3 & 1	CRS-2, RS-2 [4]	1.60-2.10	1.9	3	15-18	17
		CRS-2, RS-2 [5]	1.40-2.10	1.8	1	12-15	14
	Class 3 & 4	CRS-2, RS-2 [4]	1.60-1.76	1.65	3	15-28	17
		CRS-2, RS-2 [6]	1.05-1.20	1.1	4	6.5-8	8
	Class 3 & 5	CRS-2, RS-2 [4]	1.80-2.00	1.90	3	15-17	17
		CRS-2, RS-2 [5]	1.30-1.50	1.35	5	11-13.5	13
	Class 2 & 6	HFMS-2P (ON) [4]	1.60-1.80	1.65	2	13.5-18	16
		HFMS-2P (ON) [5]	1.50-1.70	1.60	6	15-19	16

[1] Decrease binder rates towards the lower limit of the range when there is heavy commercial traffic
[2] Class 2 surface treatment may cause dust problems in urban areas
[3] Do not apply to flushed surface treatments, flushed pavements or where low friction values are a concern
[4] Initial application
[5] Second application
[6] The use of Granular A aggregate in a Single or Double surface treatment is not recommended

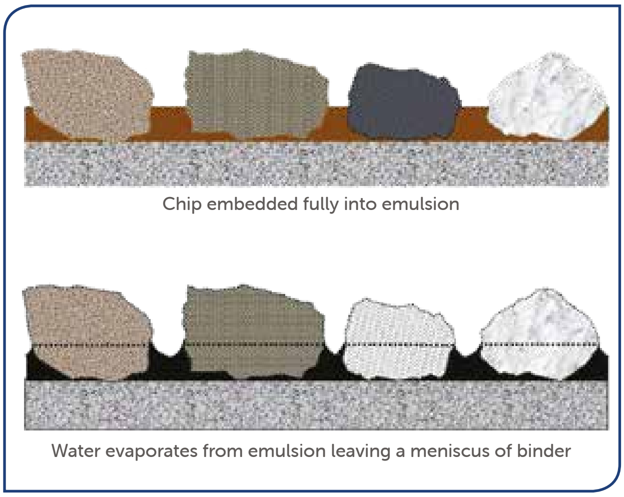
With soft surfaces or heavy traffic, embedment into the road is higher, so less binder needs to be applied. By contrast, on hard surfaces or lightly trafficked roads a higher level of binder is applied to ensure good retention of the chip. Penetration or indentation tests can be used in the field to estimate the hardness of the road surface.

If a highly absorptive cover aggregate is used then application rates may need to be adjusted upwards, especially with cutback binders, but the effect is small for traditional hard aggregates used for surface dressing / chipseal.

Overall, typical application rates are in the range of 0.20-0.32 gal/yd^2 (0.9-1.45 l/m^2) for hot applied, or 0.28-0.46 gal/yd^2 (1.25-2.1 l/m2) for emulsion. Some authorities increase the binder application rate during cool weather.

Compatibility tests

Aggregate and binder compatibility can be confirmed by simple adhesion tests in which chips are placed in emulsion or coated with emulsion, then later rinsed or immersed in water or subjected to a boiling stripping test to check adhesion. For hot or cutback binders the Immersion Tray test provides a check on "active adhesion" the ability of binder to displace water from the aggregate surface. Laboratory performance and compatibility tests have confirmed that emulsion binders perform better when the aggregate is damp, whereas hot applied and cutback binders perform best with dry aggregates. The Vialit Plate test is also used to check active adhesion by some authorities. Adhesion agents may be added to the binder (including emulsion) in response to poor results in the compatibility tests, or alternative aggregates may be selected.



Curing of cutback and emulsion binders results in a lower residue on the roadway than hot bitumen so the initial application needs to be higher, but because the chip is wetted to a greater depth the increase in final application rate need not be increased the full amount. Increase to 85-90% of the theoretical is common.

For hot applied binder, especially if polymer-modified, precoated chips or heated chips may be recommended to ensure good adhesion. The chips are treated with bitumen at a level of 0.25-0.75%, usually in a hot process. In some countries the chips are washed or coated with diesel fuel or kerosene, which may contain adhesion promoter, in a cold process.

Compatibility test results with two different emulsion recipes

Immersion tray test

Performance tests for surface dressing / chipseal

Performance tests rarely form part of the design process for surface dressing / chipseal or other spray seals. Laboratory based performance tests are typically used to aid the formulation of emulsion binders and to elucidate some of the main parameters affecting the curing and final performance of sealcoats. Field tests may be used as quality control or warranty items

Laboratory based performance tests

Simple compatibility tests described previously can be extended to evaluate the performance of the surface dressing / chipseal system compacted cover aggregate and binder. Small scale seals can be prepared and used to check cure rates, water susceptibility or low temperature performance. While the tests usually use job aggregates, standard aggregates or glass balls may be used if the focus is on the binder properties. Laboratory based performance tests rarely form part of national specifications or design methods but are useful tools for the emulsion formulator. In the Vialit Plate Test, seals are prepared on a metal plate then subjected to an impact from a steel ball, causing any poorly adhering chips to be dislodged. The test is used to check adhesion in cutback or hot binders, cohesive binder failure at low temperatures, or as an estimate of curing ratein emulsion systems.

In the Mini-Fretting, Abrasion-Cohesion or Sweåep tests, seals are prepared on roofing felt, then, after full or partial curing, are subjected to abrasion using the Wet Track Abrasion tester and either a rubber hose or stiff brush to dislodge poorly adhering chips. The tests can provide information on curing rates, or on chip retention in fully cured specimens. The sweep test has also been adapted to study adhesive failure after water immersion. The sweep test uses a brush on the WTAT and was originally designed to determine when a seal could be safely swept. However cure times in the laboratory seem to be significantly longer than in the field.

In the frosted marble cohesion test; the cohesiometer used in slurry seal mix design is adapted to study the curing of surface dressings /chipseals in the laboratory. Job or standard lab aggregate or glass marbles may be used. After defined cure times and conditions, each piece of aggregate or glass marble is subjected to a sideways force from a hooked attachment on the cohesiometer and the torque applied recorded. The results give an indication of the curing rate and bond strength.

Surface dressing / chipseal sweep test

Static immersion test for surface dressing / chipseal

Chip loss reduces friction and may lead to the appearance of bleeding. If the underlying seal is damaged by the chip pulling out binder then water penetration may occur which can be especially damaging if the chip is placed on a granular base. Chip loss can be quantified by methods based on image analysis.

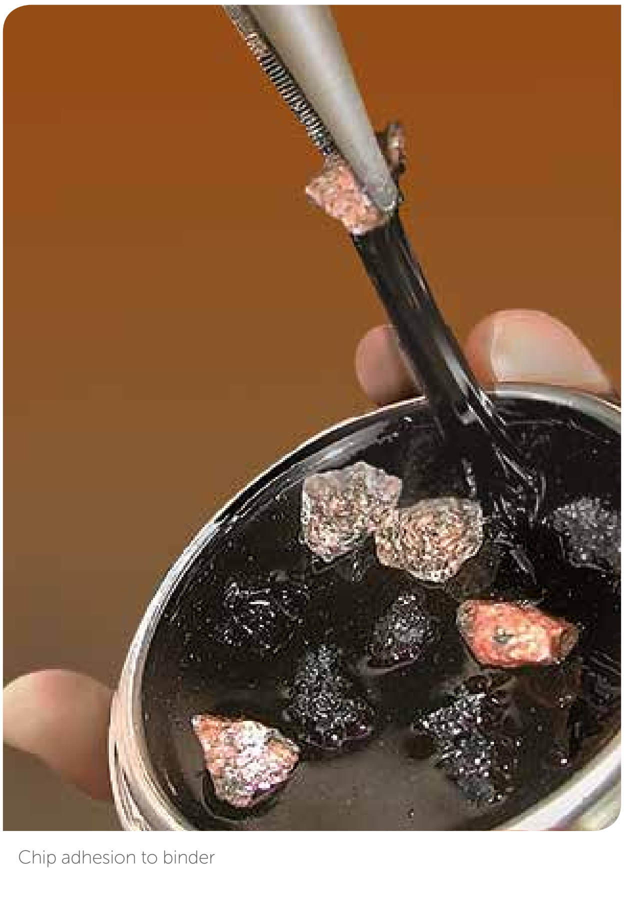
Sand patch test

In the PATTI (BBS) test, binder samples are placed on mineral sheets and subjected to a pull off test with equipment originally developed for adhesives. The test can be used to study the curing of emulsion binders and also final wet or dry adhesion or cohesive failure.

Field testing of surface dressings/chipseals

Texture depth on newly placed surface dressings / chipseals can be determined by the sand patch test. A weighed quantity of sand or glass beads is placed on the seal. Texture is calculated based on the area covered. Laser methods can also be used.

Improved skid resistance is one of the targets of surface dressing / chipseal treatment. Skid resistance of the seal may be measured after trafficking.



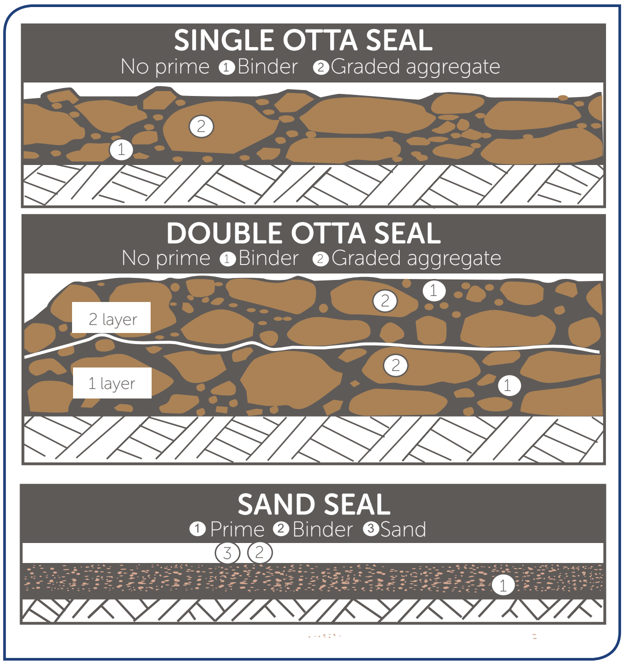
Chip adhesion to binder

Placing and design of other spray seals

Double or multiple seal design

Double and triple layer surface dressings (double and triple chipseals) can be designed as separate single seals or the first layer can be designed as a single seal with application of the subsequent layers can be based on the designer's experience. The total design binder content of the two sealcoats can be combined and divided 50/50 or 40/60 between the applications. The spread of aggregate in the first layer may be reduced to 90-95% of the application rate derived from a single seal design to allow room for the second layer of aggregate. In the racked in system the first application of cover aggregate may be reduced to 80-85%. It is compacted before applying the second cover.

Each successive layer of aggregate is generally half the dimension of the previous layer and the application rate of aggregate and binder also is about half. Coarse gradations to 25 mm (1 inch) may be used for the first layer in double layer or racked in seals, and finer material or choke sand may be used for the second layer. Because of the fine material on the surface, the larger chips are less likely to be dislodged by traffic and cause damage.



Sand seal

Sand used in sand seal should meet minimum cleanliness requirements with sand equivalence greater than 50 for example, or clay content of less than 1.5%, and should be low in minus 200 mesh material (less than 5%). The top size should be less than 1/4 inch (6.3 mm) but unlike chipseal it need not be single sized. A typical application rate would be 10 kg/m^2 of sand and 1-1.5 l/m^2 of binder (18 lbs/yd^2 of sand and 0.22-0.33 gal/yd^2 of binder). The sand is applied using a sand spreader. Double sand seals can be applied for low traffic roads. Cutback bitumen or rapid or medium set emulsion of low residue content are used for sand seal. When a sand seal is placed over a granular base then a binder suitable for prime is used at an application rate of approximately 2 l/m^2 (0.44 gal/yd^2) to allow for some penetration into the base. Steel wheel rollers can be used for compaction. The compatibility of the sand with the emulsion or cutback should be confirmed. For cutback binder, an adhesion agent will probably be required to ensure good adhesion to damp sand.

Graded aggregate seal (Otta seal)

A wide variety of aggregates may be used, crushed or uncrushed. An aggregate top size of 20 mm (~3/4 inch) is used with a 10% maximum of minus 200 mesh. Aggregate application is around 20 kg/m2 (37 lbs/yd^2), binder (road oil, medium or slow curing cutback or emulsion) around 1.6-2.5 l/m^2 (0.35-0.55 gal/yd^2). The emulsions used are typically of medium setting grades, often high float emulsions containing solvent. An adhesion agent should be used with siliceous aggregates, including when employing anionic emulsion binder. There is no accepted design procedure. The target is that the binder will be forced towards the surface so that practically all the aggregate is coated, which may take prolonged compaction with rubber tired rollers and trafficking under controlled speed to achieve. During this period aggregate pushed to the shoulder by traffic may need to be put back on the road or additional aggregate may be used to treat fatty spots. A second layer of graded aggregate seal may be placed, usually some weeks or months after the first to allow time for the binder to migrate to the surface and a portion of the solvents to evaporate. The surface of Otta seal may be treated with a fog seal or sand seal.

Primer seals or first seals

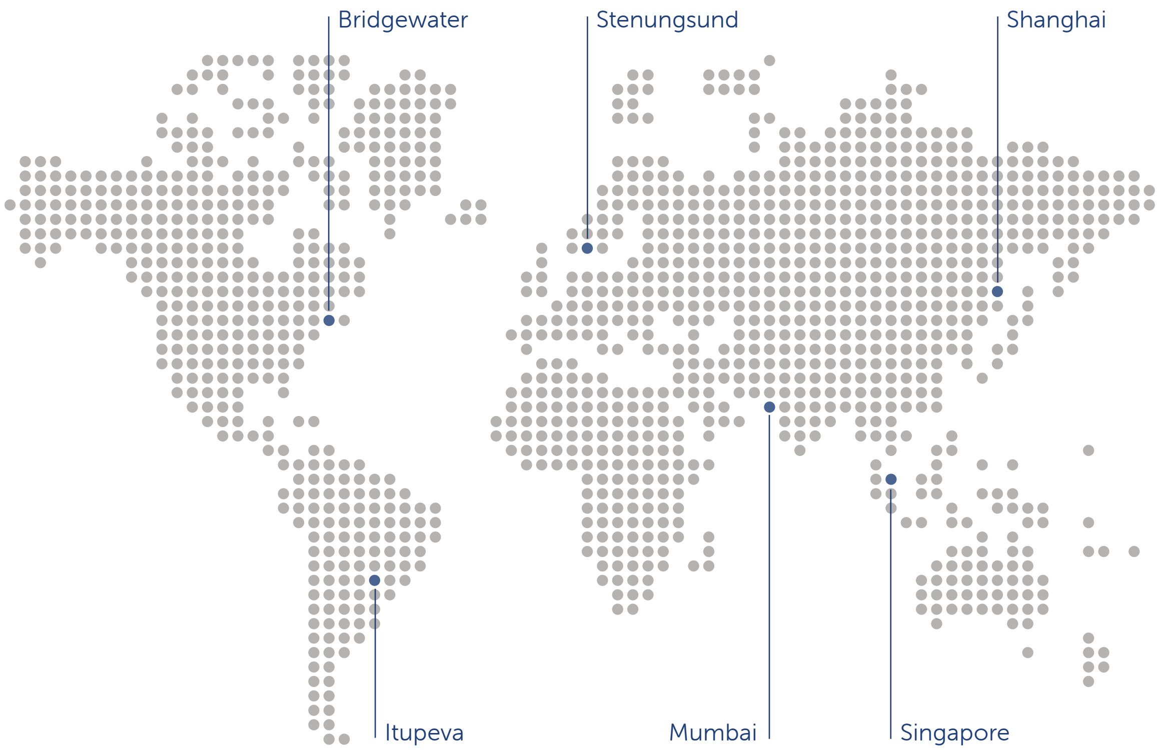
Sealing of granular base or gravel roads presents problems. The surface may be regraded and compacted to provide a homogeneous substrate. The surface may be primed and the prime allowed to cure, and sanded if necessary to avoid pick up by construction equipment. A single seal is not usually a permanent wearing surface for an unbound base and the goal is usually to provide at least a double seal, or to eventually cover the seal with a hot or cold mix overlay. A double seal may be placed in one operation or the second layer applied several weeks or months after the first seal. With a soft unbound base a large chip – like 20 mm or 3/4 inch – may be used to allow for embedment. After construction the seal may be swept and fog sealed.

Application of fog seal over surface dressing / chipseal

Fog seals may be applied to new surface dressing / chipseal to reduce early chip loss or raveling and provide a black surface for road marking. A wide variety of emulsion grades are used for fog seal, often diluted 50/50 before use. If rapid set grades are used they may need to be diluted with soap solution at the emulsion production site. Slow-set and quick-set grades can be diluted with water. Soap solution or water should be slowly added to the emulsion, rather than the other way around. With fog seal over surface dressing / chipseal the application rate should be low enough not to cover the high points of the chip, to maintain friction and avoid the need for sanding. Typical application rates are 0.08-0.12 gal/yd^2 (0.36-0.54 l/m^2) diluted emulsion.

Our research & technical support laboratories

We provide emulsion formulations to its customers all over the world in fully equipped laboratories. Conveniently located for shipment of samples and with good knowledge of local requirements, the laboratories are able to develop emulsion recipes to match the needs of local materials.



Overview of our products

Product overview

Product	Region	Comments	Applications
Redicote E-9	A, E	Builds medium viscosity	Products for cationic rapid set emulsions for surface dressing / chipseal primer seal, scrub seal and sand seal, and cationic medium set emulsions for graded aggregate seal
Redicote E-16	E, S	100% active liquid emulsifier that builds medium viscosity	
Redicote E-4819	A, E, S, C	Builds high viscosity	
Redicote E-4900	A	100% active liquid emulsifier that builds high viscosity	
Redicote C-580	A, E, S	100% active high viscosity building emulsifier that is soluble in acidified water at ambient temperatures	
Redicote EM22	E	Liquid emulsifier for fast cure in surface dressing	
Redicote EM24	E, S	Liquid emulsifier with high viscosity build and fast breaking emulsions	
Redicote EM44	E, S	Liquid emulsifier for viscosity control and good emulsion stability	
Redicote EM-44A	A	Liquid emulsifier for viscosity control and good emulsion stability	
Redicote E-62	A	Produces high float character to emulsion residue	Products for anionic rapid set emulsions for chipseal and medium set emulsions for graded aggregate seal
Redicote C-150AP	A	Designed to be easily blended with emulsions	Adhesion promoter for anionic emulsions for chipseal and graded aggregate seal
Diamine OLBS	E, S	Low viscosity, liquid product for cutback and soft bitumen mixes	Active adhesion promoters for chip seals using cutback or hot asphalt
Diamine HBG	S	Pelletised form for convenient on-site addition	
Redicote E-16	E, S	Liquid product for cutback and soft bitumen mixes	
Wetfix 312	A	100% active, lower odor antistrip suitable for cutbacks and hot bitumen	
Wetfix BE	E, S, C	Suitable for a wide range of applications including soft bitumen	
Wetfix N422	E	Heat-stable product for soft bitumen mixes and surface dressing with hot bitumen	
Redicote AP	A	Suitable for both anionic and cationic emulsions Heat-stable product for surface dressing with hot bitumen	Bitumen additive for improved emulsion quality with polymer-modified binders Active adhesion agent for hot applied seals

A = North and South America, E = Europe, Middle East, Africa, S = South Asia, C = China
Products may not be available in every country within a region

Active adhesion promoters with hot binder or cutbacks

Overview

Surface dressing / chipseal made with cutback or hot applied binders face particular adhesion problems because the cover aggregate is not heated and often contains moisture. Furthermore the old road surface may not be dry. Unlike emulsions, the viscosity of the hot binders may increase significantly on cooling and this high viscosity may make it impossible for a good bond to form between binder and wet aggregate.

Adhesion promoters/anti-stripping agents used in hot mix processes are designed to prevent bitumen from stripping off aggregate coated when it was hot and dry (passive adhesion). They may not provide the "active" adhesion needed for the bitumen to actually displace water from cold wet surfaces and form a durable bond.

Some surface-active anti-stripping agents (known as active adhesion promoters) can decrease the surface energy of the bitumen-aggregate interface, allowing the bitumen to displace water and coat the aggregate surface.

Testing active adhesion

In simple tests, damp aggregate is mixed with binder and subjected to a static immersion, rolling bottle or boiling stripping test before estimating coverage. In the Immersion Tray Test, binder is placed in a tray, covered with water or placed into a water bath, and individual chips are pushed through the water and into the binder. After a period of time the chips are removed and the coating of the face in contact with the binder is estimated. With high viscosity binders the test may be done warm. The Vialit Test can also be modified to test active adhesion. The plate is coated with binder, then wet chips are placed into the binder. The plate is immersed in water. The adhesion is then tested in the normal way by striking the back of the plate with a metal ball and counting chips knocked out of the seal.

Liquid active adhesion promoter

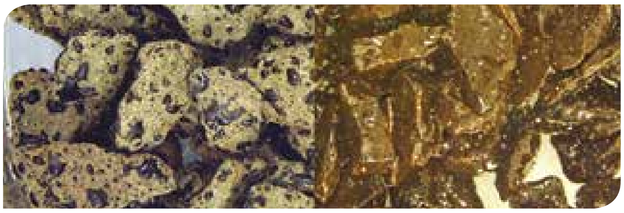
Active adhesion promoter Duomeen HT / Diamine HBG

Loss of cover aggregate due to poor adhesion

Use of active adhesion promoters

Active adhesion promoters are added to the binder at 0.5-1.5%, generally at higher dosages than needed for hot mix products. The agents can be added at the refinery but preferably at the bitumen storage depot or directly into the distributor. Liquid products can be pumped into the bitumen delivery line, or into the distributor or bitumen storage tank. Pelletized products are available for easy addition to the distributor in the field.

Active adhesion agents may lose activity if the treated binder is stored hot for extended periods before use. The source and the acid value of the bitumen used will also influence the loss of activity. If storage of the treated binder is unavoidable, then a heat-stable product must be selected and storage temperatures should be minimized where possible.



Static immersion test – without adhesion promoter (left) and with Wetfix BE (right)

Passive adhesion

The ability of a bitumen to maintain the integrity of the adhesive bond with aggregate to prevent stripping under wet conditions.

Active adhesion

The ability of a bitumen to displace water from an aggregate surface and maintain the adhesive bond to the aggregate.

Formulating cationic high residue rapid-set emulsions

Overview

We offer a range of products for the formulation of cationic rapid set (CRS) emulsions to cope with the range of bitumen types available and which offer different handling characteristics. CRS emulsions are prepared with low levels of emulsifier (typically 0.15-0.35%) to achieve the rapid-setting properties. As a result they are particularly sensitive to bitumen type and manufacturing conditions. Problems encountered include: sieve residue formation during production, or during storage and handling; problematic too high or too low viscosity; changes in viscosity during storage; slow curing or poor adhesion. These problems often cannot be solved by adjustments to the production process, and require changes to the emulsion recipe. Some problems can be solved by adjusting production parameters such as production rate, mill speed, temperatures, etc.

Emulsion viscosity

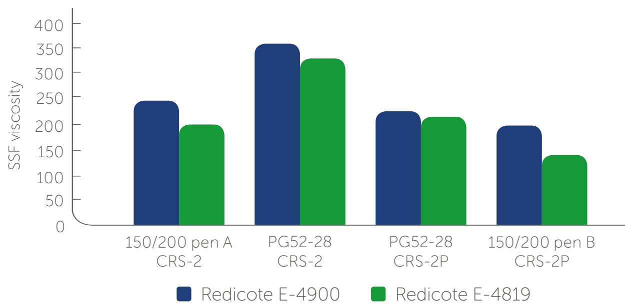
A key and often challenging specification item for CRS emulsions is viscosity. Emulsions for spray seal must have a viscosity sufficiently low to give a good distribution of emulsion across the surface of the roadway, yet viscous enough to prevent run off and give sufficient meniscus. ASTM and European standards for high residue (>65%) emulsions specify an emulsion viscosity in the range of 100-400 SSF at 50°C and in Europe, 30 to 70 STV seconds at 40°C (depending on performance class). The viscosity of these emulsions is very sensitive to the recipe which is why we offer a range of emulsifiers designed to provide different levels of viscosity build in the emulsion.

Major factors in viscosity include: binder content, emulsifier content, salt content of the bitumen, particle size and particle size distribution. There is a relationship between binder content and viscosity. Low emulsion viscosity can always be corrected by increasing the binder content, within the specified limits. High emulsion viscosity can be corrected by reducing binder content only so far as the specification minimum residue.

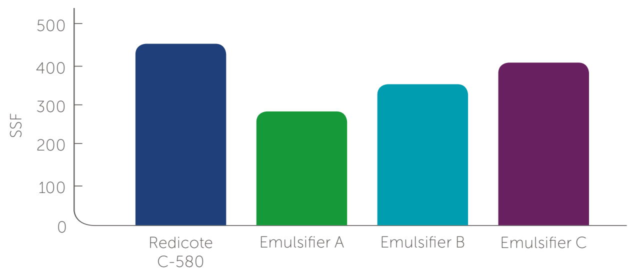
Problematic high viscosity may result from so-called viscosity building bitumens, which typically have high acid values and contain high levels of salt. Salt may lead to the transfer of water into the bitumen phase by osmosis, which raises initial emulsion viscosity and can lead to changes of viscosity during storage. Control of viscosity usually can be achieved by including 0.05-0.25% calcium chloride or sodium chloride in the formulation, which reduces the osmotic gradient.

Problematic low viscosity may be associated with bitumens with low salt contents or with hard water but is mostly associated with latex and polymer-modified emulsions. Latex contains salt, which when included in the soap tends to reduce emulsion viscosity. A polymer-modified emulsion may have a broad particle size distribution, which also tends to lead to lower viscosity. Strategies to increase emulsion viscosity include raising the binder content, injecting latex into the asphalt phase instead of the soap, or selecting a viscosity building emulsifier.

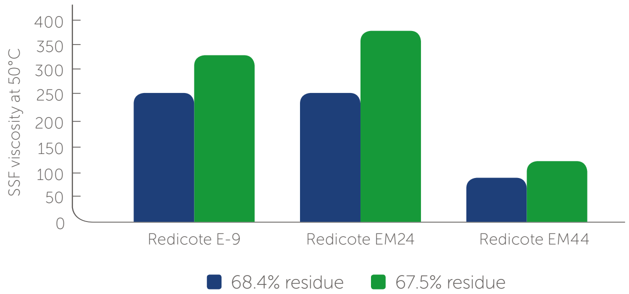
If viscosity is changing during storage this can be partly corrected by higher emulsifier dosage, inclusion of calcium chloride in the recipe and lower storage temperatures.



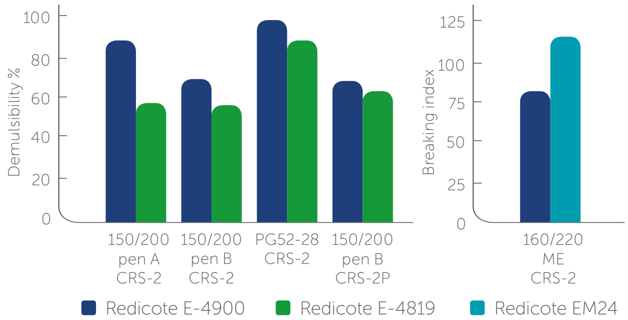
CRS-2 chipseal emulsion viscosity with various bitumens and emulsifiers



Redicote C-580 comparison with other emulsifier
Viscosity at 122°F/50°F comparison for CRS-2 emulsions



CRS-2 emulsion viscosity with different residue contents and emulsifiers



CRS-2 chipseal emulsion reactivity breaking behavior with various emulsifiers

Selection of emulsifiers for viscosity control

Redicote E-9 and Redicote E-16

Classic fatty diamine emulsifiers provide stable emulsion at low dosage with neutral viscosity build and good adhesion. These qualities mean recipes can be adapted to a wide range of bitumen sources by the incorporation of calcium chloride, changes in residue content, pH or emulsifier dosage.

Redicote E-4819, Redicote E-4900, Redicote C-580 and Redicote EM24

Products build emulsion viscosity to reduce residue contents close to the specification minimum, leading to cost savings. Generally these produce emulsions that are more reactive than Redicote E-9 at the same dosage.

Redicote EM44 and Redicote EM-44A

Liquid emulsifiers provide the lowest emulsion viscosity and are used when high viscosity is not required or with bitumens which build problematic high viscosity. These products often provide the best emulsion quality with difficult to emulsify bitumens. They are very easily dispersed in water for fast neutralization.

Redicote EM22

Emulsifier is formulated for fast curing. It does not build emulsion viscosity.

Emulsion stability

A number of emulsion stability problems can be encountered with some bitumens, such as sieve residue formation during emulsion production or storage, latex separation, settlement, and severe viscosity changes during storage.

The simplest response to emulsion quality issues is to reduce the soap pH and increase the emulsifier level. Use of 0.05-0.15% calcium chloride in the soap recipe can help emulsion quality, especially with high acid value asphalts. Redicote EM44 or EM-44A, Redicote E-9 and Redicote E-16 provide emulsions with the best storage stability, including good resistance to shear, and stability to temperature changes.

Peptisers

Redicote AP is a product added to the bitumen phase before emulsion production helping the emulsification process. The result is a smaller emulsion particle size, which can translate into higher viscosity and reduced settlement. The product is most often used with challenging binders such as polymer-modified bitumens.

Reactivity and breaking behavior

Specifications generally include an item related to the reactivity of the emulsion. In the Americas the emulsion is reacted with a solution of opposite charge to assess emulsion demulsibility – high demulsibility means higher reactivity. In Europe the emulsion is reacted with mineral filler to determine breaking value – low breaking value means more reactive emulsion.

Meeting specifications for reactivity and breaking behavior in the field may demand adjustment of the recipe. Increase in emulsifier dosage will decrease the reactivity of the emulsion as measured by these tests. Conversely, lower emulsifier dosage always increases reactivity, as does a higher soap pH.

Redicote EM22, Redicote EM24, Redicote E-4819, Redicote C-580 and Redicote E-4900 provide the highest reactivity and best breaking experience in the field. Redicote E-9 and Redicote EM44 or Redicote EM-44A provide more storage stable emulsions with somewhat slower reactivity.

A combination of emulsifier choice, pH changes and emulsifier dosage changes will most often solve problems with emulsion viscosity and stability while maintaining the required reactivity.

Tips for viscosity control

Emulsifier dosage

The higher the dosage of viscosity building emulsifiers like Redicote E-4819, Redicote C-580 and Redicote EM24 then the higher the viscosity achieved. If the higher dosage gives too low demulsibility, this can be solved by using a higher soap pH.

With viscosity building bitumens the higher the dosage of an emulsifier like Redicote EM44 or Redicote EM-44A which don't build viscosity, then the lower the viscosity attained.

Soap pH

Generally with viscosity building emulsifiers, higher viscosity is attained at lower soap pH. A higher emulsion soap pH generally leads to higher viscosity in latex modified systems.

Latex

Latex added via the soap phase or post-added to emulsion will reduce the viscosity compared to an unmodified emulsions prepared at similar residue content. Latex added via the bitumen phase generally increases emulsion viscosity.

Polymer-modified binder

Polymer-modified binders lead to larger particle size and lower emulsion viscosity than similar emulsions prepared with unmodified bitumen. To ensure the highest viscosity, use a viscosity building emulsifier at higher dosage and production conditions designed to produce a small particle size.

Troubleshooting surface dressing / chipseal

Problem	Possible cause	Possible solution
Too low emulsion viscosity	Low residue content Too high calcium chloride content Low emulsifier dosage Wrong emulsifier type for bitumen Latex Broad particle size distribution Emulsion pH	Raise residue content Reduce or eliminate calcium chloride Raise emulsifier dosage Select viscosity building emulsifier Add portion of latex to the bitumen line Check particle size and adjust manufacturing conditions Check pH (emulsifier dependent)
Too high emulsion viscosity	High residue content Problematic asphalt Wrong emulsifier type for bitumen Latex injection into bitumen line	Reduce residue content Include calcium chloride in the recipe Select viscosity controlling emulsifier Add portion of latex to the soap line
Fail demulsibility or filler index	Emulsifier content too high Too high emulsifier in soap phase Emulsion pH Too high calcium chloride (cationic grades)	Reduce emulsifier content Add portion of emulsifier to bitumen phase Raise emulsion pH (cationic grades) Replace with sodium or potassium chloride
Fail float test (anionic grades)	Too low emulsifier content Too low polymer content Bitumen source	Increase emulsifier dosage Increase polymer content Select alternative bitumen Include aromatic solvent or fuel oil in recipe
Emulsion builds sieve on storage, handling, or heat-cool cycles	Problematic asphalt Polymer incompatibility Broad particle size distribution	Increase emulsifier level, lower emulsion pH Include calcium chloride in the recipe Consider moving to Redicote EM44 or EM-44A Consider Redicote AP if using polymer-modified bitumen Check particle size and adjust manufacturing conditions
Severe viscosity drop on storage, handling, or heat-cool cycles (emulsion)	Problematic asphalt Latex injection into bitumen line Broad particle size distribution	Include calcium chloride in the recipe Increase emulsifier level, lower emulsion pH Split latex injection between asphalt and soap lines into mill Check particle size and adjust manufacturing conditions
Emulsion running off the road	Low emulsion viscosity Too much emulsion Wet cover aggregate Damp pavement or rain showers	Increase bitumen content Check application rate Check moisture content of aggregate stockpile Wait for better weather
Poor embedment of chips	Delay or no rolling of cover aggregate Low binder application Binder cured before chips placed	Roll cover aggregate directly after chip application Check application rate Adjust emulsion reactivity, increase hot bitumen temp Apply chips immediately after binder application
Early raveling (chip loss)	Cold or freezing conditions Slow cure, low paving temp (emulsion) Fast cure, low paving temp (bitumen) Opened to traffic too early Poor embedment of chips Dusty aggregate Aggregate/emulsion compatibility	Avoid paving in cold conditions, road and air should be at least 60°F (15.5°C) and rising Adjust system reactivity, use warm emulsion Increase bitumen application temp Control traffic speed for extended period See poor embedment of chips above, consider fog seal Use clean chips or anionic emulsion Increase emulsifier level or post-add adhesion promoter Switch emulsion type (cationic to anionic or vice versa)
Early fatting up of binder in wheels paths (bleeding)	Low cover aggregate High binder application rate Underlying road surface soft or rich Raveling of aggregate	Check chip spreader calibration Check distributor calibration, check binder application rate Reduce binder application rate See early raveling above
Binder striping / non-uniform coverage	Plugged distributor nozzle Insufficient pressure Low application rate Distributor speed	Clean distributor nozzles Check distributor pressure Increase application rate Slow down distributor
Loose cover aggregate	No sweeping Poor embedment of chips Early raveling / chip loss	Sweep seal within 24 hours to remove excess chips See poor embedment of chips above, consider fog seal See early raveling (chip loss) above

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Nouryon

Nouryon is a global, specialty chemicals leader. Markets and consumers worldwide rely on our essential solutions to manufacture everyday products, such as personal care, cleaning goods, paints and coatings, agriculture and food, pharmaceuticals, and building products. Furthermore, the dedication of more than 7,900 employees with a shared commitment to our customers, business growth, safety, sustainability and innovation has resulted in a consistently strong financial performance. We operate in over 80 countries around the world with a portfolio of industry-leading brands. Visit our website and follow us @Nouryon and on LinkedIn.

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