ROADING NEW ZEALAND

Bitumen Emulsion Guide

Using Bituminous Emulsion
For Chipsealing Applications

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Introduction

This guide provides information for specifiers, engineers, contractors and road network asset managers on the use of bituminous emulsions for chip seals.

A more detailed guide for practitioners covering the transfer, storage, handling and spraying of bituminous emulsion is also available.

Background

Bitumen and Binder for Chipseals

Roads in New Zealand have been chip sealed since about 1880 and in about 1910 the first emulsified road binders were used.

Binders for chip seals today are bitumen based with various additives. Kerosene is used as a cutter to temporarily soften the bitumen and assist with adhesion, and an agent is often used to improve adhesion to chip in wet conditions. Flux oils such as Automotive Gas Oil (AGO) can also be used to soften the base binder. Because the proportions of cutters and / or flux oils are relatively small, they do not alter the viscosity enough to enable pumping or spraying without heating. In premium binders for specific applications, the bitumen binder can be further improved by adding polymers to improve temperature susceptibility and toughness.

There are two methods of temporarily altering viscosity of a bitumen binder to enable pumping, spraying and distribution to the road surface so chip can be applied and adhere to that binder. These are emulsifying and heating.

Bituminous emulsions are heated to less than 90°C, whereas hot cut back binders are typically heated to around 170°C. The final on road binder can be identical in terms of base bitumen grade and additives, regardless of whether the binder is heated and sprayed hot or emulsified and sprayed at a lower temperature.

As with most alternatives, each option needs to be considered to ensure the best performance is achieved.

The textbook *Chipsealing in New Zealand*, available from NZTA, provides history and detailed information on chip sealing, bituminous binders, emulsion manufacture, its chemical properties and uses.
Recent Advances

Plant and Technology

While emulsified road binders have been used in New Zealand since the early 1900s, manufacturers have more recently invested extensively in research and development. This has improved the understanding of the chemistry, properties, manufacturing parameters and performance of bituminous emulsions. Plants are now capable of manufacturing high performance emulsions that can achieve results that were previously considered unattainable.

Examples include:
- High application rates for single coat seals (in excess of 3 ltrs/m²) without bituminous emulsion run off
- Improved spray-ability (no streaking)
- Improved “set up” time (speed of cohesion strength gain)
- Improved storage stability

How Emulsions Work

To appreciate some differences between emulsion and hot cutback binders, an understanding of adhesion and cohesion is helpful.

*Chipsealing in New Zealand* defines adhesion and cohesion as:

- **Adhesion**: “The action by means of which a fluid substance, e.g. a bituminous binder, sticks to the surface of a solid body, e.g. chip. It arises through intermolecular attraction between the contact surfaces.”

- **Cohesion**: “The ability of a material to resist, by means of internal forces, the separation of its constituent particles.”

In comparison to bituminous emulsions, hot-applied binders have poor initial adhesive strength but good cohesive strength. Poor initial adhesive strength manifests itself as stripping in wet conditions and is a main reason to include adhesion agents in the binder. These work at the interface between the binder and chip, increasing the intermolecular attraction between the contact surfaces. Without adhesion agents, hot-applied binders are likely to suffer stripping in wet conditions, especially in the early part of the seal life.

Bituminous emulsions have excellent initial adhesion but take time to build cohesive strength. Cohesive strength is built as the water used in the emulsification process separates from the bitumen and evaporates. The speed at which this occurs can be increased by appropriate choice of emulsifier systems. Once the water from the bituminous emulsion is no longer present, an equivalent binder with equivalent cohesive strength to the hot-applied binder remains.

The differences in adhesive properties and cohesive timing are summarised here:

<table>
<thead>
<tr>
<th>Property</th>
<th>Bitumen emulsion – water based</th>
<th>Hot cut-back binders – oil based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhesion</td>
<td>Bituminous emulsions have very high adhesion in dry conditions and adequate adhesion in wet conditions.</td>
<td>Hot cut-back binders have adequate initial adhesion in dry conditions and very poor adhesion in wet conditions.</td>
</tr>
</tbody>
</table>
Cohesion

| Bituminous emulsions have adequate initial cohesion but take time (hours or days) to achieve full cohesion as the retained water evaporates. | Hot cut-back binders have good cohesion but take time (months or years) to achieve full cohesive properties due to the softening effect of the retained cut-back. |

Over time the final binder on the road surface can be the same base grade with the same additives included, but the two delivery systems are different in the way they allow the binder to react to the road surface and the chip when first applied.

**Where to use Bituminous Emulsions**

Bituminous emulsion binders are suitable for all chip sealing applications. They are particularly suited to first coat seals and the damp cool conditions experienced in the early or later part of a sealing season, if there is sufficient evaporation to achieve binder cohesion.

**Polymer Modified Bitumen (PMB) and Polymer Modified Emulsion (PME)**

Polymer Modified Bitumen has been used in chip seals for many years. Adding a polymer to a binder can increase “toughness” of the finished seal and improve the binder’s ability to cope with road temperature variations.

Adhesion is a recognised challenge when applying Polymer Modified Bitumen (PMB) as a hot binder. Stripping can result if absolute best practice is not followed. Traditionally PMBs have been sprayed in the warmer, more settled months of the year and in many cases using pre-coated chip. Because bituminous emulsions adhere to chip differently from hot-applied binders, sprayed polymer modified binders applied as emulsions (PMEs) have superior adhesion to the surface and sealing chip compared to hot applied PMBs.

Using PMEs negates the need for pre-coating and can mean they will adhere better than hot-applied PMBs in less favourable conditions. The climatic conditions and time of year can be broadened without significantly increasing risk.

**The Benefits of Bituminous Emulsions**

**Environmental**

Research quoted in *Chipsealing in New Zealand* has shown that when binders are sprayed as hot cut-backs “Approximately 20% of the added kerosene evaporated while being sprayed and 30% within 2 hours following application.”

When spraying bituminous emulsions it is expected that very little, if any, cut-back (kerosene) is lost to atmosphere while spraying, meaning that less kerosene (if any) is necessary in the binder.

*Chipsealing in New Zealand* also notes: “Bitumen emulsions may be applied at lower temperatures than most other binders, at ambient temperatures, and also contain less or no hydrocarbon diluents (e.g. kerosene) compared with hot-applied binders. In New Zealand the production, transportation and application of bitumen emulsions uses less energy and produces less carbon dioxide than using hot cut-back bitumens (Slaughter 2004). Therefore the use of bitumen emulsions has health, safety, and environmental benefits.”
Safety

The use of bituminous emulsions has significant safety benefits over the use of hot cut-back binders. The principles of New Zealand health and safety legislation require us to eliminate hazards wherever possible. Applying bituminous emulsions instead of hot cut-back binders eliminates several significant safety hazards that hot cut-back binders present to practitioners and the general public.

Safety benefits of emulsion over hot cutback include:
- Eliminated risk of fire or explosion due to hot volatile vapours
- Reduced burn risk due to emulsion being sprayed at up to 90°C compared to hot binders which are typically sprayed at around 170°C and up to 190°C
- Reduced emissions to atmosphere and fume hazard

Technical

Aggregates of the pavement or road surface and sealing chip adhere to the binder while in the emulsified state in a different manner to adhesion in a hot-applied binder. This superior adhesive property allows designers to use less residual binder in application spray rates, which in turn can reduce the incidence of flushing. The on road viscosity of the bituminous emulsion (while in the emulsified phase) is dramatically different to hot sprayed binders and allows for different sealing techniques to be employed. Cutter contents can be significantly reduced, which lessens any environmental impact. This can also mean less flushing.

In general, if kerosene cutter is used in a hot applied cut-back binder, little to none is used in the equivalent bituminous emulsion.

Seal Design

Bituminous emulsions can be used for all chip seal applications where hot-applied binders would typically be used. Conventional application rate design principles can be applied to bituminous emulsions with the appropriate factor for water (residual binder) being applied. It is generally accepted however that, due to the different adhesive nature of the bituminous emulsion, lower residual binder application rates can be achieved.

If desirable, less residual bitumen can be applied. This is seen by many as a significant advantage in reducing the likelihood of future flushing.

Many experienced practitioners believe emulsion allows construction of chip seals using techniques which cannot be used as successfully with hot-applied binders.

Advantages and Limitations of Bituminous Emulsion

Advantages include:
- Less energy required in heating
- Greatly improved adhesion
- Suitable for dry and damp conditions
- Suitable for first coat seals
- Less hydrocarbon emissions to atmosphere
- Lower residual spray rates
- Safer product
- Less risk of burns
- Risk of explosion eliminated
- Less carbon dioxide produced
Limitations include:

- Some risk of run off in wet weather immediately following spraying. Water based system emulsions are suited to damp or wet conditions but should not be applied when raining or if rain is imminent.
- Break and cure times will be affected by environmental conditions.
- Water in the emulsion will take longer to evaporate in damp humid conditions than dry hot conditions. Adapting techniques can reduce this effect.
- If rain occurs ‘oily runoff’, predominantly kerosene, after spraying hot-applied cut back binder is not usually noticed. However, bituminous emulsion will produce a coloured stain if rain occurs before all of the water evaporates. Handling guides should include provisions to minimise these risks and also detail procedures to protect against run-off and how to deal with spills.

Specifications and How to Specify Emulsion for Chipseals

New Zealand uses the New Zealand Transport Agency (NZTA) M / 1 Specification for Roading Bitumens which ensures the properties of the base bitumen used in asphalt mixes, hot cut back binders and bituminous emulsions are consistent and suitable for New Zealand conditions.

It is important for chip seal performance that the final applied seal in terms of texture, chip retention etc. meets the NZTA P / 17 performance based Specification for Re-seals.

When spraying hot cut-back binders the base bitumen penetration value is specified because this contributes to the long term performance of a seal coat. The specified test to obtain this measure is the American Society for Testing and Materials (ASTM) Standard Test Method for Penetration of Bituminous Materials (ASTM D5). The same base binder can be applied as an emulsion and should be specified.

Penetration Test (ASTM D5) is used to define four grades of bitumen;

<table>
<thead>
<tr>
<th>Grade</th>
<th>General Application</th>
<th>Physical Characteristic</th>
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<tbody>
<tr>
<td>180/200</td>
<td>Chip sealing</td>
<td>Soft</td>
</tr>
<tr>
<td>130/150</td>
<td>Chip sealing</td>
<td></td>
</tr>
<tr>
<td>80/100</td>
<td>Hot-mix asphalt binder, chip-sealing</td>
<td></td>
</tr>
<tr>
<td>60/70</td>
<td>Hot-mix asphalt binder</td>
<td>Hard</td>
</tr>
</tbody>
</table>

When contemplating the use of cutter in any binder it should be considered why cutter is required and the fact that little to no cutter will be lost to atmosphere when sprayed as an emulsion.

Other properties of bituminous emulsions such as actual residual binder content, viscosity and bitumen droplet size are not necessarily significant in regard to the chip seal specification.

Final on road performance is what is most important and specifying the base binder grade and cutter requirement is all that is necessary.

Because properties such as viscosity and % bitumen content have a significant impact on the emulsion storage life, spray-ability, break and cure times, specifying any of these could restrict the manufacturer and result in a less than optimum outcome. It is better to allow
manufacturers some room to innovate and develop emulsion properties which best suit the conditions and produce the required end result.

When specifying hot applied Polymer Modified Binders (PMBs) or Polymer Modified Emulsions (PMEs) it is common to specify a percentage residual polymer required in the binder.

**Practitioners’ Guide to the Use and Handling of Emulsions**

A more detailed guide for practitioners covering the transfer, storage, handling and spraying of bituminous emulsion is also available.