Asphalt Binders for Thin Maintenance Surfaces

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Introduction

Asphalt is used as a binder for thin maintenance surface (TMS) applications because of two key properties, it is waterproof and it adheres relatively well to the aggregate. Since asphalt is too stiff at room temperature to apply to the road surface, it is usually applied as either a cutback asphalt or an asphalt emulsion. The asphalt emulsions can be further divided into high float emulsions, cationic emulsions or polymer-modified binders, which are emulsions with polymers added to them. These types of binders are discussed further below.

Cutback Asphalt

Cutback asphalt is asphalt that is thinned with solvents such as kerosene or naphtha (gasoline), which is called cutter. The following factors should be considered in the use of cutback asphalt:

- The type of solvent used controls the curing time of the cutback.
- Rapid curing cutbacks use naphtha, while medium curing cutbacks use kerosene.
- The higher the content of cutter in the cutback asphalt, the less viscous and more fluid the cutback asphalt will be.
- Cutback asphalts are useful when the penetration of a hard pavement surface is needed and when the seal coating process must be extended late into the construction season.
- Cutback asphalts also have a much higher percentage of residual asphalt compared to emulsions, which leads to more asphalt being left on the road surface for the same amount of binder applied.
- Cutback asphalts stay active longer, which means that they are able to penetrate and coat the dust that may be on the aggregate.
- A disadvantage is that the solvents used to thin the asphalt evaporate, give off hydrocarbons into the atmosphere, and pose environmental risks and safety problems when they are used.

Asphalt Emulsion

Asphalt emulsions are fine asphalt particles that are brought into contact with a chemical solution (emulsifier) to provide stabilization, and then are dispersed in water. This makes them less harmful to the environment and safer to work with, which is the primary reason why they are used more often than cutback asphalts. The following factors should be considered in the use of asphalt emulsion:

- Asphalt emulsions are divided into three major types: cationic, anionic, and non-ionic. Only the first two types are used in construction and have a positive (cationic) and negative (anionic) charge.
- Emulsions are then further classified based on how fast they "break," revert back to their asphalt state. Classifications include rapid, medium, or slow setting emulsions.

- The principal investigator has noted anecdotally that in New Zealand emulsions have been formulated that work late in the season, thus extending the construction season, which contradicts the usual practice in the United States.

High Float Emulsion

High float emulsions are made with a special family of emulsifying agents that leaves a gel structure behind in the asphalt residue. The following factors should be considered in the use of high float emulsion:

- High float emulsions were developed for low volume roads in areas where a graded cover aggregate is to be used.
- High float emulsions are also quite effective when used with somewhat dusty aggregates because they provide a thicker asphalt film on the aggregate and the aggregate can penetrate much more uniformly. This is because high float emulsions are slightly anionic (sets slower than most cationic emulsions) and there is a small amount of solvents in them that act as a cutter in penetrating the dust. A thicker asphalt film coats the aggregate; therefore, high float emulsions do not flow and drain as readily as conventional emulsions.
- Rapid setting high float emulsions set slower than rapid setting cationic emulsions; this slower setting time allows for the liquid to have more time to penetrate the layers of dust that may be present on the aggregate.
- Reportedly, bleeding at high temperatures and brittleness at low temperatures is less likely to occur with high float emulsions because after the emulsion is allowed to cure, the residue that is left behind has a higher viscosity from a gel like structure that is left behind. Results of our test section performance did not always corroborate this claim.

Cationic Emulsion

Since aggregates are negatively charged, cationic emulsions are more often used than anionic emulsions. Cationic emulsion droplets have a positive charge; thus they are attracted to the negatively charged aggregate, since opposite electrical charges attract each other. When the asphalt particles and the aggregate particles are attracted to each other, this event is called breaking. According to the *Minnesota Seal Coat Handbook,* "Breaking refers to the event when the asphalt and water separate from each other. This occurs as the emulsifier leaves the surface of the asphalt particles due to its attraction to the surface of the aggregate. Since asphalt is heavier than water, the asphalt particles will settle to the bottom of the solution"[1]. Figures 1 and 2 (from Janisch and Gaillard, *Minnesota Seal Coat Handbook*, 1998) show depictions of this breaking process.

[1] Janisch, D. W., and Gaillard, F. S. 1998. *Minnesota Seal Coat Handbook*. Minnesota Local Road Research Board Report MN/RC – 1999-07. St. Paul, MN: Minnesota Department of Transportation.

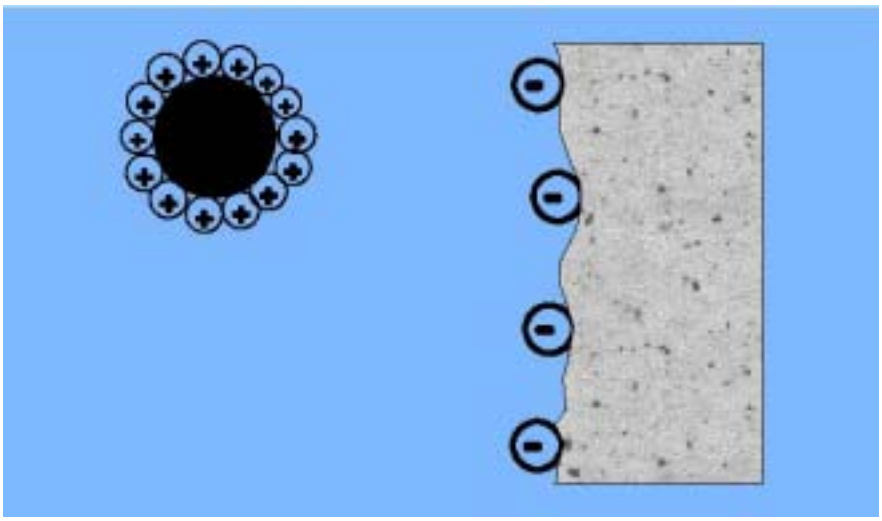

Figure 1. Cationic Emulsion Before It Begins to Break

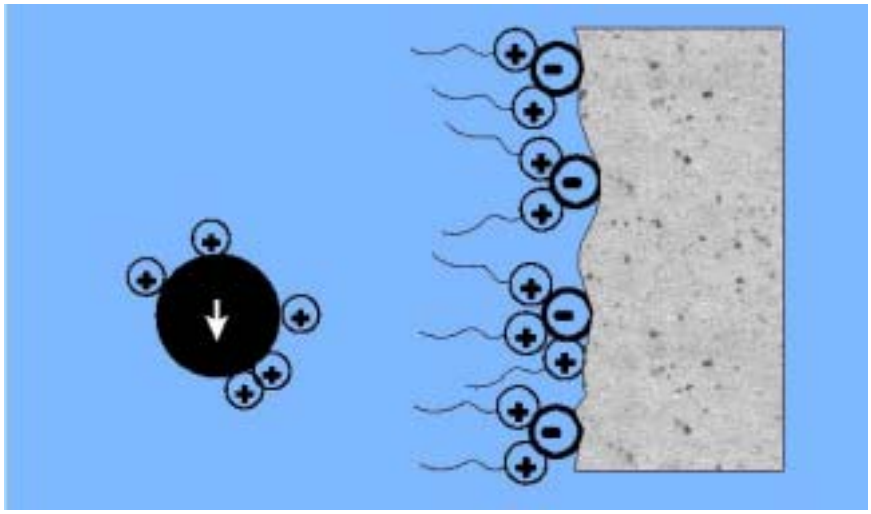

Figure 2. Cationic Emulsion Beginning to Break

Note:

- Given the correct aggregate, cationic emulsions have performed reliably in the field and they set up more quickly than anionic emulsions.
- Cationic rapid set (CRS) emulsions adhere to the aggregates much faster, thus allowing for the road to be opened to traffic sooner. However, when a CRS emulsion is used, the cover aggregate must be placed much faster so as to ensure the emulsion breaks after it has had time to coat the aggregate.
- CRS emulsions work well with clean and dust-free aggregate. However, if dusty aggregate is to be used, then pre-coating the aggregate prior to its use is required; this will be discussed more later.

Polymer-Modified Binder

Properties of asphalt emulsions can be enhanced with the addition of polymers to the emulsion, creating a polymer-modified emulsion. Note:

- When polymers are added to an emulsion, there is an increase in early stiffness of the binder, which leads to a better early aggregate chip retention.
- When compared with non-polymer-modified binders, the flexibility of the treated surface is increased in cold weather and over time as a result of the emulsion being modified with the addition of polymers.
- Bleeding and flushing of surfaces treated with polymer-modified emulsions is reduced in warm weather because polymers enhance binder stiffness at high temperatures.
- When polymer-modified emulsions are used, there is an increase in cost, typically about 30 percent.

Depending on the roadway and the circumstances for the road, the benefits of the polymer-modified emulsion may warrant its use. Some roads that may warrant their use are high volume roads and areas where more turning, starting, and stopping occurs, such as roads in municipalities. For each of the previously mentioned types of asphalt binders, Table 1 lists their advantages and disadvantages for use in TMS.

Table 1. Advantages and Disadvantages of Binder Types

Type	Advantages	Disadvantages
Cutback asphalt	• Best at binding dusty aggregate. • Some possible penetration into dry road surfaces increases bond. • Will retain aggregate that is not spread immediately after shooting binder.	• Subject to bleeding and tracking. • Some products are flammable. • Emits hydrocarbons during curing process. • Curing can take considerable time. • Aggregates must be dry.
Cationic rapid setting (CRS)	• Binds clean aggregates with low clay content securely to road surface. • Cures quickly. • Works with damp aggregate. • Commonly available and familiar to industry participants.	• Ineffective for dusty aggregates or aggregates with high clay content. • Aggregate must be spread immediately behind distributor truck.
High float	• Binds aggregate with more dust and clay when compared to CRS. • Cures quickly, but not as quickly as CRS. • Works with damp aggregate. • May coat aggregate more thickly, yet reduce movement that causes bleeding due to “gel” structure of cured emulsion.	• Does not cure as quickly as CRS (but more quickly than cutback). • Industry participants may not be as familiar with this product as CRS, depending on geography and local experience. • Some hydrocarbons released during curing due to the use of cutter (kerosene) in this product (much less than standard cutback).
Polymer-modified (added either to CRS or high float)	• Greater flexibility during cold weather, mitigates cracking. • Greater stiffness in warm weather, mitigates bleeding and retains aggregate in areas of turning, accelerating, and decelerating traffic. • Higher early strength during curing leads to better chip retention.	• Higher cost compared to non-polymer-modified binder.

Problems with Aggregate and Binder Interactions

Dusty Aggregate Problems

Dusty aggregate does not react well with some binders that are used in TMS. This is because the dust particles, which have a large negative charge on them, prevent good adhesion between the aggregate and the asphalt binder because the binder binds to the dust instead of the aggregate. If dust-free aggregate is not available, the following must be done:

- The material needs to be washed with clean potable water and then the cleaned aggregate needs to be restockpiled and allowed to dry.
- A cutback or high float emulsion should be used for the binder as stated above.
- The aggregate should be pre-coated with a thin film of asphalt emulsion or hot asphalt cement. Precoating aggregate increases aggregate retention.
- If a precoating process is to be performed, the dust content should be limited to no more than three percent[2].
- Even though some asphalt has been applied to the aggregate during the pre-coating process, the amount of asphalt binder to be applied to the roadway should be the same as that for non-precoated aggregate. The aggregate chips should be considered as "black rock" with the precoat asphalt assumed to provide little actual binding properties.
- For precoated aggregates more than 90 percent of the visible area should be covered[2].
- The cost of precoated aggregate is higher than untreated aggregate, but there is less aggregate loss and better bonding between the aggregate and the asphalt binder. The cost of pre-coated aggregate is around $19/ton, delivered[3].

Stripping Problems of Aggregate

Some high-quality aggregates do not bind well with any type of binder; quartzite is one example of these aggregates. To reduce the stripping of the aggregate from the road surface and the binder, two things can be done; either the material can be dried or an anti-stripping agent can be added to the material.

Dried Aggregate

- The susceptibility of stripping aggregate from the roadway is reduced when dried aggregate is used compared to the use of aggregate with its natural field moisture content.
- The amount of stripping of dried aggregate is reduced by about 25 percent by using dried aggregate compared to aggregate at its field moisture content[4].

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[2] Kandhal, P. S., and Motter, J. B. 1991. Criteria for Accepting Precoated Aggregates for Seal Coats and Surface Treatments. *Transportation Research Record 1300*, 80-89.
[3] Parker, G. 2002. E-mail to author, July 31.
[4] Selim, A. A. 1989. Enhancing the Bond of Emulsion-Based Seal Coats with Antistripping Agents. *Transportation Research Record 1217*, 46-52.

Anti-Stripping Agents

- The use of anti-stripping agents with the aggregate enhances chip retention the most when compared to using aggregate with its field moisture content and aggregate that has been dried.
- With the use of Redicote-82-S as the anti-stripping agent, the amount of aggregate loss is about 30 percent less than the amount of aggregate loss when using aggregate with its field moisture content (Salim, 1998).
- Anti-stripping agents should be added to the emulsion instead of applied to the aggregate itself for the following reasons[5]: This yields a higher friction value. It is much easier and cheaper to add the agent to the emulsion than to try and coat the aggregate.
- The use of an anti-stripping agent and dried aggregate further increases the amount of initial aggregate that is retained.
- The skid resistance of the road surface seems to be improved with the use of an anti-stripping agent. The addition of the agent reduces the amount the aggregate is allowed to rotate.

[5] Selim, A. A., and Tham, T. 1993. Improving Chip Retention and Reducing Moisture Susceptibility of Seal Coats. *Transportation Research Record 1392*, 20-26