CHAPTER 3. ASPHALT BINDERS

The main reason asphalt is used in road applications is because it is waterproof and adheres to stone. At room temperature, most asphalts are very stiff, too stiff to apply to a roadway. To get it into a form that can be applied requires the viscosity to be reduced. This can be done by:

- Heating
- Making a cutback asphalt
- Making an asphalt emulsion

The two methods most often used for constructing seal coats are using cutback asphalts and asphalt emulsions.

CUTBACK ASPHALTS

Cutback asphalts (liquid asphalts) are asphalts that are dissolved in a petroleum solvent (cutter). Typical solvents include naptha (gasoline) and kerosene. The type of solvent controls the curing time of the cutback and thus when it will obtain its ultimate strength. Rapid curing cutbacks use naptha (gasoline) while medium curing cutbacks use kerosene. The amount of cutter affects the viscosity of the cutback asphalt. The higher the cutter content, the lower the viscosity and the more fluid it will be. The use of cutbacks has declined rapidly over the years due to concerns over pollution and health risks as the solvents evaporate into the atmosphere.

One advantage cutbacks have over emulsions is a much higher residual asphalt percent, typically over 80 percent. This compares with just over 65 percent for asphalt emulsions. The result is more asphalt cement left on the roadway after curing, for the same volume of binder applied.

Cutback Classification

Cutbacks are divided into two classifications, Rapid-Curing (RC) and Medium-Curing (MC) depending on the solvent used. They are further defined by a number which indicates the minimum kinematic viscosity (fluidity) of the cutback. The lower the number, the more fluid the cutback is. The shaded grades in Table 3.1 are the ones typically used for seal coating.

Table 3.1. Cutback Asphalt Grades and Properties (Mn/DOT 3151.2B & 3151.2C)

Cutback Grade	Curing Speed	Viscosity of Cutback[A]	Penetration of Residue[B]
MC-30	Medium	30 - 60	120 - 150
MC-70	Medium	70 - 140	120 - 150
MC-250	Medium	250 - 500	120 - 150
MC-800	Medium	800 - 1,600	120 - 150
MC-3000	Medium	3,000 - 6,000	120 - 150
RC-70	Rapid	70 - 140	80 - 120
RC-250	Rapid	250 - 500	80 - 120
RC-800	Rapid	800 - 1,600	80 - 120
RC-3000	Rapid	3,000 - 6,000	80 - 120

[A]Kinematic viscosity of the cutback at 140 deg.F (60 deg.C), centistokes
[B]Penetration of the residue at 77 deg.F (25 deg.C), 100g, 5 sec.

ASPHALT EMULSIONS

An emulsion is one phenomena that occurs when you mix two incompatible components together. Common examples of emulsions are milk, margarine, butter, beer and paint. Emulsions are made up of two components with one dispersed in the other. Maintaining the dispersion requires some way of overcoming the lack of compatibility. The methods that have been found to work over many years are high shear blending and chemical treatment. An asphalt emulsion consists of asphalt particles dispersed in water and chemically stabilized as shown in Figure 3.1.

As molten asphalt is blended into fine droplets, the asphalt is brought into contact with a chemical solution (emulsifier) which provides the stabilization. After discharge, the emulsion consists of water with fine particles of asphalt dispersed in it. The only thing between the asphalt particles is water and the emulsifier. Since asphalt is not soluble in water, keeping it dispersed in fine particles is a significant feat.

Emulsion Classification

Emulsions are divided into three grades for classification: cationic , anionic and non-ionic. In practice, only the first two types are used in roadway construction and maintenance. The cationic and anionic designation refers to the electrical charge of the emulsifier surrounding the asphalt particles. Cationic emulsions have a positive (+) electrical charge surrounding the asphalt particles while anionic emulsions have a negative (-) electrical charge.

Since opposite electrical charges attract, anionic emulsions should be used with aggregates having a positive (+) charge. Similarly, cationic emulsions should be used with aggregates having a negative (-) charge. Failure to use materials with opposite electrical charges may result in the materials repelling each other, causing failure.

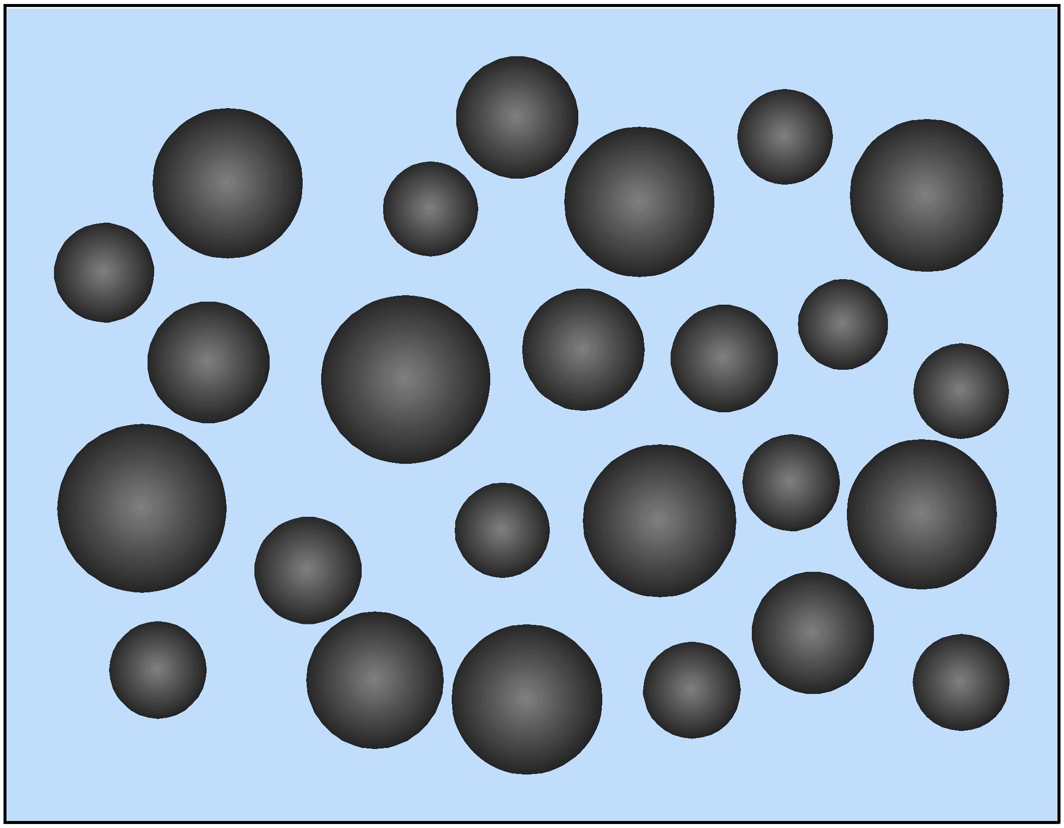

Figure 3.1. Asphalt emulsion

In addition to being classified by their electrical charge, emulsions are further classified according to how quickly they will revert back to asphalt cement. The terms RS, MS and SS have been adopted to simplify and standardize this classification. They are relative terms only and stand for Rapid-Setting, Medium-Setting and Slow-Setting. As the emulsifier is drawn toward aggregate surfaces with an opposite electrical charge, the asphalt particles begin to settle to the bottom of the emulsion. The speed at which this occurs is indicated by the RS, MS and SS designation.

Five grades of high-float emulsions are also available. High-float emulsions, so designated because they pass the Float Test (AASHTO T-50 or ASTM D-139), have a quality imparted by the addition of certain chemicals that permit a thicker asphalt film on the aggregate particles with a minimum probability of drainage. This property allows high-float emulsions to be used with somewhat dusty aggregate with good success.

Finally, emulsions are subdivided by a series of numbers that relate to the viscosity of the emulsion and the hardness of the base asphalt cement. The numbers “1" and “2" are used to designate the viscosity of the emulsion. The lower the number, the lower the viscosity and the more fluid the emulsion is. If the number is followed by the letter “h”, the emulsion has a harder base asphalt. The grades in the following tables which are shaded are suitable for seal coat projects.

Table 3.2. Anionic (-) Emulsified Asphalt Grades (Mn/DOT 3151.2E)

Grade	Setting Speed	Viscosity of Emulsion[A1]	Penetration of Residue[B]
RS-1	Rapid	20 - 100	100 - 200
RS-2	Rapid	75 - 400[A2]	100 - 200
HFRS-2	Rapid	75 - 400[A2]	100 - 200
MS-1	Medium	20 - 100	100 - 200
MS-2	Medium	$\geq$100	100 - 200
MS-2h	Medium	$\geq$100	60 - 100
HFMS-1	Medium	20 - 100	100 - 200
HFMS-2	Medium	$\geq$50[A2]	100 - 200
HFMS-2h	Medium	$\geq$50[A2]	60 - 100
HFMS-2s	Slow	$\geq$50[A2]	$\geq$200
SS-1	Slow	20 - 100	100 - 200
SS-1h	Slow	20 - 100	60 - 100

[A1]Emulsion Viscosity, Saybolt Furol at 77 deg.F (25 deg.C), sec.
[A2]Emulsion Viscosity, Saybolt Furol at 122 deg.F (50 deg.C), sec.
[B]Penetration of Residue at 77 deg.F (25 deg.C), 100 g, 5 sec.

Table 3.3. Cationic (+) Emulsified Asphalt Grades (Mn/DOT 3151.2E)

Grade	Setting Speed	Viscosity of Emulsion[A1]	Penetration of Residue[B]
CRS-1	Rapid	20 - 100	100 - 250
CRS-2	Rapid	100 - 400	100 - 250
CMS-2	Medium	50 - 450	100 - 250
CMS-2h	Medium	50 - 450	60 - 100
CSS-1	Slow	20 - 100[A2]	100 - 250
CSS-1h	Slow	20 - 100[A2]	60 - 100

[A1]Emulsion Viscosity, Saybolt Furol at 122 deg.F (50 deg.C), sec.
[A2]Emulsion Viscosity, Saybolt Furol at 77 deg.F (25 deg.C), sec.
[B]Penetration of Residue at 77 deg.F (25 deg.C), 100 g, 5 sec.

Emulsifiers

Emulsifiers are the chemical solutions that give the asphalt particles the ability to stay suspended in water. The two types of emulsifiers; cationic and anionic are both comprised of salts.

a) Anionic Emulsifiers are comprised of acids reacted with a base such as caustic potash or caustic soda to form a salt. It is this salt that is the active emulsifier. The emulsifier attaches itself to the asphalt particles. The number and density of these emulsifier molecules determine how much negative (-) charge is on the surface of the asphalt particles. Figure 3.2 shows an anionic emulsified asphalt particle.

b) Cationic Emulsifiers are also made of acid salts. Cationic emulsifiers give a positive (+) charge to the asphalt particles. The most often used emulsifiers in Minnesota, by a wide margin, are cationic. This is because most aggregates have a negative charge and thus attract cationic emulsifiers, causing a good bond. Figure 3.3 shows a cationic emulsified asphalt particle.

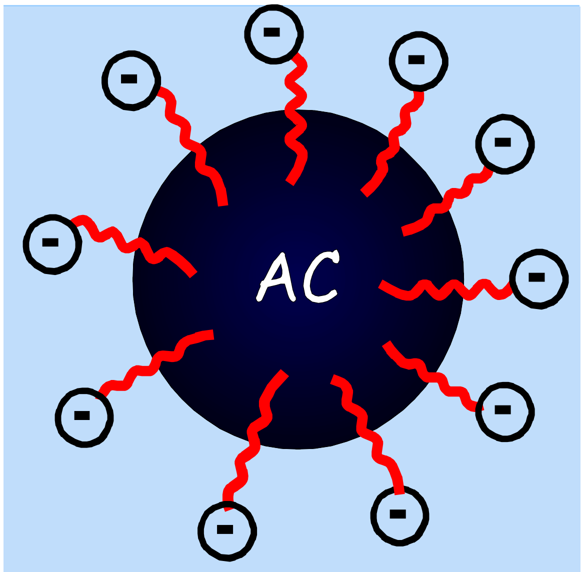

Figure 3.2. Anionic (-) Emulsion

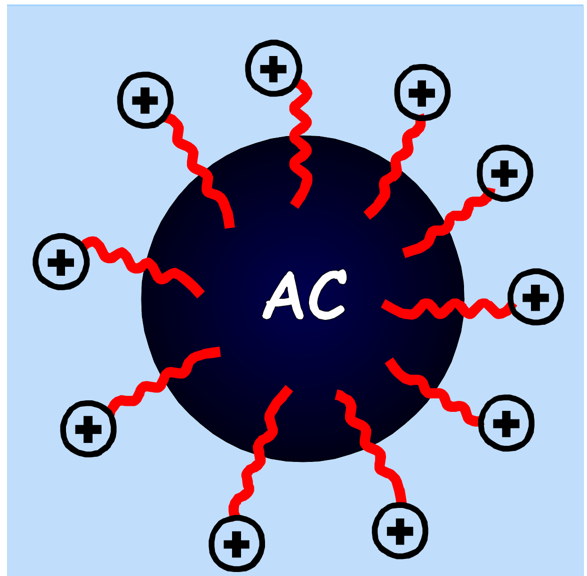

Figure 3.3. Cationic (+) emulsion

Cationic Versus Anionic

Overall, cationic emulsions perform more reliably in the field and set up more quickly than anionic emulsions, provided the correct handling and application procedures are used.

In addition:

- Cationics are less sensitive to weather because they have a chemical break.
- Cationics can be stabilized without making break times longer.
- Cationics are more critical in handling.
- Cationics need close attention to storage procedures.
- Cationics are more suitable for aggregates, silica aggregates included.
- No precoat is required for a cationic emulsion if aggregate is clean and dust-free.

Properties of Emulsions

All the properties of emulsions and their behavior under various conditions are directly related to the type and strength of emulsifier used.

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 it's attraction to the surface of the aggregate. Since asphalt is heavier than water, the asphalt particles will settle to the bottom of the solution.

Since ***anionic emulsions*** have a negative charge, as does almost every mineral, there will be no electrostatic attraction between the emulsion and the aggregate surface since like charges repel each other. For an anionic emulsion to break the particles must get so close to each other that the repulsion forces are overcome by the attractive forces that exist between all things. This occurs by forcing the particles together in some way. During seal coating, this occurs as the water evaporates out of the emulsion. In Minnesota, the most commonly used anionic emulsion for seal coating is HFMS-2.

Cationic emulsions have a positive charge and since opposite charges attract, they are drawn toward most aggregate particles. Thus, a direct and very rapid reaction between the emulsion and an aggregate or pavement is possible as shown in Figures 3.4 and 3.5. The size of the charge, affects stability, ie. the larger the charge, the more rapid the reaction. The other mechanism which affects curing is evaporation. After the chemical break is completed, the water must still be completely evaporated for the residual asphalt to achieve full strength. In Minnesota, the most commonly used cationic emulsion is CRS-2.

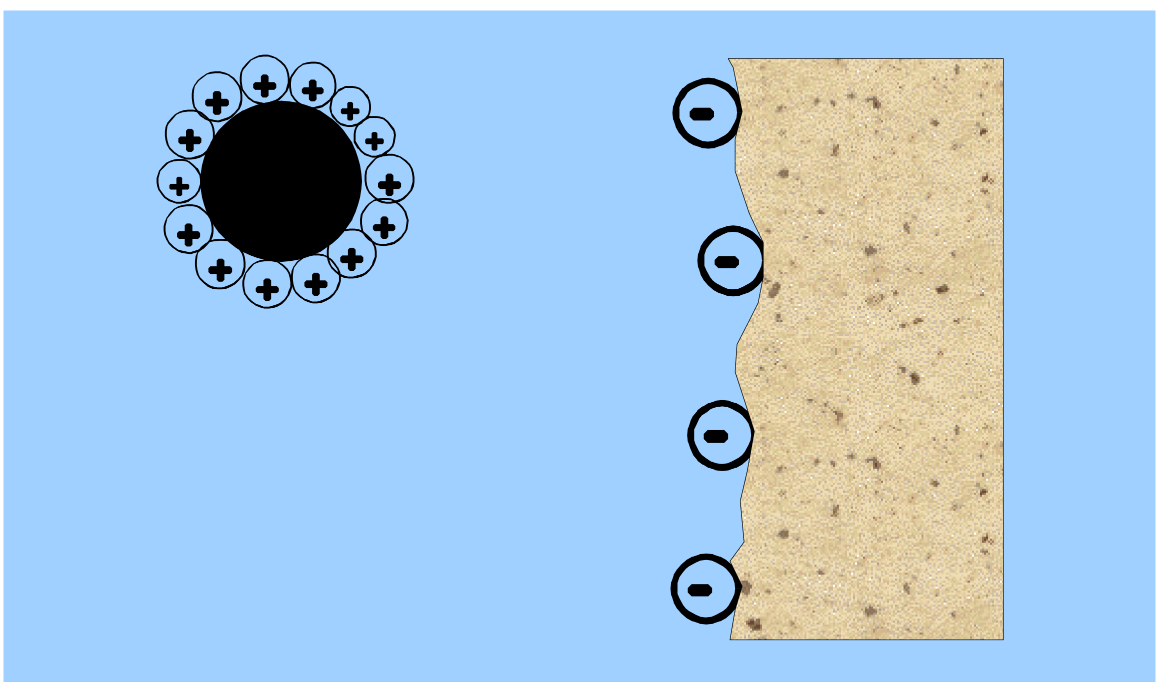

Figure 3.4. Cationic Emulsion before "breaking".

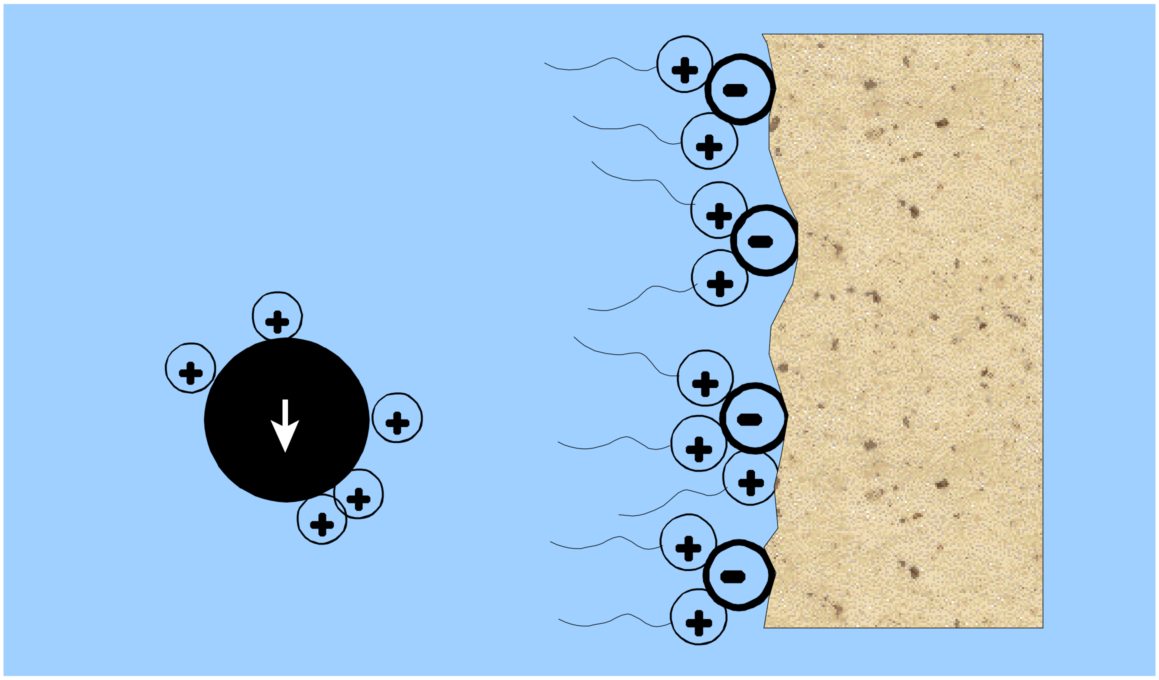

Figure 3.5. Cationic emulsion beginning to "break"

Polymer Modified Emulsions

Certain properties of asphalt emulsions can be enhanced by the addition of polymers. Common polymers used in emulsions are natural and synthetic latex, SBR and SBS polymers. Typically, about 2.5 to 3 percent polymer, by weight, is added to the emulsion.

Advantages of using polymers are:

- Increased viscosity of the residual asphalt which helps to minimize bleeding
- Better early chip retention due to increased early stiffness
- Enhanced flexibility over time

The main disadvantage of using polymer modified emulsions is the additional cost. Modified emulsions typically cost 30 percent more than conventional emulsions. However, in high traffic areas where windshield damage is a concern, the added cost is often warranted.

ADVANTAGES OF ASPHALT EMULSIONS

The main advantages of using emulsions rather than cutbacks can be summarized in terms of pollution control and safety.

Pollution Control

Kerosene and gas fumes are green house gases. In a cutback, they evaporate into the air and become pollutants. The cutbacks are designed this way. In an emulsion, there are no such pollutants.

Safety

Since emulsions are water based, they have no flash point and are not flammable or explosive. Drums of emulsion kept in the sun will not expand or burst. Being water based, emulsions do not pose any health risk to workers. Since they can be used at cooler temperatures (125 - 185^o F., 52 - 85^o C.), the likelihood of severe burns is also much less. The binder material should be accompanied by a Material Data Safety Sheet (MSDS).

STORAGE AND HANDLING OF ASPHALT EMULSIONS

As discussed earlier, there are advantages of using emulsions compared to hot asphalt cement and cutbacks. There are a few simple rules for successful use of asphalt emulsions. They are simple if one remembers how emulsions are made.

Pumping

Pumps compress or shear the material that they pump. This results in the emulsion being compressed. If this happens too severely or often the emulsion will become coarser and may go back to asphalt cement. Pumps should be selected carefully. Centrifugal pumps and some types of positive displacement pumps may be used.

Temperature

When materials get cold they shrink. In an emulsion, this means that the asphalt droplets get closer together. Thus, if the emulsion gets too cold, the asphalt particles can become too close together causing the emulsion to revert back to asphalt cement.

When materials get hot they expand. Thus for an emulsion, heating is a useful thing. However, when water gets hot its evaporation rate increases enormously. If the water leaves the emulsion, the asphalt droplets get closer together and can go back to asphalt cement. If any part of the emulsion gets hotter than 200^{o}F (95^{o}C), localized boiling may occur causing the droplets back to asphalt cement.

This has a number of important results:

- When heating emulsion, do it gently and only to specification.
- Use agitation.
- Warm pumps before use.
- On bulk tanks in cold areas, electrical tracing is advisable.
- Do not apply direct heat to an emulsion with a fire or blow torch.

Cleaning

For emulsions, cleanliness is very important. A sloppy operation will produce problems. When an emulsion comes in contact with air it can begin to break. When a cationic emulsion comes into contact with metal it can also begin to break. Thus, if a pump is left without flushing it will clog. If lines are left part full of emulsion they will clog. The higher the performance of the emulsion the more critical cleaning is. Cleaning should be done before storage of equipment and it should be done thoroughly.

Cleaning Procedure:

1. Flush thoroughly with WATER.

2. Flush with kerosene, not diesel, distillate or other solvent. While these materials may cut asphalt cement but they are also incompatible with the emulsion and may break it rather than allow it to be flushed away.

3. Finish with a water flush. DO NOT FLUSH INTO THE EMULSION TANK.

4. If the pump or line is already clogged with asphalt cement, gentle heat may be applied at the blockage. Do not apply up the line as this will break the emulsion there.

5. Soak pumps with kerosene for an hour or more.

6. Reflush with water after blockage is removed.

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