Understanding and Using Asphalt

Asphalt is a dark brown to black material mostly made of hydrocarbons. Natural deposits exist in Lake Trinidad, Venezuela; in the La Brea Tar Pits near Los Angeles; and in porous rock called rock asphalt. However, most asphalt used today comes from crude petroleum.

Asphalt is what remains after crude petroleum is distilled to produce fuels and lubricating oils. The amount of asphalt in a crude ranges from a few percent for light crudes to about 60% for heavy crudes. An asphalt's properties depend on the crude petroleum's chemical make-up and on the refining process.

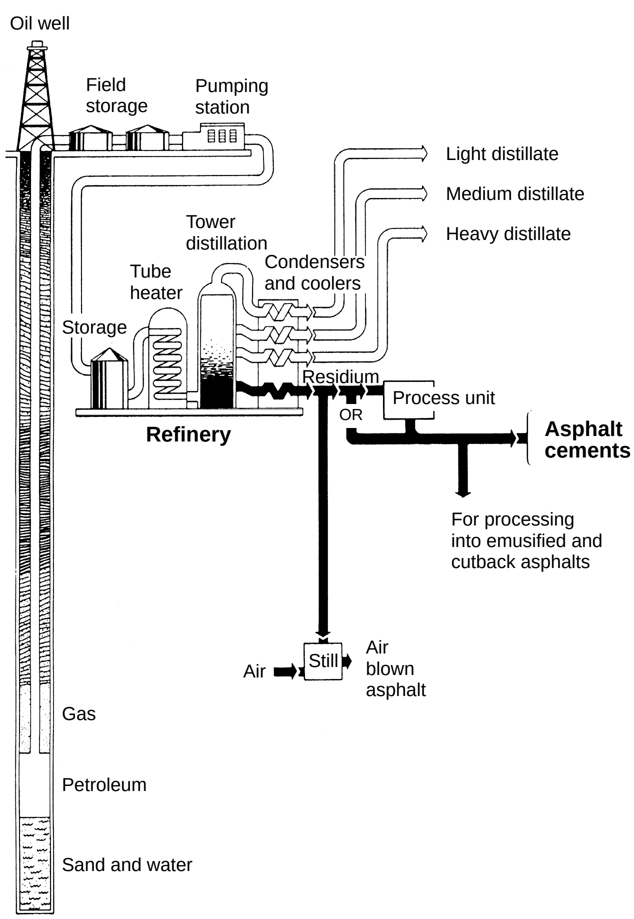

Figure 1. Production of asphalts from refining petroleum crudes

Asphalt is valuable for construction because it is sticky, waterproof, strong, and durable. It is also highly resistant to many acids, alkalis and salts. People have known of asphalt's advantages at least since the ancient Mesopotamians who used it about 5000 years ago to cement masonry and build streets, and to waterproof temple baths and water tanks. It may even have been used as a water repellent in Noah's Ark. The first asphalt pavement was laid in Newark, New Jersey in 1870.

Today asphalt is by far the most widely used paving material. About 96% of the 2.4 million miles of paved roads in the United States are paved with some type of asphalt. Not surprisingly, more than 85% of all asphalt produced today is used for paving applications. The rest is used in buildings, agriculture, hydraulics, erosion control, industry, railroads, and other applications.

Although asphalt is solid or semi-solid at normal air temperatures, it is produced in a variety of types and grades ranging from hard, brittle solids to almost water-thin liquids. It is liquefied by heating, by adding a solvent (making a product called *cutback*), or by emulsifying with water and an emulsifier (creating a product called *emulsion*). As a liquid it can be sprayed directly on a surface or mixed with aggregate and sand.

This bulletin describes the properties and uses of the three most common types of construction asphalts.

Asphalt types

Three general types of asphalts are used in construction today: asphalt cement, emulsified asphalt, and cutback asphalt.

Asphalt cement, also called paving asphalt, is a component of hot mix asphalt which is primarily used to construct flexible pavements (blacktop). This material is different from the other two types of asphalt because it is semi-solid and highly viscous (resistant to flow) at normal air temperatures.

Asphalt cement is liquefied by heating then mixed with aggregates to produce hot mix. The mix is kept hot until it is spread on the road and compacted. Being very sticky, asphalt cement adheres to the aggregate particles and binds them together. After cooling to normal air temperature, hot mix makes a very strong paving material which can sustain heavy traffic loads.

Asphalt cements are produced in different grades that vary in consistency or resistance to flow. To maintain acceptable consistency in pavements, softer grades are usually used in cold climates while harder grades are used in hot climates.

Emulsified asphalt, or emulsion, is made from asphalt cement. It is tiny particles of asphalt cement mixed with water and an emulsifying agent — usually a detergent. Emulsions were first developed in the early 1900s and began being widely used in 1920s for dust control. Emulsions are called liquid asphalts because, unlike asphalt cements, they are liquid at normal air temperatures and therefore do not require heat to liquefy.

To produce emulsions, hot asphalt cement and water containing the emulsifying agent are pumped at high pressure through a colloid mill. The emulsifying agent coats the asphalt particles and puts an electric charge on their surfaces. This charge causes the asphalt droplets to repel one another so they don't combine. These charges are used to categorize emulsions as cationic (positive charge) or anionic (negative charge).

Charges are important because they affect the compatibility of emulsion with mineral aggregates. An *anionic* emulsion should be used with limestone aggregate that usually bears a positive surface charge. A *cationic* emulsion should be used with siliceous gravel and sandstone because these aggregates usually bear a negative surface charge.

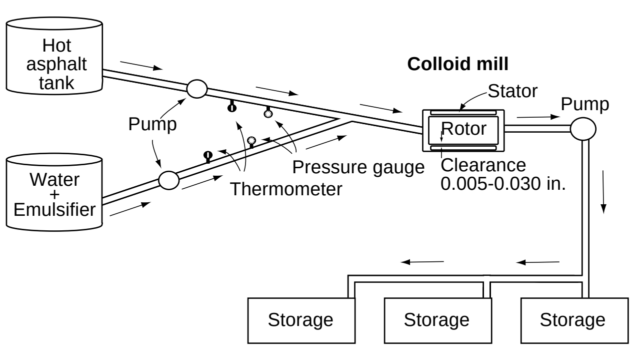

Figure 2. Manufacture of emulsified asphalt

After an emulsion is mixed with aggregates it sets or breaks. The asphalt droplets react with the aggregate and coalesce or combine, squeezing out the water. The water then evaporates, leaving the asphalt droplets to set and produce a continuous film on the aggregates.

All emulsions are further graded according to their setting rate: *rapid setting (RS), medium setting (MS),* and *slow setting (SS)*. The type and amount of emulsifying agent controls the rate of setting.

Select and use emulsions according to their setting rates. ASTM Standard D3628 recommends that RS emulsions be used for seal coats and penetration macadam pavements. The MS emulsions are recommended for open-graded cold asphalt-aggregate mixtures. SS emulsions are used for tack coats, slurry seals, and dense-graded cold asphalt-aggregate mixtures.

Cutback asphalt is another liquid asphalt that can be used at normal air temperatures without heating. Cutbacks are produced by adding (cutting back) petroleum solvents to asphalt cements instead of water. Cutback asphalts set when the solvent evaporates after being applied to the aggregate. The evaporation rate depends on the type and amount of solvent used in the cutback.

Cutbacks have three grades based on relative evaporation rates. *Rapid-curing (RC)* is produced by adding a high volatility solvent such as gasoline or naphtha. *Medium-curing (MC)* is produced by adding an intermediate volatility solvent such as kerosene. *Slow-curing (SC)* is produced by adding an oil of low volatility such as diesel or other gas oil.

RC cutbacks set faster than MC which in turn set faster than SC. Cutbacks come in different grades that vary significantly in their consistency. Specifications are given in the following ASTM Standards: D2026 for SC, D2027 for MC, and D2028 for RC.

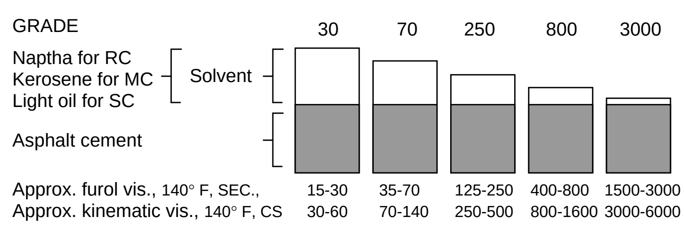

Figure 3. Composition of cutback asphalts

Cutbacks are increasingly being replaced by emulsions due to environmental regulations and other concerns. Emulsions release far fewer volatiles into the atmosphere and aren't as wasteful of high-energy, high-cost products. Cutbacks have low flash points and are less effective than emulsions when applied to damp aggregate, pavements or soils.

Cutback use is restricted in Wisconsin. Rapid-curing and medium-curing cutbacks can be used as a prime coat or for dust control only during May and September. All other uses of these cutbacks are prohibited during these months as well as the other months of construction season. Use of slow-curing cutbacks is not restricted.

Main uses of asphalts

Asphalts are used in two ways. They are either mixed with aggregates at plants then hauled to the paving site and compacted on the road, or they are sprayed in relatively thin layers with or without aggregates.

Plant mixed asphalt products are called *asphalt concrete mix.* These can be produced and laid down hot, using asphalt cements, or cold, using emulsions or cutbacks. These mixes usually contain about 5% asphalt and 95% aggregates by weight. Aggregates give the mix most of its ability to carry or resist loads while the asphalt coats and binds the aggregate structure.

Hot laid mixes, also called hot mix asphalt, are produced by mixing heated aggregates and asphalt cements in special mixing plants. These very strong, stiff mixes are usually used for surface and subsurface layers in highways, airports, parking lots, and other areas which carry heavy or high volume traffic.

Cold asphalt mixes are produced by mixing damp, cold aggregates with emulsions or cutbacks at mixing plants — either stationary plants or portable ones brought to the site. Although not as strong and stiff as hot mix, cold mixes may be more economical and flexible, and less polluting. They are used for areas with intermediate and low traffic, for open graded mixes, and for patching.

Sprayed asphalt applications include asphalt-aggregate applications, usually called surface treatments or seal coats, and asphalt-only applications such as tack coat, prime coat, fog seal, and dust prevention.

Surface treatments and seal coats usually include one or more applications of asphalt and aggregate which are less than 25 mm (1 in.) thick each. Examples are sand seal, chip seal, double and triple seal, and slurry seal.

A single seal involves spraying an asphalt product and following at once with a thin (3⁄8 in.) aggregate cover. The cover is rolled as soon as possible so that two-thirds of the aggregate depth is embedded into the asphalt layer. For multiple seals, the process is repeated a second or third time. Each succeeding time the aggregate should be about half the size of that used in the previous layer.

Slurry seal is different from other sprayed applications because the asphalt emulsion is mixed with the aggregates in a special truck mixer just before spreading.

Surface treatments are used to provide:

- low-cost, all-weather surfaces for light traffic roads
- waterproof layers to keep water from penetrating into underlying layers
- skid resistant surfaces for pavements that have become slippery
- temporary cover for base courses
- renewal for pavements which have deteriorated from aging and cracking

Asphalt-only surface applications are very thin surface applications. They are used as follows:

- *Tack coat* to ensure bond between new and old surface.
- *Fog seal* to seal small cracks and surface voids and renew old asphalt surfaces that have become dry and brittle with age.
- *Prime coat* to prepare a granular base for an asphalt mix surface course by strengthening, waterproofing and improving adhesion.
- *Dust palliative* to keep dust down and make a road passable in bad weather.
- *Mulch treatment* to temporarily stop soil erosion during vegetation growth.

Several grades and types of asphalt are suitable for each type of construction. Choosing the grade depends mainly on climate conditions at the job site. Colder sites usually require softer grades of asphalts. Pollution regulations in Wisconsin limit the use of certain grades of cutbacks. Emulsion use may be limited during certain weather conditions. Seasonal restrictions are necessary to ensure proper curing and setting.

Pavement maintenance and rehabilitation

Asphalts play a major role in maintaining and rehabilitating pavements. For every type of pavement failure (distress) there is at least one asphalt type that can treat the damage. There are four major types of pavement failures: cracking, distortion, disintegration, and slippery surface. These are described and illustrated in the *Asphalt PASER Manual* available from the Wisconsin Transportation Information Center (see References).

Cracking includes thermal, reflective, alligator, joint, edge, slippage, and shrinkage cracks. Cracks create a rough surface which allows water to enter the base and sub-base and soften these layers and leads to pavement deterioration. Crack sealing is an effective maintenance treatment if done early in the life of the pavement.

Pavement distortions include rutting, shoving, corrugations, settlement depressions, and frost upheaval. These are some of the most serious pavement failures because they require major patching, rehabilitation or reconstruction to bring the pavement to good condition.

Disintegration of the pavement surface includes raveling and potholes. Raveling is the progressive loss of surface material by weathering and/or traffic action. It is caused by poor construction, inferior aggregates, poor mix design, or aging of the asphalt. An early application of a fog seal can retard raveling. Extensive raveling may require a slurry, sand, or chip seal depending on the surface condition and traffic. Potholes may be patched and are best treated with permanent pavement repairs.

Slippery surfaces are also a major concern because they make the pavement unsafe for vehicle stopping and maneuvering. They are caused either by excess asphalt or by polishing of aggregates. Bleeding or flushing is the result of excess asphalt in rich asphalt mixes, improperly constructed or designed seal coats, or a prime or tack coat which is too heavy. Heavy traffic can force or flush asphalt to the surface. Also, hydrophilic (water loving) aggregates may cause the asphalt to strip off and migrate to the surface.

Bleeding can often be corrected by repeated applications of hot sand, rock screenings, or coarse aggregates. Aggregates, which should be larger than the asphalt film thickness, are rolled into the film. If bleeding is light, you may also apply a hot-mix asphalt friction course or an aggregate seal coat with absorptive aggregates.

Traffic action polishes aggregates. The condition is common with certain types of weak aggregates. The only way to repair this condition is to cover the surface with a skid-resistant treatment. A thin overlay, a sand seal, or a chip seal with hard angular aggregates should be used.

Properties and specifications for aggregates and asphalts

Selecting the proper types of asphalts and aggregates to construct a pavement or solve a pavement problem involves looking at different test results which describe their properties. Asphalt and aggregate are usually defined by a specification system which gives the range of properties needed to meet a certain grade or type.

Aggregates for asphalt mixtures

The amount of aggregate in an asphalt paving mixture is generally 90%-95% by weight or 75%-85% by volume. Asphalt pavement performance is heavily influenced by aggregates which carry most of the traffic loading. Their suitability for construction depends on size, gradation, toughness, cleanliness, shape, absorption, and affinity to asphalt. Size and gradation (mix of various sizes) are the most important.

When aggregates of different sizes are combined, then mixed with asphalt and compacted, the resulting structure should have a reasonable amount of voids. These voids, also called *voids in the mineral aggregates* (VMA), provide space for asphalt coating and for expansion from temperature changes.

Aggregates in the field are usually stockpiled in different sizes. These should include at least fine and coarse piles. Some contractors use several fine and coarse aggregates to compose a mix at optimum cost. *Coarse* aggregates have a maximum size larger than ¼ inch. *Fine* aggregates are equal to or smaller than ¼ inch.

Gradation is the distribution of sizes as a percentage of the total weight of the aggregates. WisDOT specifications have gradation bands that specify the allowable limits on several selected sizes. Standardized sieves are used to measure the gradation of a combined aggregate. The aggregate is shaken through a stack of sieves in which the top one has the largest opening and the bottom one has the smallest. The aggregate left on each sieve is weighed and its percentage is calculated or plotted on a standard gradation chart.

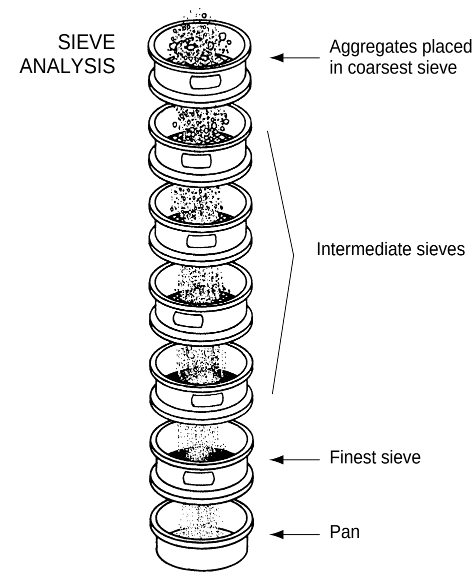

Figure 4. Determining size and gradation of aggregates

Toughness measures aggregate strength and resistance to polishing and breaking. It is measured by tumbling aggregate in a drum with steel balls. The amount lost when the aggregate is sieved on a specific sieve size is an indicator of toughness or resistance to abrasion.

Surface texture of aggregate influences its workability and the strength of the asphalt mixtures. A rough, sandpaper-like surface texture tends to increase strength more than a smooth surface. It requires more asphalt for the same workability.

Shape is important because it changes the workability and strength of asphalt mixtures. Irregular and angular particles, like crushed stone and gravel, tend to interlock more when compacted and therefore to resist displacement. An indicator of angularity is the percentage by weight of aggregates with one or more fractured surfaces. Some state agencies and certain mixture design procedures require a minimum percentage of aggregates with one fractured surface and two fractured surfaces.

Absorption is important because highly absorptive aggregate soaks a significant amount of asphalt into its pores, leaving too little to coat and lubricate the mix.

Affinity to asphalt is important particularly when pavements are subjected to high moisture. Aggregates with low affinity to asphalt lose their asphalt cover rapidly when it is stripped by water. Using hydrophilic or water loving aggregates, like quartzite and some granites, can result in major pavement failures when used in wet areas.

Asphalt cements

Asphalt is thermoplastic; it softens when heated and hardens when cooled. Asphalt pavements are subjected to a wide range of temperatures at which the asphalt should maintain enough stiffness and strength to prevent failures like cracking (at low temperatures) and rutting or shoving (at high temperatures).

Asphalt properties can be controlled using specifications from tests conducted at different temperatures. Grades for your location should be selected depending on your climate. In general, softer grades are used in cold climates while harder grades are used in hot climates. Viscosity, penetration, flash point, ductility, solubility, and specific gravity are the important properties.

Viscosity test This test measures the amount of time it takes for paving asphalt to flow between two markings in a capillary tube. The result is reported in *poises.* There are two types of viscosity tests. Absolute viscosity is done at 140° F (60° C) using a specific capillary tube attached to a vacuum pump. The pump is used to move asphalt in the tube between two points while time is measured. Kinematic viscosity is done at 275° F (135° C) using a narrower capillary tube without applying vacuum. The asphalt for this test is left to flow under its own weight and the time to flow between two markings is measured.

The temperature of 140° F was selected because it represents the average high temperature pavement asphalts reach in summer. The viscosity value at 140° F should be selected to ensure that the asphalt cement can resist pavement distortion.

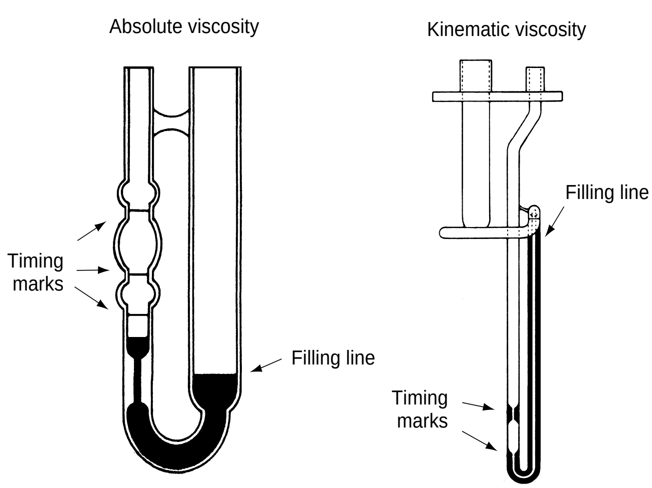

Figure 5. Viscometers for asphalt cement

In cold climates like Wisconsin an asphalt with a viscosity of 1000 to 2000 poises is used while in hot climates like the Arizona desert a viscosity of 3000 to 4000 poises may be required.

The 275° F temperature represents the temperature at which asphalt is mixed and compacted during construction. The viscosity at 275° F should be above a certain level to keep asphalt cement from running off during mixing and compaction, but should not be so high as to make mixing and compaction difficult.

Penetration test Although rapidly being replaced by the viscosity test, penetration is still used in specifications and referred to in selecting asphalts. A container of paving asphalt is brought to 77° F (25° C) then a needle of prescribed dimensions, supporting a 100 gram weight (3.53 oz), is allowed to bear down on the asphalt for exactly five seconds. The distance the needle penetrates into the asphalt is measured. This becomes the penetration value of the asphalt. Penetration is a measure of asphalt stiffness at intermediate pavement temperatures.

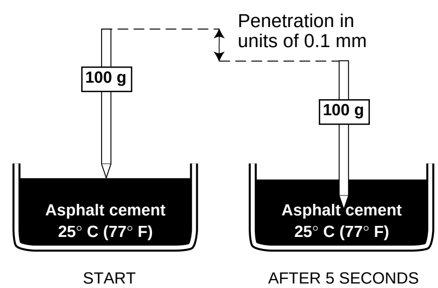

Figure 6. Penetration test

The value range should be such that the asphalt cement is not too hard to prevent cracking nor too soft to prevent distortion at temperatures dominating the pavement site. For example, in Wisconsin a 120-150 penetration asphalt is commonly used while in Arizona a 40-50 penetration asphalt is used.

Flash point test This test measures the temperature to which asphalt may be safely heated without instantaneously igniting in the presence of an open flame. This temperature, however, is usually well below the temperature at which the asphalt will burn.

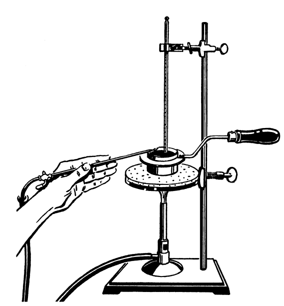

Figure 7. Flash point test

Ductility test This measures the ability of an asphalt cement to stretch without breaking. This test is conducted at 77° F (25° C). In it a specially shaped sample is submerged in a water bath and stretched at a rate of one cm (0.4 in.) per minute until it breaks. The elongation of the sample at break, measured in centimeters, is its ductility. Many asphalt technologists consider ductility a good indicator of asphalt quality and pavement durability. A higher value is more favorable.

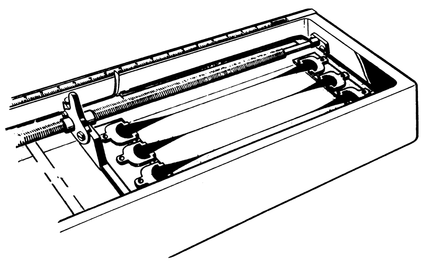

Figure 8. Ductility test

Solubility test This test measures the purity of the asphalt. It dissolves a sample of paving asphalt in a solvent and filters out the insoluble portions. The soluble portion represents the active cementing elements.

Specific gravity test This test measures the weight of a specific volume of an asphalt at a selected temperature. Specific gravity is the ratio of the weight of any volume of material to the weight of an equal volume of water at the same temperature. A designation of 1.05/60° F indicates that the material is 1.05 times as heavy as an equal volume of water when both are at 60° F. It is necessary to know the specific gravity of asphalt to design asphalt-aggregate mixtures. Specific gravity is used to estimate air voids and density, both indicators of well-designed mixes. Mix design influences the stability and durability of pavement layers.

Aging tests Asphalt cement testing also includes two aging tests. The thin film oven test (TFOT) is used to simulate how asphalt ages (reacts with oxygen and hardens) in the field during mixing, transport, and compaction. In this test 50 grams of asphalt are placed in standard 5 ½ inch diameter metal pans on a tray rotating inside a 325° F (163° C) oven. The asphalt is kept in the oven for 5 ¼ hours before it is taken out and tested. On the West Coast, the rolling thin film oven test (RTFO) is used instead of the TFOT.

Asphalt cement grades and specifications

Several standard grades of asphalt cement are available commercially. Currently, two standard specifications classify asphalt cement based on consistency measured at standard temperatures.

ASTM D946 is primarily controlled by the penetration test. Five standard penetration-graded asphalt cements are used for paving grade asphalt: 40-50, 60-70, 85-100, 120-150, and 200-300. Since higher penetration means softer asphalt cement, 40-50 is the hardest grade and 200-300 is the softest grade. This specification also includes requirements for flash point, viscosity at 275° F, ductility, and solubility.

ASTM D3381 is primarily controlled by the viscosity test. The test is either done on the original asphalt or after aging in the RTFO test. In both cases the viscosity is measured at 140° F (60° C) and reported in *poises*. Viscosity grades based on original asphalt tests are: AC-2.5, AC-5, AC-10, AC-20, AC-30, and AC-40. Grades based on the asphalt residue (AR) from the RTFO test are: AR-1000, AR-2000, AR-4000, AR-8000, and AR-16000. The grading also includes requirements for penetration, flash point, solubility, ductility, and solubility.

WisDOT standard specifications provide a valuable guide for quality control and design.

In the past few years the Strategic Highway Research Program (SHRP) developed a new asphalt binder grading system that uses new, more fundamental, engineering tests. The system, called *Superpave™ Performance-Graded (PG) binder specification,* is expected to be officially adopted within a few years. The system uses rheological tests to measure properties at pavement design temperatures which are estimated from actual weather data. Asphalt test temperatures ensure that it can perform adequately in the local environment. Superpave, which stands for **Su**perior **Per**forming **Pave**ments, is a complete system that also includes design, analysis, and performance prediction of asphalt mixtures.

Emulsified asphalt grades and tests

Emulsified asphalts are produced in several types and grades based on the emulsifying agent and other manufacturing controls. Emulsions can be anionic or cationic. There are several grades for each type:

Anionic	Cationic
RS-1	CRS-1
RS-2	CRS-2
MS-1	—
MS-2	CMS-2
MS-2h	CMS-2h
HFMS-1	—
HFMS-2	—
HFMS-2h	—
HFMS-2s	—
SS-1	CSS-1
SS-1h	CSS-1h

The *RS, MS,* or *SS* indicates the emulsion's rate of setting. The *h* means that a harder base asphalt is used.

The *HF* indicates high-float emulsion. This contains a chemical that permits the asphalt emulsion to form a thicker film on the aggregate with minimum drainage. Tests for emulsified asphalt properties measure viscosity, rate of setting, storage stability, particle charge, and ability to coat aggregates.

Saybolt Fural viscosity test measures the resistance of emulsified asphalt to flow at 77° or 122° F (25° or 50° C).

Settlement test is used to detect the tendency of asphalt globules in the emulsion to settle out and separate from water during storage for five days. The **storage test** can also be used. This uses a similar set-up but is completed in 24 hours. These tests determine how often the emulsion must be mixed to ensure proper application.

Sieve test complements the settlement test and determines the percent of asphalt cement present in the form of pieces, strings, or relatively large globules.

Classification test distinguishes between rapid-setting cationic emulsions and other types by their failure to coat a sand-cement mixture.

Demulsibility test indicates the relative rate at which asphalt globules in a rapid-setting emulsion will break when spread in a thin film on soil or aggregates.

Cement mixing test is used for slow-setting grades of emulsified asphalts.

Coating ability and water resistance test determines the ability of an asphalt emulsion to coat aggregates, to withstand mixing action, and to resist the washing action of water after mixing. The results of this test tell us which emulsions are suitable for mixing with coarse aggregates.

Particle charge test is used to separate anionic from cationic emulsions for rapid and medium setting grades.

Distillation test determines the relative proportion of asphalt cement and water in the emulsion. The residue from the test is the asphalt cement used in producing the emulsified asphalt. Additional tests including penetration, solubility, and ductility are made on the residue.

Cutback asphalt grades and tests

There are several grades for each of the three types of cutbacks — *rapid curing (RC), medium curing (MC),* and *slow curing, (SC).* The grades include 70, 250, 800, and 3000. These designations indicate the minimum allowable kinematic viscosity in *centistokes* measured at 140° F (60° C). One additional grade, MC-30, serves as a special priming grade in some sections of the United States. The maximum allowable viscosity for each grade is twice the minimum allowable. The most viscous (stiffest) grades of the three cutbacks (RC-3000, MC-3000, and SC-3000) are only slightly thinner than the lowest grade of asphalt cement (AC-2.5). The least viscous (thinnest) grades (RC-70, MC-70, and SC-70) have the consistency of dairy cream at a room temperature of 77° F (25° C).

Viscosity test used for cutbacks is the same as the kinematic viscosity test for asphalt cements except that it is performed at 140° F in a water bath instead of at 275° F in an oil bath. Several other tests are used for cutbacks.

Flash point is particularly important for cutbacks because they are normally used at temperatures above their flash point. This means they present some danger and should be handled properly. For the SC types, the Cleveland Open Cup Test (also used for asphalt cements) is used. Due to their high volatility, RC and MC types are tested with the Tag Open Cup Test which uses indirect heat.

Distillation test is used to separate the asphalt cement from the diluent (solvent). It determines the amount of condensate driven off at specified temperatures and shows both the volatility characteristics of the diluent and its quantity. The asphalt residue from RC and MC cutbacks is then tested for penetration, ductility, and solubility. For SC cutbacks only the total condensate is measured, and only kinematic viscosity is measured on the residue. SC cutbacks are also tested for solubility.

Water test measures the amount of water, if any, in cutback asphalts. Cutbacks should be water-free because water causes foaming when the material is heated, creating a hazardous condition.

Specific gravity of cutbacks is determined as for paving asphalts. It is useful in making volume corrections and in designing cold mixes.

Assuring quality with specifications

Asphalt concrete Because asphalt concrete is a mixture of asphalt cement and aggregates, the specifications used for ordering materials should cover both components. A mix design for the paving project is needed to determine the amount of asphalt for the specific aggregates. A different mix design is usually necessary for every source and maximum size of aggregate.

There are several standard mix design procedures. These involve making mixes of asphalt and aggregates in different proportions, compacting the mix samples in the laboratory using standard equipment, and measuring the volumetric properties and strength of the samples. The Marshall Mix Design method is commonly used. Mixes using four or five different asphalt contents are produced. Asphalt content is selected to give optimum density, resistance to load, and air voids. The mix design can then be used to check the quality of the asphalt concrete during construction.

Quality control and assurance are usually done by measuring mix density, asphalt content, air voids, and stability. Density and asphalt content are measured using nuclear gauges or by extracting samples from the finished pavement and using standard laboratory procedures.

Surface treatments Specifications for surface treatments should determine the type and grade of asphalt and the gradation and type of aggregate. The range of asphalt and aggregate application rates should be specified, but actual rates should be adjusted for field conditions; the asphalt grade and application rate is correct if:

- It is fluid enough when applied to spray properly and cover the surface uniformly, yet thick enough to remain in a uniform layer and not puddle in depressions or run off the pavement crown.
- It retains the proper consistency after application to wet the applied aggregate.
- It cures and develops adhesion quickly.
- It holds the aggregate tightly enough to the road surface after rolling and curing that it will not be dislodged by traffic.
- When applied in the right amount it does not bleed or strip with changing weather conditions.

Standard specifications Determine your specific job requirements. Consult the Wisconsin DOT manual *Standard Specifications for Road and Bridge Construction* when ordering materials, setting specifications, and determining construction procedures. This useful reference manual covers all aspects of road construction.

Inspection For good quality assurance you must inspect the construction process. Take samples of all materials to test for their compliance with your project specifications. Proper design specifications and inspection will pay for themselves through good quality construction.

Asphalt pavement recycling

Although timely maintenance can extend a pavement's usefulness, eventually its material will become old and need replacement. Old asphalt pavement materials do not have to be wasted. They can be recycled as part of the reconstruction process.

Old pavement material is called Reclaimed Asphalt Pavement (RAP). RAP is combined, as necessary, with new asphalt and/or recycling agents, and/or new aggregates to produce hot mix paving mixtures. This hot mix recycling process is widely used in Wisconsin.

Recycling is popular because it saves significantly both on costs and on natural resources, such as aggregates and asphalts. It also can improve pavements without changing their thickness, which is important under bridges and on streets with curb and gutter. When recycling is used, the RAP composition should be determined, including aggregate gradation, asphalt content, and asphalt viscosity. New aggregates and new asphalts, or recycling agents, should be added to meet the required new mixture design specifications. Recycled mixtures containing up to 50% RAP have shown performance in the field that is comparable to new mixtures.

References

This list includes both the sources for this factsheet and other recommended publications on asphalts.

Asphalt Institute publications

Available from the Asphalt Institute, Research Park Dr., PO Box 14052, Lexington, KY, 40512. All are in the *Manual Series* unless noted.

Asphalt Cold Mix Manual (MS-14), 3rd ed.

The Asphalt Handbook (MS-4), 1989.

Asphalt Hot-Mix Recycling (MS-20), 2nd ed.

Asphalt in Pavement Maintenance (MS-16), 1993.

A Basic Asphalt Emulsion Manual (MS-19), 2nd ed.

Introduction to Asphalt (MS-5), 8th edition.

Performance Graded Asphalt Binder Specification and Testing Superpave series No. 1 (SP-1), 1st edition.

Specifications for Paving and Industrial Asphalts Specification series No. 2 (SS-2), 1987-88.

Wisconsin Transportation Information Center

Available from the T.I.C., 432 North Lake St., Rm. 741, Madison, WI 53706, tel: 800/442-4615, fax: 608/263-3160.

Asphalt PASER Manual, 1987

Road Drainage, Wisconsin Transportation Bulletin No. 4

Seal Coating and other Asphalt Surface Treatments, Wisconsin Transportation Bulletin No. 10

Other publications

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 By Hussain Bahaia. (Figures 2 and 3 are adapted from **Hot Mix Asphalt.** All other figures are from **The Asphalt Handbook.** See references above.) **Wisconsin Transportation Bulletin** is a series of fact sheets providing information to local town, municipal and county officials on street and highway design, construction, maintenance and management. They are produced and distributed by the Wisconsin Transportation Information Center, a project of the University of Wisconsin-Madison Department of Engineering Professional Development, funded by the Federal Highway Administration, Wisconsin Department of Transportation and UW-Extension. Copies are available free while supplies last from the **Transportation Information Center,** UW-Madison, Department of Engineering Professional Development, 432 N. Lake Street, Madison, WI 53706. Phone: 800/442-4615; Fax: 608/263-3160; e-mail: Donald@Engr.Wisc.Edu