The Life Cycle of Asphalt

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Asphalt highway: I-495 in Maryland.

Editor's note: *When buyers and users of products have a need to influence the makers and sellers of those products to improve them, how and where do they get together to talk? When manufacturers need feedback on the performance of their products, or want reactions to proposed product changes, where are the established communications links to facilitate such exchanges? There are various responses to these questions, obviously, but one that has proved to be effective over the years is within the committee structure of the Transportation Research Board. TRB's attention to balance in the membership of each committee tends to ensure that all perspectives—users, manufacturers, sellers, academics, government, contractors, associations, and others—are represented. The institution's reputation for objectivity and fairness provides a climate in which these committee members can meet to exchange information freely for the benefit of all.*

In the following article, the work of the TRB Committee on General Asphalt Problems reveals how the TRB process has worked as a successful catalyst for communication between the producers and users of asphalts. Similar opportunities exist in many other standing committees of the Transportation Research Board! Those who want to take part are encouraged to get involved in the discussions of the TRB committees that deal with their particular areas of interest.

Asphalt properties change as soon as the asphalt is added to hot aggregate to form a paving mix. The rate of change is greatest during hot-mix production, followed by a more gradual hardening during its service life in the pavement. These changes in asphalt properties, particularly viscosity, are profoundly affected by the mix design and construction practices used. All asphalts are affected; only in degree are they different.

To define research needs, it is imperative to understand the entire design, construction, and weathering processes and their effect on asphalt, mix, and pavement behavior. This is the charge of the Transportation Research Board Committee on General Asphalt Problems. It is a "national user-producer committee" where all aspects of asphalt, asphalt supply, mix design, construction, and pavement life are discussed. The committee members include asphalt producers, members of the National Asphalt Paving Association, contractors, equipment manufacturers, members of the Asphalt Institute, highway engineers, representatives from FHWA, and representatives from ASTM and AASHTO Committees on Materials. Action items are referred to the appropriate TRB committees or to committee members. This article is a producer's view of what has been accomplished in paving asphalt tests and specifications and where we are heading. Some views on needed research are included.

ASPHALT PHASES PERTINENT TO PERFORMANCE

Asphalt passes through three phases during its service life before recycling:

1. As manufactured.
2. In the paving mix during and shortly after construction.
3. Aging in the pavement under traffic and weather.

These three phases are illustrated by the three temperature viscosity curves shown in Figure 1.

The first phase represents the asphalt as supplied to the user. Two viscosities are important: The viscosity at 135° C is useful for estimating the temperature at which the asphalt should be pumped and mixed. The viscosity at 60° C is used for grading asphalts and as one component in estimating the degree of hardening caused by heating. Other tests in this stage include solubility and flash point to satisfy purity, shipping, handling, and storage requirements.

Phase two represents the condition of the asphalt in the paving mixture during, and shortly after, construction. The asphalt hardens during production of the mix. The low-temperature viscosity (or stiffness) and temperature suscepti-

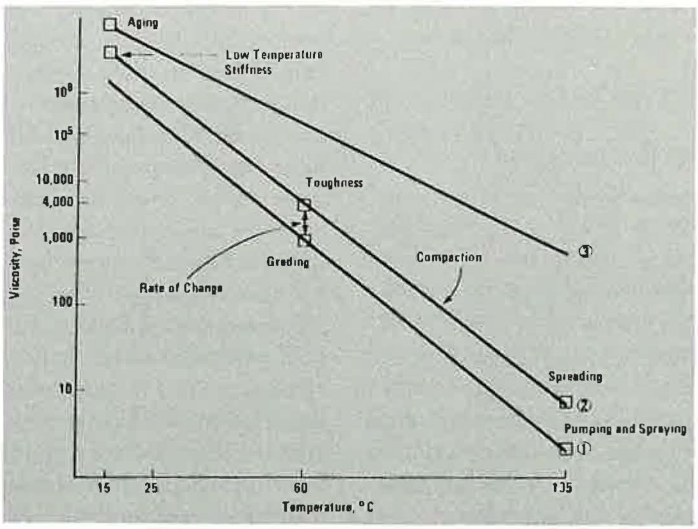

FIGURE 1 Functional paving asphalt specifications.

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bility are characteristics of asphalt that are considered during mix design to mitigate thermal cracking in cold climates. Penetration tests are normally used. The two viscosities at 60° and 135° C are particularly important during construction. Hot-mix hardening is estimated by comparing the 60° C viscosity before and after artificial aging. Current asphalt specifications typically permit no more than a fivefold increase.

The third phase represents the temperature-viscosity characteristics in the pavement after many years of useful service. The asphalt has hardened and may have also experienced syneresis—the separation of the asphalt into insoluble components. (Engineers say it has lost its "stickem and stretch.") Ductility at 25° C is the most commonly used test for syneresis. It measures the extension (elongation) at rupture (break).

These concepts, and their implementation in the form of new asphalt test procedures and specifications, have been a major concern of the Committee on General Asphalt Problems. The committee has supported the development of the viscosity at 140° and 275° F tests and the Thin Film and the Rolling Thin Film tests. Current ASTM and AASHTO Viscosity Graded Asphalt Specifications are based on these test methods. These specifications describe the asphalt as shipped from the refinery and during the Phase 2 paving process. They may not define asphalt that is aging in the road (see later discussion).

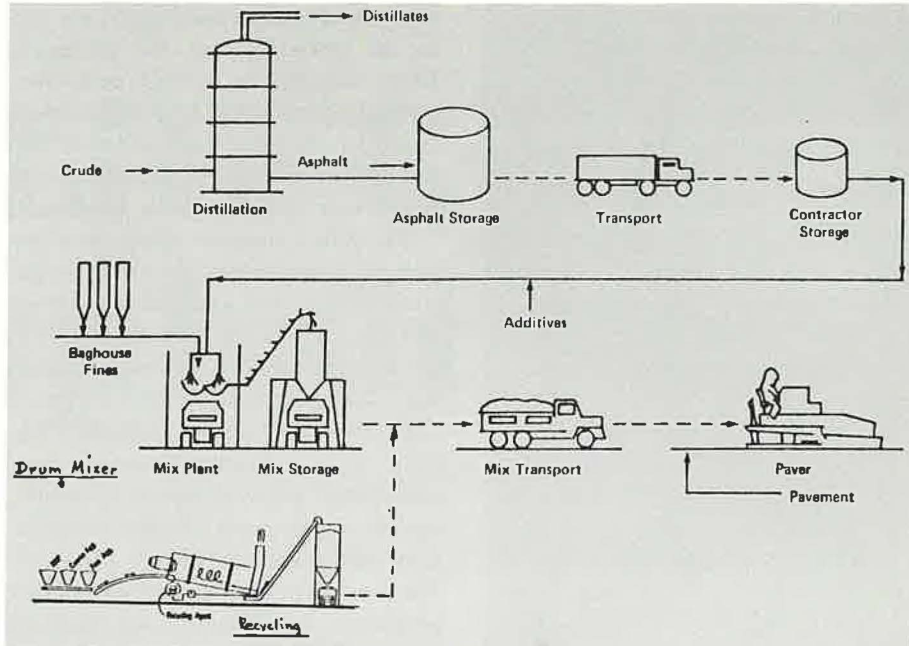

FIGURE 2 The paving process.

CONSTRUCTION PROCESS

The viscosity at 140° F after the Thin Film Test or Rolling Thin Film Test simulates what takes place in the asphalt during construction. The amount of hardening or softening is controlled by the mix design and contractor operations. The critical mix-preparation and construction steps that affect asphalt are shown in Figure 2. These practices can either lower asphalt viscosity or increase it.

Practices That Lower Viscosity

Before paving starts, the asphalt can be softened to a viscosity lower than when shipped from the refinery by

- Contamination during transport,
- Chemical interaction in storage, and
- Addition of liquid adhesion additives.

Asphalt contamination in transport trucks is well understood. As little as 1 percent MC-30 in AC-20 could take the asphalt out of grade. Chemical interaction is not well understood. Logically, a contractor or user engineer would assume that two asphalts of the same grade from two different suppliers could be blended since each meets the specifications. But such is not always the case (Figure 3). Note that both asphalts meet specifications, but the blend of the two was softer than either of the components. In fact, all blends containing more than 20 percent of the other product were out of specification because of chemical interaction. Before filling a storage tank with asphalt from another supplier, a trial blend and test for compliance to specifications should be made, or the tank should be emptied.

The most commonly used additives are those to improve adhesion. Most liquid adhesion additives soften the asphalt. Only a few will cause hardening with select asphalts. Contractors are often not aware of the softening or hardening effect that can occur, which can cause construction problems.

Other causes of lower asphalt viscosities in the mix are lower mix tempera-

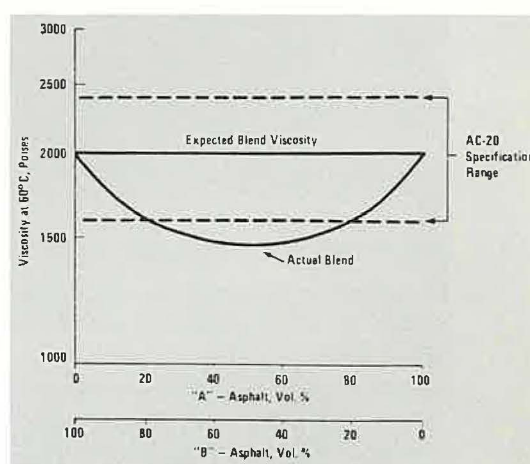

FIGURE 3 Effect of chemical interaction on blending of asphalts.

tures, low filler content, drum-mixer operations, and short dwell time in surge bins.

When softening occurs, the ability to obtain pavement density will be affected. Aggregate texture and filler content control the type and grade of asphalt needed for easy compaction, to meet density requirements, and to provide a tough, nonscuffing pavement. The effect on pavement density is shown in Figure 4. The crushed aggregate mix density is higher when a lower viscosity asphalt is used. The crushed aggregate is harder to compress; thus the lower the viscous resistance of the asphalt, the higher the density. The asphalt acts as a lubricant, allowing the aggregate particles to flow past each other more easily.

Nevertheless, with some gravel mixes, the contractor will have problems with lower viscosity asphalts. The viscous resistance of the asphalt is needed to prevent displacement under a roller, and a higher viscosity may be required.

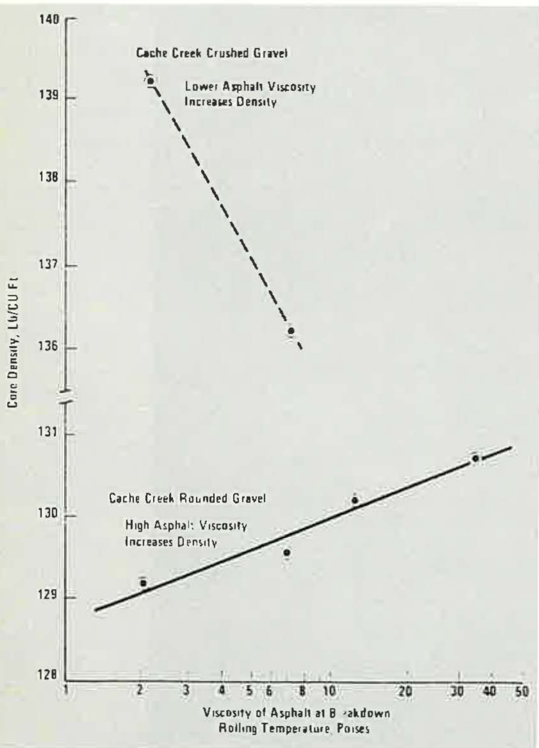

FIGURE 4 Effect of aggregate on compaction.

Why not use crushed aggregates exclusively? Cost. Not only are gravels less expensive to produce but they require less asphalt (Figure 5). The asphalt content of a gravel mix may be lowered by using a lower viscosity asphalt. As a rule of thumb, gravel mixes use about 0.5 percent less asphalt, a significant cost savings. Softer asphalt requires about 0.25 percent less asphalt. But there is a trade-off; gravel mixes will be slower in setting and harder to compact.

There is a trend toward harder asphalts to accommodate gravels. Use of a new asphalt grade, AC-30, is growing rapidly. In areas where low viscosity and less-temperature-susceptible asphalts are required to reduce thermal or thermal-fatigue type cracking, the best way to solve density and tenderness problems with gravel mixes is to crush the gravel.

Practices That Increase Viscosity

The asphalt can also be hardened by mix design and construction practices to a viscosity close to or even exceeding that permitted by the Thin Film Oven Test specification. Such practices could improve compaction of uncrushed gravel mixes, but it would be difficult to compact crushed aggregate mixes into a high-density, low-void-content pavement. These practices are:

- Use of high filler/binder ratios in the mix (lean mixes);
- Use of excess fine fillers, such as baghouse fines;
- High mixing temperatures;
- Low throughput rate in a drum mix plant; and
- Long holding times in surge bins.

Early raveling, cracking, and damage by stripping can be expected.

As indicated, the same asphalt from the refinery will vary widely in the paving mix, depending on the construction practices used.

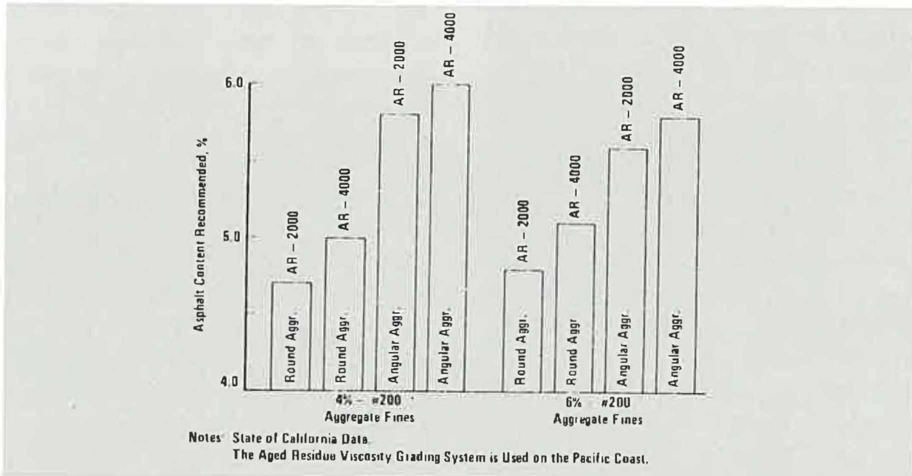

FIGURE 5 Effect of asphalt grade and aggregate surface texture on optimum asphalt recommendations.

LONG-TERM AGING OF ASPHALT IN PAVEMENT

After the effects of construction practices were more clearly understood, research shifted toward a study of long-term asphalt aging in mixes (the Phase 3 Curve). The most recent studies have been conducted by the State of California Transportation Laboratory. The studies were done on carefully prepared laboratory briquettes using three distinctly different asphalts representing high-, moderate-, and low-temperature susceptibility. Mixes from these asphalts were made using both absorptive and nonabsorptive aggregates, and the test specimens were compacted to three void contents, 3-5 percent, 7-10 percent, and 10-12 percent, in the laboratory. These briquettes were weathered for 4 years in four climate areas ranging from a high mountain site with a mean yearly temperature of 41.6° F to a hot, dry desert with a mean yearly temperature of 73° F.

The major findings of the studies included:

- High average air temperature (thermal-oxidation) is the most significant factor affecting the rate and amount of asphalt hardening.
- Asphalts manufactured from different crude sources can cause changes that occur under equivalent conditions.
- Differences in aging between asphalt types are most apparent in the hot desert climate.
- Aggregate porosity increases weathering rate even though more asphalt is used in the mix (this is most apparent in hot climates).
- Void content also contributes to the rate of oxidation with higher voids being the most detrimental (the effect of voids is similar among all asphalts).

A laboratory test, the California Tilt-Oven Durability Test, was developed that correlated to the weathering in the most critical climate—the hot desert environment. The test also correlated well with aging in a nearby test road, although the laboratory test was slightly more severe.

The California Tilt-Oven Durability Test ages the asphalt for 168 hours (7 days) at a temperature of 215° F (113° C). The temperature susceptibility of the aged asphalt is determined by the penetration test at 25° C and asphalt viscosity at 60° C. High-temperature susceptibility is a property that is related to thermal cracking and rutting of pavements. The penetration-ductility requirements are important for durability. The penetration at 77° F indicates the hardness of the material at ambient tem-

Chevron oil refinery: where asphalt begins.

peratures, whereas the ductility test is a measure of asphalt elongation or extension at break. The ductility requirement is meant to minimize syneresis, the separation of asphalt components on aging.

Asphalts that meet the California Tilt-Oven Test criteria will be used to construct test roads in the hot deserts of California. The Committee on General Asphalt Problems will review performance and test data as they develop.

RESEARCH AND IMPLEMENTATION NEEDS

The major need is to correlate asphalt durability with pavement performance. The test projects must be designed and constructed to eliminate design and construction variables and concentrate on long-term aging in pavements. Sufficient asphalt must be saved so that scientists can study new and improved analytical procedures in the future without the need for additional test roads. Funding for test roads, such as those under way in California, should be provided for an extended period—at least 5 years.

There is also a need to gain better control of pavement construction because pavements will be carrying heavier trucks equipped with high-pressure, low-contact-area tires. Of particular importance are studies on construction control methods in which density is determined and recorded during rolling.

As vehicle weights and tire pressures increase, harder asphalts, thicker pavements, and hard crushed aggregates will be needed. Research should be directed toward study and implementation of new mix design tests that better measure asphalt and filler effects, including creep tests, split tension tests, and dynamic stripping tests that stress and measure the asphalt/aggregate bond strength.

Research on asphalt composition deserves support on a continuing basis. Asphalt composition is too complex to be correlated well with road performance. Too much may be expected from current tests that measure molecular weight and size; various elements, such as metals, carbon, oxygen, hydrogen, and nitrogen; wax; and aromatic, saturated, and polar components.

Differences between asphalts are apparent. But current chemical parameters are not as precise as physical properties in defining asphalt behavior in a road. More work is needed in this field. These issues are now being considered by the TRB Committee on General Asphalt Problems.

Editor's note: *In the preceding article, it is concluded that "more work is needed," and more work is in the offing. The Strategic Highway Research Program (SHRP), now in its pre-implementation phase at the American Association of State Highway and Transportation Officials (AASHTO), includes asphalt as one of its six major research areas. SHRP, projected as a $150-million, 5-year research program, was recommended by the TRB committee that guided the study entitled Strategic Transportation Research Study (STRS). The study committee sought to identify areas in which concentrated and coordinated research, properly supported, could be expected to produce results that could offer substantial savings when implemented. The committee concluded that if the research on asphalt paving materials could bring forth only a 1 percent reduction in cost, the potential savings could be $100 million a year.*

SHRP Interim Director Gary Byrd is moving rapidly to address those questions that must be answered in the pre-implementation phase leading to the beginning of actual research some time in 1986. Cooperation among AASHTO, the Federal Highway Administration, and the staff of the National Cooperative Highway Research Program has provided Byrd with six contractors, each responsible for developing detailed designs for the research to be undertaken in each of the six technical areas, including asphalt. Byrd and the contractors are being assisted by six Advisory Committees composed of professionals knowledgeable in each of the six technical areas, and by a seventh Advisory Committee on Overview and Integration.