A2D02: Committee on Characteristics of Nonbituminous Components of Bituminous Paving Mixtures
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Current and Future Use of Nonbituminous Components of Bituminous Paving Mixtures

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Asphalt mixtures are a combination of asphalt binder and a variety of nonbituminous materials. In addition to aggregates, which constitute the largest volume of asphalt mixtures, nonbituminous materials used in paving mixtures include

- Mineral and other fillers, including carbon black;
- Waste materials, including rubber, reclaimed asphalt pavement (RAP), shingles, glass, plastic, and toner;
- Aggregate substitutes (slag, manufactured lightweight materials);
- Polymers;
- Fibers;
- Lime;
- Sulfur;
- Antistripping agents;
- Antioxidants;
- Hydrocarbons;
- Oxidants; and
- Extenders.

The use of such materials is discussed here, and some are categorized as value-added recovered or reprocessed materials, waste products, or byproducts. The use of a number of other components is also discussed, as are anticipated future trends in the use of nonbituminous components in bituminous paving mixtures.

When any nonbituminous component is added to a bituminous paving mixture, a number of important questions need to be answered:

- What improvement is needed?
- What material component will provide the improvement?
- What properties will be compromised?
- How will the component be incorporated?
- Should compatibility be considered?
- Can the material be stored, and are there any special handling characteristics?

- Does the component affect routine test methods and results?
- What is the effect on life-cycle cost?
- How can the component be specified?

VALUE-ADDED RECOVERED OR REPROCESSED MATERIALS

Materials used in the production of asphalt pavements are typically selected to provide the lowest cost solution to meet the demands of traffic and environment. The materials—aggregates, asphalt binder, and additives—must be selected carefully. Availability, costs, and effect on performance must be considered.

The asphalt paving industry has successfully used recovered or reprocessed material for many years. The industry recycles large quantities of RAP, scrap tires, glass, slag, and shingles every year. Most of these products are used because they add value to the pavement. Cost, performance, and environmental concerns must be evaluated to determine if a product has value added. The best example of value-added material is RAP because (*a*) it reduces costs by saving on materials (aggregate and binder); (*b*) performance has generally been shown to be equal to or better than that of mixes consisting solely of virgin materials; and (*c*) the environment suffers no adverse effects. In fact, a primary consideration in adding any material, whether virgin or recovered, to hot-mix asphalt (HMA) should be its effect on the recyclability of the pavement.

WASTE PRODUCTS

Unlike value-added recycled materials or byproducts used in HMA to benefit the performance of the product or the industry, waste products provide little or no measurable benefit. Because the paving industry uses large quantities of material, it is often viewed as a possible user of recovered materials from other waste streams. However, any waste material used must be available in sufficient quantities to make it economically feasible. Products such as glass and ground porcelain toilet bowls have been successfully used in HMA, but the additional cost of processing and handling these materials is not offset by improvements in pavement performance. HMA has been proposed as a medium to encapsulate and dispose of soils contaminated by leaking underground storage tanks. Numerous other waste products have also been and will be proposed for incorporation into HMA pavements, resulting in coinage of the terms “linear landfills” and “trashphalt.”

A standard protocol is needed for the evaluation of waste products that addresses the engineering properties of the resulting HMA, as well as health, safety, and environmental impacts during construction and during the service life of the pavement. Regardless of the materials used, it is imperative that the pavement be recyclable.

BYPRODUCTS

The growing use of Superpave, stone matrix asphalt (SMA), and open-graded friction courses (OGFCs) has increased the difficulty for the aggregate industry to balance production of coarse and fine aggregate particle sizes. SMA is gap-graded by nature, as are many Superpave mixtures. SMA has a low percentage of intermediate fine aggregate, and OGFC typically contains little, if any, dust. Both require high percentages of clean, well-shaped coarse aggregates. Mix designs meeting Superpave’s requirements for voids in mineral aggregate (VMA) and ratio of fines to effective asphalt content at relatively high laboratory compaction often require large deviations from the maximum density line with relatively low fines contents. Vertical and horizontal shaft impact crushers have been used to improve aggregate shape to better meet the requirements of these mix design systems. However, impact crushers tend to produce increased fines when used on hard aggregates. All of these changes are leading to an increase in quarry waste fines.

The use of Superpave, SMA, and OGFC also affects the use of RAP and baghouse fines. RAP, especially that produced by milling, tends to be high in fines. Although RAP can be screened, the fine fraction contains the highest asphalt content and therefore significant cost benefit. Dust collection systems (baghouses) became prevalent in asphalt plants in the late 1970s to meet stricter environmental regulations. Historically, baghouse fines have been successfully returned to HMA mixtures with no detrimental effect on the pavement quality and performance.

Concerns about fines are primarily related to their stiffening effect on the HMA mixture, effect on air voids content and voids filled, potential to act as asphalt extenders, and potential moisture sensitivity. Research indicates that limits placed on fines through gradation controls or proportion by weight (fines to effective asphalt ratio) are not uniform for all types of fines or fillers. Guidelines should be developed on the basis of bulk volume concentration of fines determined from, for example, Rigden voids, limiting stiffness of the mastic formed by the binder and fines, or mixture performance properties. The industry is expected to work to balance the use of aggregate size fractions, RAP, and baghouse fines while maintaining HMA quality and performance.

OTHER NONBITUMINOUS COMPONENTS

Various materials are added to asphalt binders to change mixture behavior, primarily to enhance the roadway performance characteristics of asphalt mixtures. Most fall into one of the following categories:

- Mineral fillers,
- Fibers,
- Extenders,
- Hydrocarbons,
- Oxidants,
- Antioxidants,
- Polymers, or
- Antistripping agents.

Mineral Fillers

Except in areas with very clean aggregates, mineral fillers (e.g., hydrated lime, carbon black, fly ash, Portland cement, and silica fume) have not been widely used since the rise in the use of baghouses. However, specification changes in the 1990s (e.g., Superpave) aimed at mixture rutting resistance have sometimes resulted in very clean mixtures with excessively high VMA. Consequently, some mixtures will probably again incorporate mineral filler to gain a more favorable balance of volumetric properties without sacrificing rut resistance.

Fibers

Like mineral fillers, fibers have not been widely used in asphalt mixtures. Small, limited field trials have used mineral, polyester, and polypropylene fibers to add toughness and fracture resistance to mixtures. The primary use of fibers, however, has been in specialty mixtures, such as porous friction courses that are typically open-graded and in SMA. In these cases, cellulose and mineral fibers have been used as stabilizers to facilitate constructability by preventing binder drain down. This type of fiber use will likely continue.

Extenders

Extenders are intended to replace a portion, or even all, of the asphalt binder. They, too, have not been widely used because petroleum asphalt remains an inexpensive, widely available product. Perhaps the best examples of the use of extenders occurred in the late 1970s and early 1980s, when sulfur products were used in many laboratory and field experiments. A spike in the cost of asphalt binders, which approached $200 per ton, and concerns about future availability caused purchasing agencies to explore less expensive replacements for asphalt binders. As long as asphalt is available and its cost remains stable, in the low $100 per ton range, it is likely that extenders will not be widely used.

Hydrocarbons

Hydrocarbons—refinery products such as aromatic and napthenic oils and vacuum gas oils—are widely used as softening agents to modify the viscosity of asphalt binders. With the arrival of performance graded binders, however, these products have also been used to attain the low-temperature performance properties. At this writing, significant basic and applied research is being conducted to develop low-temperature additives that cause proportionately higher improvements in low-temperature properties without sacrificing high-temperature properties. Typically, most past modification efforts followed a different approach because the properties of the base asphalt binder were generally found to control low-temperature behavior. Soft base asphalts have typically been used to provide the creep and viscous flow characteristics needed to resist cracking at low temperatures, whereas polymers or crumb rubber modifier have been added to improve high-temperature performance, especially stiffness and elasticity.

Other hydrocarbons used in the past have been used specifically to improve rutting resistance. Natural asphalts such as Gilsonite (rock asphalt) and Trinidad Lake asphalt have been used because of their extreme stiffness. Tall oil has been used in a gelling process to produce rut resistant binders. These products are used regionally, a trend that is expected to continue.

Oxidants and Antioxidants

Chemical oxidants and antioxidants have not been widely used in asphalt mixtures, although many field trials have evaluated their effect on mixture performance. Binders containing manganese salts to facilitate oxidation underwent field trials in the 1980s; the performance of these pavements was somewhat mixed. Manganese salts are not commonly used in the United States, although there appears to be some use in Asia. Antioxidants such as carbamates (e.g., lead and zinc), carbon black, phenols, and ethyoxylated amines have also undergone field trials, with limited success. In recent years, hydrated lime has been experimentally shown to be an oxidation inhibitor.

Polymers

By far the most common nonbituminous products used are polymers. Many polymer substances have been incorporated as binder modifiers, and most fall into one of two categories: elastomeric or plastomeric.

Elastomers include copolymers of styrene and butadiene (e.g., styrene butadiene diblock, styrene butadiene triblock or radial, styrene isoprene, and styrene ethylbutylene). These products are normally milled into the asphalt binder at temperatures above 160°C by a high shear mixer. Also included in the elastomer category are styrene butadiene rubber latex (SBR), polychloroprene latex, polyisoprene, and crumb rubber modifier. The most common, SBR, is normally introduced as a latex emulsion and is flashed into the asphalt. Crumb rubber traditionally has been introduced and reacted in agitated tanks of hot (177–196°C) asphalt, although now some organizations are milling the crumb rubber into the binder like other elastomeric modifiers.

Plastomers include ethylene vinyl acetate, polyethylene (unstabilized and stabilized), and various compounds based on polypropylene. These products may require high shear mixing, depending on the modification process. A 1992 usage study by the Asphalt Institute indicated that about 5 percent of all binders were modified with some type of polymer. Most members of the industry expect that number to increase because of the increasing use of high-temperature spread performance graded (PG) binders and downward pressure on the price of polymer modifiers.

Antistripping Agents

Many antistripping agents have been used in asphalt mixtures in the past, including amidoamines, imidazolines, polyamines, hydrated lime, organo-metallics, and acids. Of these products, the amines and hydrated lime have been used most commonly. In all cases, the purpose of these products is to inoculate the mixture against moisture damage, often called stripping. Many liquid antistrip compounds have an objectionable odor. New formulations are less objectionable, but are typically more expensive. Considerable research is ongoing among various industry groups to develop products that promote adhesion between the asphalt binder and aggregate in the presence of moisture. One example is a newly developed product that uses SBR in combination with other polymers to promote a tenacious bond between asphalt and aggregate. It is likely that these and similar new products will continue to be developed in the future.

CONCLUSION

It seems extraordinary that after the extensive use of asphalt modifiers in the past, the asphalt engineering community still does not have a large database of life-cycle cost analyses to prove the benefit (or lack thereof) of using modified binders. Many laboratory analyses have shown modified binders to be superior in engineering or performance-related properties, yet the results of field trials have often been confusing. It has sometimes been difficult to identify performance differences between modified binder sections and control sections. Other factors (e.g., structural section, construction factors, traffic) often confound the analyses. If the merits of modified binders are to be realized, a concerted effort will have to be made to carefully design, construct, and monitor field experiments. Furthermore, mixture tests methods will have to be developed that reliably predict field performance.

In the late 1990s, specifying the use of modified binders became a somewhat contentious issue in the context of the Superpave PG system. Although the PG system was intended to be blind to methods and components in the manufacturing process, some researchers believe that the basic Superpave binder test methods do not adequately characterize modified binders. Research is under way to evaluate whether new test methods or amendments to the Superpave PG binder specification are needed. In the interim, some agencies have added older procedures to the PG specification (e.g., “PG Plus”). Still others have considered resurrecting recipe types of binder specifications that were often used for modified binders before the PG system was adopted. Such modified PG specifications may be used until ongoing research provides more answers.

Many factors will influence the future use of nonbituminous components such as binder modifiers. For example, the growth in popularity of warranty specifications may mean that proprietary recipes will arise that use specific combinations of asphalt binder and modifiers to meet the project needs of the contractor, as occurred when asphalt-rubber binders were introduced. The future will likely see the rise in engineered asphalt technology companies that sell, not modifiers, but technology and expertise. Such companies will likely develop modified binder systems in which manufacturing process is as important as modifier components.

The number and type of nonbituminous components are expected to increase with changes in materials technology and as availability of natural resources declines. The challenge will be to ensure that the nonbituminous components included in paving mixtures add value to the transportation system by reducing costs, improving performance, or both, without affecting the recyclability of the pavement or causing adverse environmental or health effects.