



SUPERPAVE SYSTEM

DESIGNING AND BUILDING MORE DURABLE ASPHALT PAVEMENT

DON LUCAS

Asphalt concrete covers more than 90 percent of the surfaced roadways in the United States and for many decades has provided a safe and resilient riding surface. But in the past 20 years or so, increased traffic, heavier trucks, and higher-pressure tires have shortened asphalt pavement life. Between 1970 and 1994, loads on rural interstate highways across the nation increased 440 percent, and traffic more than doubled. In Indiana, which receives the full brunt of this increased loading, premature rutting (permanent deformation in the wheelpaths) and cracking of asphalt pavements are widespread, ride quality is deteriorating, and both maintenance costs and traffic delays are up.

In the early 1980s a group of highway engineers and managers began investigating ways to eliminate rough roads and ubiquitous maintenance work. As participants in the Strategic Transportation Research Study, conducted by the Transportation Research Board, these individuals laid the foundation for the Strategic Highway Research Program, which began in 1987. A major part of this accelerated, highly targeted \$150 million program focused on asphalt—specifically on how to improve the long-term durability and cost-effectiveness of the nation's \$10 billion annual investment in asphalt pavements.

The resulting Superpave system gives highway engineers and contractors a new set of tools for designing asphalt pavements that will perform better at extreme temperatures and under heavy loads. By emphasizing the performance of the materials, the Superpave system makes possible the design of asphalt mixes for specific traffic loads and environmental conditions. Pavements built with these customized mixes will be more durable and require less maintenance. Motorists will enjoy a smoother ride and will encounter fewer work zones on roadways in the future.

THE SUPERPAVE SYSTEM

The Superpave system predominantly addresses two forms of pavement distress: rutting (permanent deformation), which is caused by inadequate shear strength in the asphalt mix; and low-temperature cracking, which results when the tensile stress in the pavement exceeds the tensile strength of the asphalt cement. Through a combination of new materials specifications, a new mix design and analysis system, and a performance prediction system, the Superpave system allows highway agencies and contractors to design a longer-lasting asphalt mix for new construction and overlays.

The system is built around three major components: asphalt binder specification (1), a volumetric mix design and analysis system (2), and mix analysis tests and a performance prediction system. These new specifications and tests require new, sophisticated test devices and hardware, which in turn necessitate additional laboratory space and staff training. Before the Superpave system could make the leap from the research phase to practice, the specifications had to be verified, validated, and standardized, and the equipment had to be manufactured and calibrated.

SHRP researchers created a strong framework for the Superpave system, but when the program ended in 1993, much still remained to be done. Fortunately for the highway industry, Congress had earmarked funds for SHRP implementation in the 1991 Intermodal Surface Transportation Efficiency Act. Those dedicated funds allowed the Federal Highway Administration, working closely with the American Association of State Highway and Transportation Officials and the Transportation Research Board, to develop the Superpave system to a level at which the technology could be used routinely by highway agencies and contractors. Assisting FHWA in the imple-

Don Lucas is deputy commissioner and chief highway engineer, Indiana Department of Transportation.



INDIANA DEPARTMENT OF TRANSPORTATION

The Superpave binder specification and mix design procedures were used on 16 projects in Indiana last year; by 2000, all of the state's asphalt projects will be built using the Superpave system.

mentation effort was the Asphalt Technical Working Group and its expert task groups, which were composed of technical experts from highway agencies, industry, and academia.

As part of a pooled-fund arrangement coordinated by FHWA, the highway agencies in all 50 states, Puerto Rico, and Washington, D.C., have received the tools required by the new performance-based asphalt binder specification and the Superpave volumetric mix design and analysis system. These tools include the bending beam rheometer, the dynamic shear rheometer, the pressure aging vessel, the rotational viscometer, and the Superpave gyratory compactor.

The direct-tension test device, which is used to measure a binder's low-temperature tensile and fracture properties, is now in the final stages of design. It too will eventually be purchased through the pooled-fund arrangement.

Training in administering the tests and operating the test equipment is being provided through the National Asphalt Training Center, located in Lexington, Kentucky; the Superpave regional centers; and the National Highway Institute. On-site technical assistance is available from FHWA's mobile asphalt laboratories. These laboratories are outfitted with the Superpave binder test equipment and the Superpave gyratory compactor and staffed with technicians skilled in Superpave procedures.

Binder Specification

Until recently highway agencies and contractors used viscosity and penetration tests to measure a

binder's properties. But those tests fail to measure the binder's properties at low temperatures, making it difficult to select the best binder for the conditions at a project site.

The Strategic Highway Research Program developed three new tests to simulate the broad range of actual environmental and traffic conditions found throughout the United States and the rest of the world. The dynamic shear test measures the binder's stiffness and phase angle at intermediate and high temperatures using the dynamic shear rheometer to determine the binder's ability to withstand permanent deformation and fatigue cracking. The bending beam test measures the low-temperature stiffness of the binder using the bending beam rheometer to predict low-temperature cracking problems. And the direct-tension test device measures the binder's low-temperature tensile and fracture properties.

These test results allow asphalt binders to be classified into performance grades. Each binder is classified according to the temperature at which it attains certain characteristics; in other words, the target physical properties of the binder remain constant, while the temperatures at which the properties are attained vary. A Superpave binder graded PG58-28, for example, meets the required physical properties at pavement temperatures as high as 58 °C (136 °F) and as low as -28 °C (-18 °F). Work conducted during SHRP and after the program ended showed that the binder specification and tests work equally well for modified and unmodified binders. Asphalt producers and suppliers are already making the switch to performance-graded binders.

Volumetric Mix Design and Analysis System

Superpave mix-design procedures specify the selection of aggregates and binders that meet certain criteria and the use of the Superpave gyratory compactor to create test specimens for determining the volumetric properties of the trial mix.

The gyratory compactor is at the heart of the mix-design system. Its primary function is to create test specimens by kneading asphalt mixes to simulate the effects of construction compaction and traffic loads. The amount of compaction varies, depending on the traffic levels and environmental conditions expected at the job site. The specimens are then tested to determine the volumetric properties (air voids, voids in the mineral aggregate, and voids filled with asphalt) of the trial mix at different compaction levels; the results

will indicate how well the mix will perform in actual service. The gyratory compactor works equally well as a quality control/quality assurance tool in the field, ensuring that the volumetric properties of the asphalt mix produced at the construction site are like those of the job mix.

Included in the Superpave mix-design procedures are aggregate angularity and gradation requirements to assure that the mix will consist of a strong stone skeleton resistant to rutting, with enough asphalt and voids to be sufficiently durable.

Mix Analysis Tests and Performance Prediction System

Superpave mix analysis procedures and performance prediction tests are intended for paving mixes that will serve in critical locations, such as interstate highways and other roads carrying high traffic volumes and heavy loads. Information from sophisticated new laboratory tests using the Superpave shear tester and indirect tensile tester is entered into computer models that predict the capacity of a mix to withstand rutting, fatigue cracking, and low-temperature cracking. As a result, pavement mixes can be designed to minimize a specific distress or combination of distresses for any combination of pavement structure, traffic, and climate.

SUPERPAVE SOFTWARE

Software was developed to facilitate the design of pavement mixes and to predict their performance. The Strategic Highway Research Program ended before completion of testing, debugging, and refining of the software. However, the software continued to be developed under the Transportation Research Board, with remaining SHRP funds; the Federal Highway Administration then assumed responsibility for completing the software. In 1995 the administration awarded a contract to the University of Maryland and a team of subcontractors to further develop and validate the Superpave software and to provide administrative and technical support. An expert task group composed of representatives from state highway agencies, industry, academia, and the Federal Highway Administration provides technical advice and support to the project.

Version 1.0 of the software, an improved version of the volumetric mix-design software originally developed under SHRP, was distributed to materials engineers in state highway departments in 1996. It allows users to design asphalt mixes in conformance with Superpave volumetric mix-design procedures. Version 2.0, a completely

SUPERPAVE CENTERS

State departments of transportation and universities have teamed up to form five regional Superpave centers. The self-funded centers, established in 1996, are intended to foster regional partnerships and to spur implementation of the Superpave system. The state-university teams provide the laboratory space and staffing for each center. The Federal Highway Administration has loaned each center a set of the Superpave test equipment. Advisory groups, composed of representatives from state highway agencies, the regional asphalt user-producer groups, materials suppliers, contractors, consultants, and universities, oversee the operations of each center.

As part of their mission to serve both highway agencies and the asphalt industry, the centers will, among other things, evaluate Superpave test equipment and protocols, provide technical assistance and hands-on training for engineers and technicians, conduct research, and support the ongoing Long-Term Pavement Performance program.

The five regional Superpave centers are listed below.

- South Central Superpave Center
(University of Texas)
512-475-7912 (fax 512-475-7914)
<http://www.utexas.edu/research/superpave/>
- Western Regional Superpave Center
(University of Nevada-Reno)
702-784-6873 (fax 702-784-1427)
- North Central Superpave Regional Center
(Purdue University)
317-463-2317 (fax 317-497-1665)
<http://www.ecn.purdue.edu/CE/Research/SUPERPAVE/Superhome.html/>
- Northeast Superpave Regional Center
(Pennsylvania Transportation Institute)
814-863-5789 (fax 814-865-3039)
<http://www.pti.psu.edu/open/superpave/index.htm/>
- Southeastern Superpave Center
(National Center for Asphalt Technology, Auburn University)
334-844-6240 (fax 334-844-6248)
<http://www.eng.auburn.edu/center/ncat/superpv.htm/>

SUPERPAVE VALIDATION

The Superpave system was thoroughly studied and laboratory-tested under the Strategic Highway Research Program. However that program ended before extensive, controlled field validation studies could be conducted through the Long-Term Pavement Performance program's planned Specific-Pavement Study 9 (SPS-9). Full-scale Superpave test sections being constructed under SPS-9 will yield information designed to validate the Superpave system. Additional performance data are being collected from test pavements at the Federal Highway Administration's Turner-Fairbank Highway Research Center, where two accelerated pavement-testing machines simulate the effects of years of traffic and loading.

WesTrack, FHWA's 2.9-kilometer (1.8-mile) oval test track located in a remote, arid, and hot area of Nevada, is also being used to validate the Superpave mix design and analysis procedures. The project focuses primarily on the construction and materials factors likely to have the greatest effect on performance.

Four driverless trucks circle the track an average of 15 hours each day. At the end of the 2-year project, they will have applied 10 million equivalent single-axle loads, simulating the effects of 10 or more years of interstate-level traffic on the pavement.

Sensors placed in the pavement continually monitor the loads on the pavement and the pavement temperature. At regular intervals the pavement's visual distress, rutting, deflection, roughness, and friction are measured.



WesTrack, located in the Nevada desert, includes test sections to validate the Superpave system.

revised, Windows-based version of these procedures, is scheduled to be available in spring 1997.

COST-EFFECTIVE SYSTEM

The Superpave implementation plan, which is continually being fine-tuned by the states, industry, and the Federal Highway Administration, lays out a practical series of steps to give the traveling public longer-lasting, more durable asphalt pavements. The savings potentially resulting from the Superpave system are huge. A recent study by the Texas Transportation Institute (3) found that switching to Superpave binders in overlays alone could yield a total annual savings to the nation of between \$1.8 billion and \$2.9 billion. The highway agencies will realize a large chunk of those savings, but the big winners will be motorists and shippers, who will encounter fewer delay-causing maintenance work zones. Many states are already convinced of the worth of changing to the Superpave mix-design system. Most have committed to the 1997 goal set by the Asphalt Technical Working Group for implementation of the Superpave binder specification.

INDIANA'S EXPERIENCE

The target date for implementing Superpave mix-design procedures in the United States is the year 2000. The Indiana Department of Transportation began experimenting with the procedures in 1993, when a SPS-9 test section was constructed on Interstate 65. Nearly four years later, the test section, which is part of the ongoing Long-Term Pavement Performance program begun under SHRP, is performing well. The state's second project, on a local road, was initiated by industry, in partnership with a county government. In 1995 Indiana constructed five additional Superpave mix-design projects: two on the Interstate system, one on a urban road traversed by many trucks, and two on less heavily traveled roads. In 1996 the state awarded 16 Superpave projects, 2 of which included sophisticated Superpave mix-analysis tests. This year Indiana plans to use the Superpave binder specification and mix-design procedures on 35 to 40 projects; by the year 2000, all of the state's asphalt paving projects will use the Superpave system. To prepare for full implementation of the system, the Indiana DOT has begun to incorporate the new tests and procedures into construction specifications and bidding process.

REFERENCES

1. Standard Specification for Performance-Graded Asphalt Binder. In *AASHTO Provisional Standards*. AASHTO Specification MP1-93, American Association of State Highway and Transportation Officials, Washington, D.C., 1996.
2. Standard Specification for Superpave Volumetric Mix Design. In *AASHTO Provisional Standards*. AASHTO Specification MP2-95. American Association of State Highway and Transportation Officials, Washington, D.C., 1996.
3. Epps, J., and M.A. Coulson. *Economic Benefits of SHRP Research on Asphalt*. Research Report No. 96-1. University of Nevada-Reno.

BIBLIOGRAPHY

- Superpave Performance-Graded Asphalt Binder Specification and Testing*. Report No. SP-1. Asphalt Institute, Lexington, Ky., 1995.
- Superpave Level 1 Mix Design*. Report No. SP-2. Asphalt Institute, Lexington, Ky., 1995.
- The Superpave Mix Design Manual for New Construction and Overlays*. Report No. SHRP-A-407. Strategic Highway Research Program, National Research Council, Washington, D.C., 1994.
- Superpave Performing Asphalt Pavements (Superpave): The Product of the SHRP Asphalt Research Program*. Report No. SHRP-A-410. Strategic Highway Research Program, National Research Council, Washington, D.C., 1994.
- Understanding Superpave Mix Design* (videotape). National Asphalt Pavement Association, Lanham, Md., 1996.
- AASHTO Provisional Standards*, 3rd ed. American Association of State Highway and Transportation Officials, Washington, D.C., June 1996.

Superpave® (*SUPERior PERforming Asphalt PAVEMENTS*) is a registered trademark of the National Academy of Sciences.

TRAINING AND TECHNICAL SUPPORT

- National Asphalt Training Center Asphalt Institute, 606-288-4960 (fax 606-288-4999)
- South Central Superpave Center
(University of Texas)
- Western Regional Superpave Center
(University of Nevada-Reno)
- North Central Superpave Regional Center
(Purdue University)
- Northeast Superpave Regional Center
(Pennsylvania Transportation Institute)
- Southeast Superpave Regional Center
(National Center for Asphalt Technology/Auburn University)
- Superpave Models and Software Management
Katherine Petros, FHWA, 202-366-1340
(fax 202-366-9981; e-mail
Katherine.Petros@fhwa.dot.gov)
- Northeast Asphalt User-Producer Group
Frank Fee, 609-428-8808 (fax 609-963-0111)
- Southeast Asphalt User-Producer Group
Paul Krugler, 512-465-7632 (fax 512-302-2215)
- North Central Asphalt User-Producer Group
Dick Ingberg, 612-942-3066 (fax 612-942-3059)
- Rocky Mountain User-Producer Group
Bob Rask, 303-798-2972 (fax 303-794-5205)
- West Coast User-Producer Group
Rick Holmgren, 713-544-8257
(fax 713-544-8150)