Construction of Large-Stone Asphalt Mixes (LSAMs) in Kentucky

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Today, local highway departments are faced with the challenge of designing asphalt pavements for heavy truck loads and high tire pressures using traditional design methodologies that lack the necessary tools to account for these modern situations. Large-stone asphalt mixtures (LSAMs) are gaining popularity among highway agencies that are charged with designing heavy-duty asphalt pavements. High resistance to deformation in these mixes makes them attractive candidates for construction in heavy-truck traffic routes. As a pavement layer, LSAM develops strength by the stress-bridging effect and stone-to-stone contact. Several unique features about LSAM exist that make their construction more of an art than a science. Problems with LSAM are discussed, including segregation, poor compaction, low density, and particle crushing. Each can be avoided during large-stone–mix construction provided that appropriate countermeasures are used. Specific recommendations for large-stone–mix construction and quality improvement are given on the basis of Kentucky's experience with LSAM construction.

Kentucky has long been known for its coal, of which approximately 160 million tons are produced each year. Kentucky's highway system is an integral part of the coal transport network, carrying about 70 percent of the coal.

The structure of Kentucky's weight-distance tax law and its level of enforcement have resulted in coal truck traffic with gross weights ranging from 90,000 to 150,000 lb and tire pressures ranging from 100 to 130 psi. For pavement designers, these loads translate into truck factors ranging from 5 to 50 equivalent single axle loads (ESALs). Kentucky's asphalt pavements are designed with projected lives of 10 to 15 years. With some exceptions, these structures prove adequate for their design traffic. Unfortunately, the design process does not always identify the increased gross loads and tire pressures, and pavement design life may be reached in less than 6 years. In some locations, excessive rutting develops within the design life, which is prevalent on long, steep grades carrying a high percentage of coal trucks. This problem severely affects the top 3 to 5 in. of the flexible pavement thickness in which the shear stress reaches its maximum. Generally, this condition is considered to be a mixture problem rather than a structural problem.

The asphalt pavement community in Kentucky accepted the challenge of designing and constructing a mix that would handle such heavy and severe highway loads. A task force addressing this challenge was formed with individuals representing the Kentucky Department of Highways (DOH), Kentucky Plantmix Asphalt Industry, Kentucky Transportation Center at the University of Kentucky, Asphalt Institute, National Asphalt Pavement Association, Chevron USA Inc., and Ashland Oil Co.

The task force recommended that alterations in the aggregate gradations could provide more stone-to-stone contact and higher stress resistance (especially shear stress) and thereby yield the needed improvements in rutting and shoving resistance.

LSAM CONSTRUCTION PROJECTS

The Kentucky DOH selected several coal haul highway sections for field testing of an experimental LSAM. The large-stone gradations tested, shown in Figure 1, were selected from an initial group of 12 aggregate blends. Mix design and other laboratory activities were coordinated by researchers at the Kentucky Transportation Center, University of Kentucky.

The following large-stone construction projects in Kentucky were included for review—Louisa Bypass on US-23 in Lawrence County and Mountain Parkway in Powell County. A summary of mix design parameters is presented in Table 1. Aggregate gradation distribution of these two projects is shown in Figure 1.

Louisa Bypass Project

This 3.7-mi, four-lane project is a newly constructed pavement section located deep in the heart of the coal country in eastern Kentucky. The original subgrade (CBR 4) was modified and upgraded by 8 in. of granular subbase for half of the project's length and by a shale subbase for the remaining half. Shale was used because of an on-site shortage of rock during the subgrade and subbase construction. Variation in the subbase material provides an opportunity to evaluate long-term performance variation caused by structural arrangement. Originally, the pavement was intended to be a full-depth asphalt structure; however, because of the presence of shale in the subgrade, which is prone to rapid strength deterioration, a granular subbase layer was included. The subbase layer consisted of 4 in. of dense-graded aggregate (DGA) covered with a 4-in., open-graded, large-stone drainage layer.

Twelve inches of LSAM base layer was constructed on top of the subbase layer in three 4-in. lifts. A 1-in. surface wearing course completed the project. Asphalt grade used was AC–20, and for half of the project the asphalt in the surface wearing course was modified with a polymer. Use of polymerized

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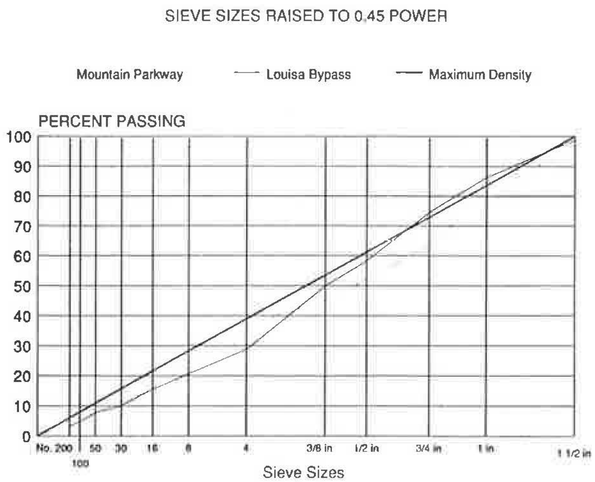

FIGURE 1 Large-stone asphalt mix project gradations.

asphalt was part of Kentucky DOH's experiment with modified asphalts.

Mountain Parkway Project

This project consisted of a series of rehabilitation projects totaling 25 mi to upgrade an old portland cement concrete (PCC) section of a four-lane parkway. The existing PCC pavement was cracked and seated and then overlayed with 6.5 in. of LSAM base layer. The LSAM was constructed in two lifts and a 1-in. surface wearing course completed the construction. Asphalt grade used was AC–20 throughout the project.

TIPS ON CONSTRUCTION OF LSAM

The following items are the result of many observations made during construction of the two previously discussed LSAM projects. Some may apply to all types of hot-mix asphalt (HMA) construction; however, in many instances large-stone mixes are more sensitive to construction errors than their conventional counterparts. Therefore, maintaining close, technical supervision over mix design, plant mixing, mix laydown, and compaction operations is important during the construction of LSAM.

Mix Design

The 6-in.-diameter by 3.75-in.-thick modified Marshall method of mix design (*1*) was adopted by the Kentucky DOH. Several factors contribute to successful LSAM mix design. For instance, adequate asphalt film thickness (9 to 11 microns) is necessary to ensure workability and durability. Film thickness is controlled by asphalt content and percent mineral filler in the aggregate. In conventional HMA construction, asphalt film thickness ranges from 6 to 8 microns and fine materials act as asphalt extenders (*2*). A thicker film is desirable to assist compaction of rather harsh LSAM mixtures.

Percent voids in the mineral aggregate (VMA) must be enough to accommodate the desired film thickness at maximum field density without excessive reduction in air voids. The VMA of the Kentucky LSAM was 11.5 percent, which is consistent with the widely accepted criteria set by the Asphalt Institute (*3*) and the National Asphalt Pavement Association (*4*).

Laboratory compaction of 6-in.-diameter by 3.75-in.-high Marshall specimens can be achieved at 112 blows per side using a 22.5-lb Marshall hammer (*1,5–7*). Densities achieved in the laboratory can be closely duplicated in construction (see Figure 2).

Air voids should be in the 3.5 to 5.5 percent range with an average of 4.5 percent. This range will minimize both air and water permeabilities. Figure 3 shows the variations in the air void content of the laboratory and field specimens.

Plant Mixing

Plant mixing time may need to be slightly adjusted for LSAM. A longer mixing time, as compared with conventional HMA, may become necessary to ensure coating of larger aggregate particles.

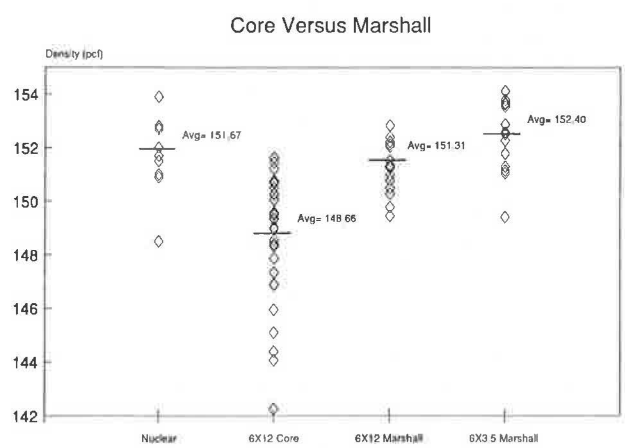

FIGURE 2 Laboratory and field density data—Louisa Bypass project.

TABLE 1 MIX DESIGN PARAMETERS FOR TWO KENTUCKY LSAM PROJECTS

	Stability (lb)	Flow (0.01 in.)	Air Voids (%)	Asphalt Content (%)	VMA (%)	Retained Tensile Strength (%)
Louisa Bypass	5,300	16	3.6	3.6	13.1	Pass
Mountain Parkway	5,900	19	4.4	3.5	13.0	Pass
Criteria	3,000 (min.)	28 (max.)	3.5–5.5	3–6	11.5 (min.)	70

NOTE: Data are based on 6-in.-diameter by 3.75-in.-thick modified Marshall specimens compacted at 112 blows per side using a 22.5-lb hammer.

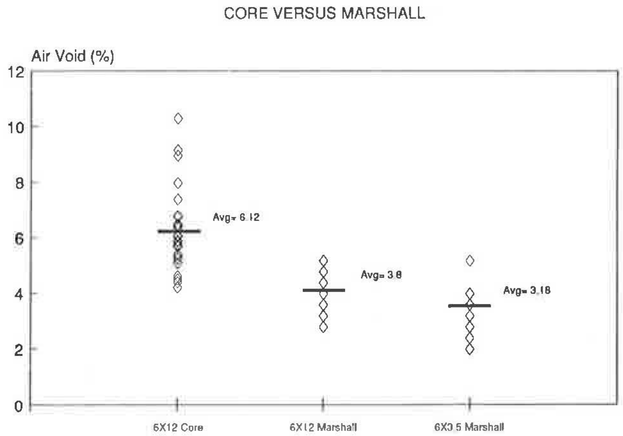

FIGURE 3 Laboratory and field air voids data—Louisa Bypass project.

In addition, careful attention to aggregate feeding and mixture handling to avoid segregation is essential. Cone formation of aggregate and mixture can be avoided by multiple material drops, which will minimize segregation.

Lastly, attention is necessary to ensure that the LSAM mix did not induce any unusual amount of wear on the plant's mixing equipment.

Laydown Operations

Several important laydown operational details exist that can be used to minimize segregation in the LSAM. For instance, coarse particles that accumulate in the paver wings should be discarded and never incorporated into the flow of the mix to the screed hopper.

The mixture in the receiving hopper bed should be maintained at a minimum depth of 18 to 24 in. to prevent accumulated coarse particles from reaching the slat conveyor. Receiving hopper gates should be set to provide as nearly a continuous flow of mixture as possible. Continuous operation of the distribution augers at full capacity is required to ensure mass movement of material for the entire screed.

Paver speed should be regulated to accommodate the mixture production and transport rates. Stop-and-go operation of the paver should be avoided to reduce segregation, improve spread texture, and eliminate any tendency for screed settlement (*5,6*).

A minimum lift thickness of 3.5 in. will minimize the effect of large aggregate boundary restrictions.

Compaction Operations

Although most LSAM gradations are coarsely graded and tend to be harsh, required density can be readily achieved with proper use of a variety of suitable, conventional compaction equipment (*5–7*).

Primary compaction should start immediately after mixture spreading. Density can be readily achieved at compaction temperatures ranging from 250°F to 300°F. Compaction at lower temperatures requires a considerable increase in roller coverage and is not recommended. Lateral displacement of this rather harsh mix was not a problem. For example, a successful compaction sequence included the following: (a) two passes of vibratory roller in the static mode for breakdown rolling, (b) six passes of vibratory roller at high frequency and low amplitude for primary compaction, (c) four passes of pneumatic roller to complete compaction, and (d) two passes of a static roller to smoothen the surface.

Because the stone-to-stone contact structure of LSAM can produce high point stresses on large aggregate particles during compaction, the frequency and amplitude of the vibratory roller may need to be adjusted to reduce particle breakage and to optimize compaction. This practice is especially necessary whenever relatively rigid bases (Mountain Parkway LSAM overlay on cracked and seated PCC project) are encountered.

Quality Control

A quality control routine should follow the construction of LSAM closely in order to ensure adherence to design parameters such as aggregate gradation, asphalt content, density, and air void content. Moving averages should be maintained and used as the basis for evaluating variability of mixture parameters. A schematic of the concept of moving averages that is recommended for quality control is given in Figure 4.

Asphalt extraction and gradation tests should be conducted on as large a quantity of LSAM material as the equipment will permit to ensure that the samples will be representative of the bulk material. In lieu of time-consuming extraction tests, total daily mixture output of the plant and asphalt cement tonnage is a convenient and relatively accurate way of determining the average daily asphalt content.

Compaction pattern is a function of the equipment that is available at the construction site and should be determined initially by construction of a test section (at least 500 ft long and 12 ft wide). Construction of a control strip is also useful for detecting potential segregation problems. Rolling patterns and coverages that are needed to produce the desired density should be maintained throughout the job. The Kentucky projects used a target density on the basis of 93 to 94 percent of

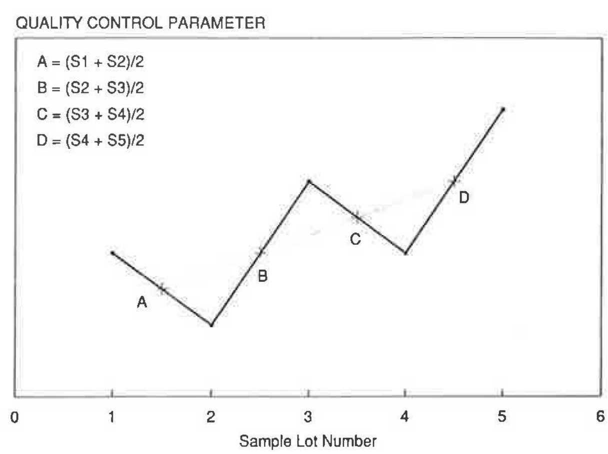

FIGURE 4 Schematic representation of the moving average concept.

solid volume (i.e., 6 to 7 percent air voids). Control range was set at 92 to 97 percent of solid volume.

Field density evaluation must be made frequently to ensure that the compaction procedure is adequate. If the desired density is not being achieved, adjustments to roller coverage should be made. If large adjustments are required, a new test section should be constructed.

CONCLUSIONS AND RECOMMENDATIONS

The experience in Kentucky indicates that LSAM can be designed and constructed with minimum modifications to existing procedures. Special attention must be devoted to plant and paver operations for reducing the probability of segregation. Lift thickness should not be reduced below 3.5 in. (for 1.5-in. top size gradation) to ensure adequate degrees of freedom for particle reorientation during compaction.

Mix design procedures for LSAM are not well developed. The modified Marshall stability test (6-in.-diameter by 3.75-in.-thick specimen) is the best mixture design procedure currently available for LSAM. However, further development and standardization of mix design procedures on the basis of the 6-in. modified Marshall approach is needed. Current construction equipment and procedures are appropriate for LSAM. Careful attention to production and construction details is essential for providing a uniform mixture and an effectively constructed LSAM pavement layer.

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