

# Michigan Department of Transportation - M•DOT

# Mates



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## STONE MASTIC ASPHALT

In September 1990, a group of 21 federal and state transportation officials and industry representatives traveled through seven European countries examining a new world of bituminous pavement contracting practices, construction methods, mix designs and materials. One of the most significant items was a special purpose top course bituminous mixture called stone mastic, or stone matrix asphalt (SMA), a durable, longer lasting road surface that can be used in new construction, maintenance, and rehabilitation.

The Federal Highway Administration (FHWA) selected Michigan with its similar climate and aggregate resources as those visited in Europe, as the demonstration site for testing the feasibility of using this mix in the U. S. It must be remembered that this demonstration project should not be regarded as the ultimate evaluation of bituminous road building technology in Europe. There, great attention is also given to the underlying bituminous layers and the base and subbase to ensure that the SMA overlay rests on a superior foundation. Michigan's demonstration project was mainly to establish that U. S. Asphalt contractors/producers could manufacture and place SMA mix.

The concept behind SMA is based upon three simple factors. The first is the one-sized stone-on-stone aggregate contact that forms a 'structural skeleton,' increasing the internal friction and shear resistance. Second, a hard stone is used for the aggregate, which typically makes up 70 to 80 percent of the mix by weight and is tightly controlled as to size and shape. Finally, SMA has a high asphalt cement content, generally 6 to 7 percent by weight, which requires use of modifiers as stabilizing agents. These stabilizing agents provide a thick coating of asphalt on the aggregate and prevent the intrusion of water. Modifiers are generally cellulose or mineral fibers; however, some polymer stabilizers have also been used. Fine crushed sand is used in the SMA mix as filler.

Some of the basic theory behind SMA such as optimization of stone-on-stone contact, tightly controlled size and shape, and clean aggregate has a familiar ring in Michigan. Back in the 1950s through the early 70s, MDOT used manufactured coarse aggregates and fine aggregate which were clean and required the addition of mineral filler. Our bituminous concrete mixes were proportioned to a 'stony' gradation and made with the batch plant technology which is used almost exclusively in Europe. More recently, before the introduction of the SMA mix, MDOT had been moving towards some of the same mix design concepts. The bituminous mixture production and density control specifications of the last few years addressed quality control of the sort necessary for SMA. The new generation of bituminous mixes (C Series 2, 3, and 4) are patterned after our old bituminous concrete mixes which have stone-on-stone contact. We are now in the transition stage to across-the-board implementation of these specifications.

SMA pavement mixtures were first used in Europe over 20 years ago. Initially, they were developed as stable bituminous paving mixtures that were resistant to the distress related to studded tires while also being resistant to rutting and shoving when subjected to high traffic volumes and heavy axle loads. Although the use of studded tires was

gradually eliminated (except in Sweden), SMA continues to be used on new construction as a surface layer and as an overlay on surface renewal projects.

The advantages attributed to SMA include: high stability (resistance to deformation and rutting), good wear resistance, improved low temperature performance, improved aging properties, improved skid resistance, increased service life, over a broad range of pavement applications.

The concerns associated with the application of SMA in the U. S. include: high quality of the materials required, more intensive quality control, longer mixing time due to coarse gradation and modifiers, higher production temperatures, higher material production costs, and lack of experience using SMA in drum mix plants.

The SMA aggregate is not necessarily large, but is predominantly gap-graded to a one-size, roughly symmetrical coarse aggregate which forms a structural skeleton or matrix in the compacted mix. Unlike those in a conventional dense graded hot mix asphalt (HMA), the coarse, rough textured aggregates in this matrix are in close particle-to-particle contact (Fig. 1). This structure provides high internal friction and high shear resistance, thus hindering deformation or

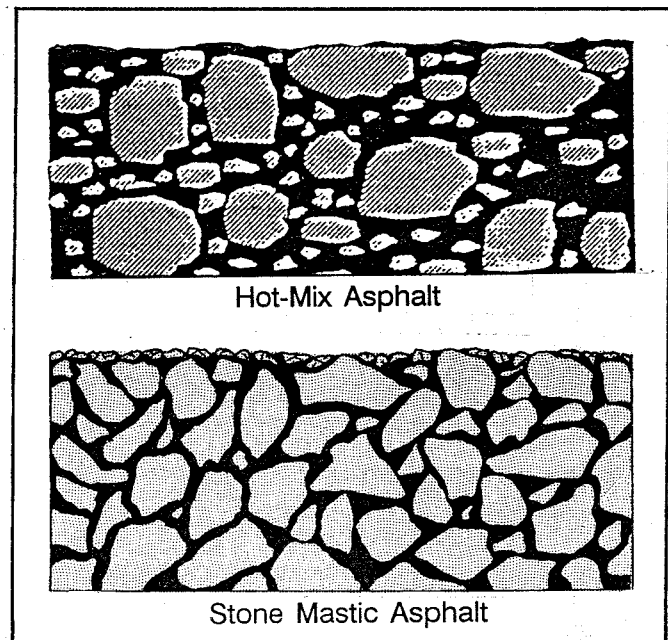


Figure 1.

rutting. The concentration of coarse aggregate (retained on the No. 4 sieve) in SMA is generally 65 to 75 percent compared to 25 to 45 percent, typical of the MDOT 20AA top course dense graded HMA (Fig. 2). The asphalt cement binder, fine sand, filler, and stabilizer additive form the mastic that binds the coarse aggregate matrix together. This mastic is high in asphalt cement content (typically 6 to 7 percent) and provides a very stable pavement that has proved in Europe to be more durable and resistant to fatigue while being less susceptible to low temperature-induced cracking.

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## MICHIGAN SMA vs. 20AAA

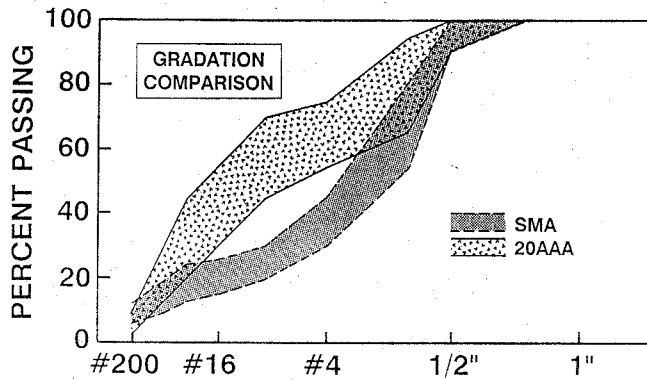


Figure 2.

The primary Michigan demonstration sections were constructed on M 52 south of I 96 in Ingham County during an Open House on August 6-7, 1991, with about 300 participants from throughout the country observing mix production and placement. The overriding goal of our project was to produce and place SMA as closely as possible to European practice with U. S. equipment and materials. Half of the primary section was produced with a 750 ton/hour drum mix plant, and the other half was produced with a standard batch plant. The thickness of the primary SMA section was 1-1/2 in. on a milled surface. Short test strips of SMA were placed on the eastbound I 96 ramps to M 52 to evaluate performance under heavy stopping and turning conditions. For control comparisons, short sections of 20AA and 4C mixtures were placed on M 52 adjacent to the primary SMA demonstration section. The M 52 site has a low average daily traffic, but it had a sound base, known pavement history, and could safely accommodate the large number of project observers.

For the primary SMA mix, a high quality aggregate was hauled 450 miles from Michigan's Upper Peninsula to the project site. While the mineral quality of this aggregate was extremely high, it was too flat and elongated to provide a good SMA, so the larger particles, which made up 45 percent of the material, were recrushed. Recrushing is a routine procedure in Germany to ensure a near-cubical shaped, symmetrical stone for all dense graded and SMA mixes. Two additional SMA mixes were made using a good local aggregate and they were placed adjacent to the primary mix sections.

Table 1.

Test Property	Mix Design	Batch Plant Produced Material	Drum Mix Plant Produced Material
Gradation			
3/4 inch	100	100	100
1/2 inch	94	95	95
3/8 inch	72	76	78
No. 4	35	42	41
No. 8	24	29	28
No. 16	19	23	22
No. 30	16	19	19
No. 50	14	17	16
No. 100	12	15	14
No. 200	10.4	12.9	12.2
Asphalt Content, %	6.5	6.5 ± 0.2	6.5 ± 0.2
Lab Compacted Voids, %	3.0	1 - 2	1 - 2
In-Place Voids, %	---	4.6	3.9
Asphalt Cement Grade	AC-20	AC-20	AC-20
Cellulose, % of Mix	0.3	0.3	0.3
Voids in Mineral Aggregate, %	18.2	16.2	15.9

The same mix design was used for production in the batch and drum mix plants. The mix design and construction control data are shown in Table 1. The mix produced in the field was finer on several sieves. During early production, this finer mix resulted in the voids in mineral aggregate (VMA) of laboratory compacted samples dropping approximately 2 percent below that measured during mix design, requiring the asphalt content to be lowered slightly. The laboratory compacted voids during early production measured for the short test strips typically ranged between 1 and 2 percent. For the primary section, comprising 80 percent of the 4,000 tons of SMA placed, the asphalt content was lowered to 6.2 percent and the voids increased slightly.

The modifier used in the primary demonstration section was cellulose fiber, added in bulk form to the batch plant and in pellet form to the drum mix plant. The pellets added to the drum were 50 percent cellulose and 50 percent bitumen by weight. The fibers successfully performed their function of stabilizing the high bitumen content during construction. Some problems with the complete melting of the pellets were suspected in the drum mix plant. The mixing temperature was increased slightly to about 310 F, and the addition of asphalt cement was moved further up the drum (effectively increasing the wet mix time) to improve breakdown and mixing of the pellets. The resulting mixtures from the batch and drum plants were essentially identical.

The two short test sections incorporating the local aggregate SMA mixes were produced in the drum mix plant, one with cellulose fibers, the other with a polymer modifier. This allowed performance comparison of the two aggregate sources as well as the fiber versus polymer modified SMA.

Conventional paving equipment was used including pavers with vibrating and heated screeds. Good compaction with the SMA was achieved with the key elements being heavy rollers immediately behind the paver while the HMA temperature was about 285 F. Two rollers were used for compaction, a 12-ton steel wheel roller and a 10-ton vibratory roller in the static mode. The vibratory roller was operated in the vibrating mode on an early test strip but it tended to pump the asphalt cement and fines to the surface; thus, the use of the roller in that mode was discontinued.

The construction of the Michigan SMA project was very successful. Of primary importance was the determination that SMA could be successfully produced in a drum mix plant, given the number of drum plants in Michigan and throughout the U. S. The mixtures produced in the batch and drum plants were identical; however, they did have Marshall air voids less than the targeted 3 percent, which has been the typical experience in other SMA projects in the U. S.

Monitoring the SMA sections will continue through core analysis, pavement surveys, friction testing and noise measurements to evaluate its performance. At least two other SMA projects will be constructed during the 1992 season on major freeway sections, now that the feasibility of manufacturing and placing the rut-resistant mixtures have been established. These projects will include several control mixtures to provide comparison of SMA's performance under heavy traffic loadings with more conventional mixes.

-Dan Vreibel

**PLEASE NOTE:** We have many personnel changes, retirements, etc., to report upon in MATES. Lengths of the articles in the last few issues have made it impossible to include these important notices. We regret this, and will acknowledge our valuable employees in a future issue.

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