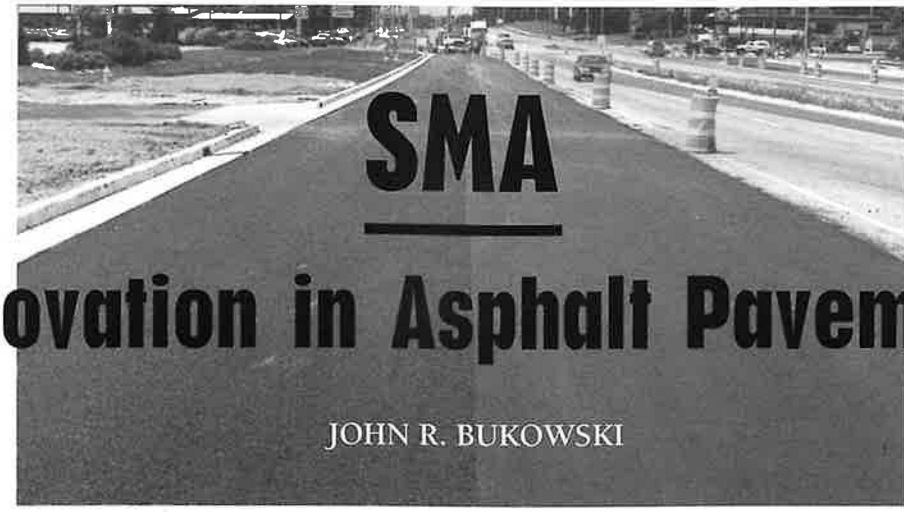

SMA

Innovation in Asphalt Pavement

JOHN R. BUKOWSKI

In 1990 a team of pavement specialists from the United States participated in a tour of asphalt pavements in six European countries. The team included representatives from the American Association of State Highway and Transportation Officials, Federal Highway Administration (FHWA), Transportation Research Board, Strategic Highway Research Program, Asphalt Institute, and National Asphalt Pavement Association. This group, under the designation of the European Asphalt Study Tour (EAST), visited Sweden, Denmark, Germany, France, Italy, and the United Kingdom (see "Paving the Way," *TR News*, May-June 1991).

These six nations have much in common with the United States. All have modern highway agencies and experienced construction industries. All are industrialized and rely increasingly on their extensive highway and road systems to move people and freight. The number of motor vehicles and the use of trucks grows continuously. Similarly, these countries have limited funds to use in addressing the ever-increasing demands on their highway systems. In part with the use of innovative materials, equipment, and contracting procedures, these countries are able to maintain their most traveled roads in excellent condition.

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SMA

SMA is the European pavement innovation that received particular attention by EAST. This pavement innovation is a special-purpose, rut-resistant asphalt surface pavement mixture. It is composed of coarse aggregate held together by a mastic of asphalt cement—mineral filler—stabilizer. Known in Germany as splittmastixasphalt, it can be loosely translated as stone mastic asphalt. It has also been referred to as skeleton asphalt and grit mastic asphalt, as well as various trademarked names. In the United States, the recent accepted terminology is stone matrix asphalt. This aptly describes the unique feature of SMA, its stone-on-stone aggregate structure or "matrix."

At the conclusion of EAST, the FHWA's Office of Technology Applications was assigned the lead in coordinating the evaluation of this technology, adapting it to this country's highway needs and construction characteristics, and implementing it in the United States.

Background

The first step to accomplish these tasks was to gather available SMA technical information from leading European proponents, particularly Germany, which is the leading source of SMA technology. In response to the need for high-performance wearing surfaces, SMA was first designed and used in the 1960s by German highway contractors. Of critical need was the development of a pavement surface that would resist rutting and abrasion under heavy traffic. Since its initial European usage, SMA has provided a successful rut-resistant pavement surface that has resulted in as much as 25 to 50 percent more service life. Use of SMA mixtures spread initially to Sweden and Denmark and then to Norway, The Netherlands, Finland, Austria, France, and Switzerland. Since that time, the Germans alone have placed millions of tons, and current production of SMA in Germany exceeds 1 million tons annually. Sweden, perhaps the next largest European user, produces more than 300,000 tons each year.

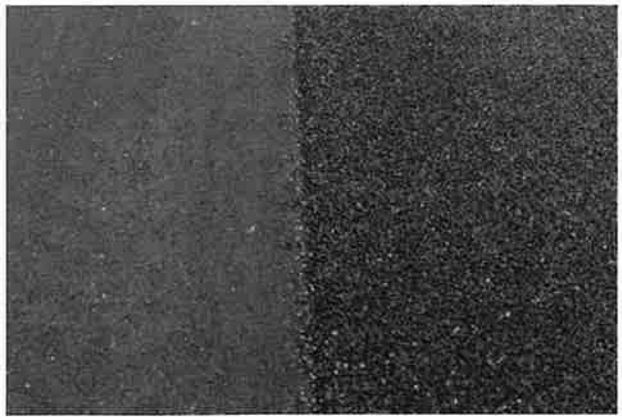
Unlike typical dense-graded (continuously sized aggregate) mixes used in this country, SMA is a gap-graded mix (emphasis on single-sized aggregate). Select materials are employed in SMA. A harder, more viscous grade of asphalt cement is used. This is modified by the addition of a stabilizer of cellulose, basalt mineral fiber or, less often, polymer. The coarse aggregate is 100 percent crushed rock. SMA contains an increased amount of coarse aggregate, mineral dust, and asphalt cement and much less of the fine-sized sand used in typical asphalt mixes. This gap aggregate gradation is necessary to achieve stone-on-stone contact. After compaction this contact forms a "stone skeleton" that resists any further densification or movement of the in-place pavement surface and is the source of SMA's increased strength. SMA aggregate itself is by necessity very durable and contains considerable crushed surfaces. Also, to maximize the stone-on-stone contacts, it has a cubical shape. The second element of SMA is the mortar, or mastic as it is known by the Europeans. This element is composed of asphalt cement, mineral dust, and stabilizer. Its purpose is to fill the voids between the coarse stone particles, thus coating them with a thick, durable film while at the same time holding these particles in close contact with each other.

The difficult task in designing and producing SMA is to ensure that it contains the correct amount of asphalt cement. Too much asphalt will push the coarse aggregate apart, whereas too little asphalt will result in a mix that is difficult to compact, contains high air voids, and has too thin and less durable an asphalt coating.

In the mix design phase, aggregate meeting the "SMA gradation" is combined using traditional compaction and mixing practices. Asphalt content is selected at approximately 3 percent air voids, similar to that used in this country for typical dense-graded mixes. However, the resulting asphalt contents used in European SMA are 6.5 to 7.0 percent, by weight of mix. Such an asphalt content, although appropriate for SMA, is much higher than that of the typical asphalt mixes used in this country.

During mixture production, the asphalt coating must be retained on the aggregate. With such a high asphalt cement content and large portion of relatively single-sized coarse aggregate, this is difficult when asphalt cement is heated to mix production temperatures. Thus there is a need for adding a stabilizer to hold the asphalt cement onto the aggregate during construction.

Finally, SMA in Germany and Sweden is produced exclusively at batch mixing plants and at a relatively low production rate. Placement is also at a slow rate, using a combination vibratory and tamping screed. Compaction is accomplished with multiple heavy steel wheel static rollers.



Comparison of SMA pavement texture *(left)* and conventional pavement surface *(right)* on a 1991 U.S. project.

After reviewing European SMA projects and assorted literature, FHWA produced a Technology Synthesis of European SMA Practices and a Model Design and Construction Guideline for use on the initial projects in this country. Five states volunteered to conduct initial projects to bring SMA concepts to the United States. Samples of their proposed SMA materials were examined in this country as well as provided to European experts for evaluation.

U.S. Projects

Construction of the initial series of field trials began in summer 1991. SMA mixes were placed in Georgia, Indiana, Michigan, Missouri, and Wisconsin. The primary objective of those early trials was to determine construction feasibility and to some extent pavement performance expectations compared with conventional asphalt mixes. Currently, these first five SMA projects are performing well under traffic with no visible problems.

The performance of these initial efforts has led to construction of numerous additional projects in the same five states, as well as projects completed or under design in Alaska, Arizona, Arkansas, California, Colorado, Illinois, Kansas, Maryland, Nebraska, New Jersey, North Carolina, Ohio, Texas, Virginia, and Wyoming.

Nearly 50 SMA pavements have been constructed in this country over the last three years. SMA construction in the United States has grown from 10,000 tons in 1991 to nearly 100,000 tons in 1992, and to more than 500,000 tons in 1993. It appears that the use of SMA in this country could soon exceed that in Germany, the present world leader in use of this type of pavement. Few innovations in the highway industry have attracted such activity in so short a time.

Initial Findings

During the evaluation of the SMA projects in the United States, some preliminary findings were made.

At the outset, practitioners were aware of the need for high-quality aggregates to be used in SMA. However, additional information on size and shape became obvious as more projects were constructed.

The precise amounts of aggregate sizes and proportions are the critical factor in defining an SMA. In order to provide the appropriate stone-on-stone contact, the amount of sand (less than 4.75 mm in size) must be kept to a minimum. The right amount of such sand in an SMA is about half as much as is used in conventional asphalt paving mixes. On the other hand, SMA requires two or three times the mineral dust (0.075 mm or less in size) of conventional mixes. With so much extra mineral dust, its properties can have a significant impact on SMA behavior. During production, the variability of sand-sized aggregates and mineral dust must be controlled if the final SMA pavement is to have its desirable performance properties. Aggregate shape is also of importance. Aggregates used in SMA must be as near to cubical as possible. Excessive flat and elongated coarse aggregates need to be eliminated to maximize the all-important stone-on-stone contact.

Mixture design methodology, important with all pavement mixtures, is especially critical to SMA. When using the wide variety of materials available for pavement construction in this country, even greater demands are placed on the mix design phase. The mix designer's ability to predict the optimum combination of ingredients needs further enhancement for SMA. This requirement comes at a most appropriate time because the Strategic Highway Research Program (SHRP) has offered the potential for vastly improved mixture methodology and prediction over previous practices.

European practice showed the need for the use of specialized stabilizers, in particular cellulose and mineral basalt fibers. With the adoption of SMA in this country, domestic sources of these fibers have been developed. Asphalt modification, with such materials as polymer, have also become common in the various state projects. Adequate blending of the stabilizers into SMA during production was another concern. European practice is to use only a slower production, batch mixing plant. Methodologies have been developed on projects in this country to use both batch and drum plants, blend stabilizers efficiently, and still maintain close to the traditional U.S. high rate of production.

In the same way, normal paving equipment, with only slight modification in operation technique, can be used successfully to place and compact SMA pavements.

Drum mix plant used to produce SMA for a 1992 U.S. project. Stabilizer has been added at center of drum along conveyor belt.

Future Developments

There is a scarcity of detailed, recorded SMA performance data from Europe. Performance has been reported as exceptional in almost every instance. In an industry in which we sometimes learn more from our mistakes than our successes, this presents some unique challenges. How are we to know the limits of the material if we have few or no failures? It may be possible to use less high-quality ingredients and still retain a reasonable likelihood of success. If so, the extent of these ingredients must be determined. A future goal of SMA implementation will be to optimize the material selection and design process.

To further understanding of SMA, state highway agencies with existing SMA projects are anxiously monitoring performance. In many states, not only is a "typical" SMA being built, but also parallel projects are being constructed, some of which are using somewhat less traditional materials in SMA. Some of the more common changes are use of local available aggregates and a variety of stabilizers. Departures from the traditional European experience should be undertaken with caution and only in modest increments. Too far a departure will result in a pavement that does not qualify as SMA, which will always require a certain degree of quality ingredients and precise design and construction control.

During 1994 FHWA will conduct a formal evaluation of the condition and performance of the existing SMA projects. It is anticipated that the results of this effort will offer increased guidelines for the use of SMA with a wider selection of materials and areas for its use. This will facilitate an optimization that has as its goal the most economical design that maximizes performance.

Currently research is being performed in the laboratory by a number of government, university and private industry organizations hoping to improve on the ability to predict SMA performance. The National Cooperative Highway Research Program's Project 9-8, Designing Stone Matrix Asphalt Mixtures, will attempt to develop an improved procedure for the use of SMA. The objectives of this work will be to define materials and properties required in SMA to maximize durability and rut resistance and to recommend an SMA mixture design procedure.

FHWA, along with a number of other government and industry highway agencies, has formed a Technical Working Group on SMA. This group has aided the initial project development and continues to provide related information and assistance in analyzing SMA technology.

At the onset of its fourth year of use in this country, interest in SMA, the European pavement innovation, is stronger than ever. Adaptation and refinement of SMA will continue. When combined with advances achieved through research like that conducted by SHRP, asphalt mixes will go far beyond those of the past, and SMA will be part of that process.

Compaction of SMA with standard steel wheel roller (non-vibratory).