UNITED STATES AIR FORCE (USAF) EXPERIENCE
STONE MATRIX ASPHALT (SMA) PAVEMENT

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ABSTRACT

Stone matrix asphalt (SMA) is a gap-graded mix with a high concentration of coarse aggregate which maximizes stone-on-stone contact in the mix and provides for excellent friction characteristics and a very strong pavement layer that is highly resistant to rutting deformation. The coarse aggregate particles are bound by a thick film of a rich matrix of mineral filler, fibers, and polymerized asphalt that provides for a longer service life by increasing mix durability and fatigue life.

SMA has proven very successful in Europe since the 1960s. United States asphalt professionals were first introduced to the mix on a European Asphalt Study Tour in 1990. The first projects in the US were constructed in 1991. Since then, many states in the US have been using SMA very successfully. In the last 10 years, many civilian airport runways in Europe and over 10 civilian airport runways in China have used this material with excellent results.

USAF experience with SMA began with a test section placed at RAF Lakenheath in 1995. This test section performed remarkably well under aircraft with very high tire pressures, over 300psi. In 1999, SMA (with no grooves) was utilized on the wearing course of the Aviano AB, Italy runway. This runway is providing excellent service to fighters and medium/heavy cargo aircraft. The last inspection, in Sep 2006, shows no rutting deformation or cracking, and its surface is still providing good friction characteristics.

Based on the success with the Aviano runway, HQ USAFE used SMA to resurface the Spangdahlem AB, Germany runway in Jun/July 2007.

1. INTRODUCTION

Stone matrix asphalt (SMA) is a gap-graded mix which contains a high concentration of coarse aggregate, thereby maximizing stone-on-stone contact in the mix and providing an efficient network for load distribution. The coarse aggregate particles are held together by a rich matrix of mineral filler, fiber, and polymerized asphalt. The fibers provide adequate stability of the bitumen and prevent draindown of the bitumen during temporary storage, transport, and placement. The stone on stone contact makes this mix highly resistant to rutting and the high asphalt bitumen content provides excellent durability.

SMA mixes, when constructed correctly, tend to provide longer life because of their increased resistance to rutting, increased durability, increased fatigue life, and increased resistance to crack propagation. Also, its rough surface texture provides good skid resistance eliminating the need to groove it provided pavement surface is sloped adequately.

The excellent resistance to permanent deformation, or resistance to rutting, is provided through mechanical interlock from the high coarse aggregate content forming a strong stone skeleton and its tough binder matrix. Its improved durability comes from the slow rate of deterioration provided by the low permeability and the high binder film thickness of the rich mastic cementing the aggregate together. The high fatigue life and improved resistance to reflective cracking from underlying cracked pavements are also the result of the higher bitumen content which provides mixes with a thicker bitumen film and lower air void content.

The gradation of the SMA mixture is very similar to that used for an open-graded mixture but unlike an open-graded mixture, a majority of the voids in between the large aggregate particles in an SMA mixture are filled with mineral filler and binder. SMA is typically designed with an air void content between three and four percent.

The asphalt content in these mixes is very critical. When the asphalt content is too high the mix may become unstable and may have bleeding problems resulting in loss of good friction characteristics. When the asphalt content is too low the mixture will not have good durability characteristics. Generally the minimum asphalt content specified for SMA mixtures is at least 6 percent in the US and even higher in some other locations.

A typical SMA mixture contains approximately 10 percent minus #200 material with a typical dust to asphalt ratio of approximately 1.5. The aggregates for these mixes must be high quality with fracture shape and rough texture to resist rutting, sufficient hardness to resist fracturing under heavy traffic loads and a high resistance to polishing and abrasion.

The most common problems with SMA are draindown and bleeding. Storage and placement temperatures cannot be lowered to control draindown and bleeding problems due to the difficulty in obtaining the required compaction. Therefore, stabilizing additives such as fibers and polymers have typically been added to stiffen the mastic at high temperatures and to allow use of even higher binder contents for increased durability. Fibers (cellulose and mineral) are commonly used stabilizing additives. A draindown test procedure (AASHTO T305) has been developed to determine the SMA mixtures susceptibility to draindown.
The cost of SMA mixes is typically about 20%-25% higher than conventional asphalt mixes because of the higher asphalt content but this can vary considerably depending on the amount of SMA that is typically constructed in the area, the quality of aggregates in the area, and the price of asphalt cement . But the difference in cost depends on the size of the project. Studies have shown that the difference in cost is recovered by the improved performance.

2. HISTORY

In the early 1960's, the European asphalt industry recognized a critical need for pavements which would be resistant to rutting, abrasion, and various pavement distresses induced by heavy traffic and studded tires. To address this need, roadway pavement contractors developed SMA.

SMA proved very successful in Germany, and its use continued even after Germany eliminated the use of studded tires. As a result, SMA is now included as a standardized mixture class in the German Roads pavement specifications. SMA was initially adopted from the Germans by Sweden and Denmark, and it is now used extensively in Norway, Finland, Austria, France, Switzerland, and the Netherlands.

SMA has proven very successful in Europe, and American asphalt professionals were first introduced to the mix on a European Asphalt Study Tour in September 1990. Since then, many states in the United States have continued to use SMA very successfully. The Georgia Department of Transportation (GDOT) performed extensive research of this mix between 1991 and 1993. Based on successful performance of the many test sections placed, they adopted SMA technology for its sound theory and for its practical approach to producing highly durable and rut-resistant pavements. The Maryland DOT has also adopted the use of SMA for the higher trafficked roadways. Based on a combination of experience from GDOT, MDOT, and the European experience, SMA has proven to provide superior performance. Some benefits include:

- Less rutting than standard mixes
- Greater fatigue life in laboratory experiments
- Reduced thermal cracking
- Increased service life
- Lower annualized cost

The use of SMA for airfield pavements has not been very extensive. In the last 10 years, several civilian airport runways in Europe and 10 civilian airport runways in China have used this material with excellent results.

3. USAF EXPERIENCE

A. RAF Lakenheath, UK taxiway test section

USAF experience with SMA began with a test section placed at RAF Lakenheath in 1993 (info from James Shoenberger, Godwin, Gilbert, and Lynch, "Evaluation of Stone Matrix Asphalt," USAEWES report GL-97-18 dated November 1997). The section of SMA was only 30 meters long and 3.7 meters wide but it was large enough to give some early impressions of SMA. A 50 penetration grade asphalt was used for this project along with a cellulose fiber to minimize draindown. The asphalt content used for this mixture was 6.8%. The mix was designed using 60 blows with a Marshall hammer. The thickness of the SMA was approximately 1.6 inches. The specified minimum density for the mixture was 97% of laboratory density.

Two years after placement the SMA had no sign of any distresses; however, the entire taxiway was reconstructed in 1995 resulting in the removal of the SMA section.

Although the section was only in place for 2 years, the SMA did perform very well and indicated that SMA could be constructed using normal procedures and equipment and had the potential to provide good performance for future airfield pavement construction. So even though this was a small test section that was only left in place for two years, it provided the groundwork for the SMA projects to follow.

B. Aviano AB, Italy runway project

In 1999, the first SMA runway project for the US Air Force was constructed at Aviano AB, Italy. The initial project scope was the replacement of the 5 cm wearing course on this runway using conventional dense graded hot mix. The US Navy was the design and construction agency and they contracted the job with Perini-Jones. The Italian asphalt sub-contractor, Cave e Asfalti, was very experienced in placing SMA and suggested that SMA be used in place of conventional asphalt mixture on this project. The proposal was considered very carefully and after placement of a satisfactory test section, SMA was chosen as the mix type to be used for the runway project.

The SMA mix design for this project utilized the Italian standard mix consisting of a 0 -15 mm aggregate gradation with an asphalt content of 5.4%, stability of not less than 13,000 N based on 75 blows compaction effort, 1-4% air voids and a minimum of 15% VMA. The asphalt was modified with an SBS modifier to provide improved performance and fibers were added to the mix to avoid draindown problems during storage, transport, and placement. The contractor and the construction agency provided excellent quality control and quality assurance. All materials and workmanship met or exceeded the specifications.

Grooving of the surface was not specified based on the history of these SMA mixes providing good friction characteristics in northern European countries. However, because of the asphalt rich mix, the new runway surface had lower friction coefficients until the asphalt film wore off under traffic and exposure to the weather. But these lower friction numbers increased after a few months and has been very good since. Other minor problems experienced were the formation of a few very small (typically only about 1 foot in diameter) fat spots likely due to draindown during construction (Figure 1). The small fat spots appear to have disappeared with time probably due to being worn off under traffic or erosion caused by environmental effects and maintenance operations on the pavement. There were also spots on the pavement where water had seeped up through the pavement surface (Figure 2). This is likely a ground water issue and is not related to any deficiencies in the SMA mixture. While this water continues to drain through the surface in hot weather it has not resulted in any performance problem to date.

Figure 1 - Fat spot shown during inspection in 2000.

Figure 2 - Water draining up through pavement when inspected in 2000.

The cost for the SMA work in this project is difficult to separate from the total scope of work. The project included milling and removing 5 cm of existing material, placement of over 13,000 tons of SMA, the replacement of 3,600 cubic meters of concrete, electrical work, arresting barriers work, markings, and shoulder pavement at a total cost of $5,600,000. The milling and SMA placement was done in seven days and the total project in 32 days.

This runway is providing excellent service to fighters and medium/heavy cargo aircraft (Figure 3). The last inspection, in September 2006, shows no permanent deformation or cracking, and its surface is still providing good friction characteristics.

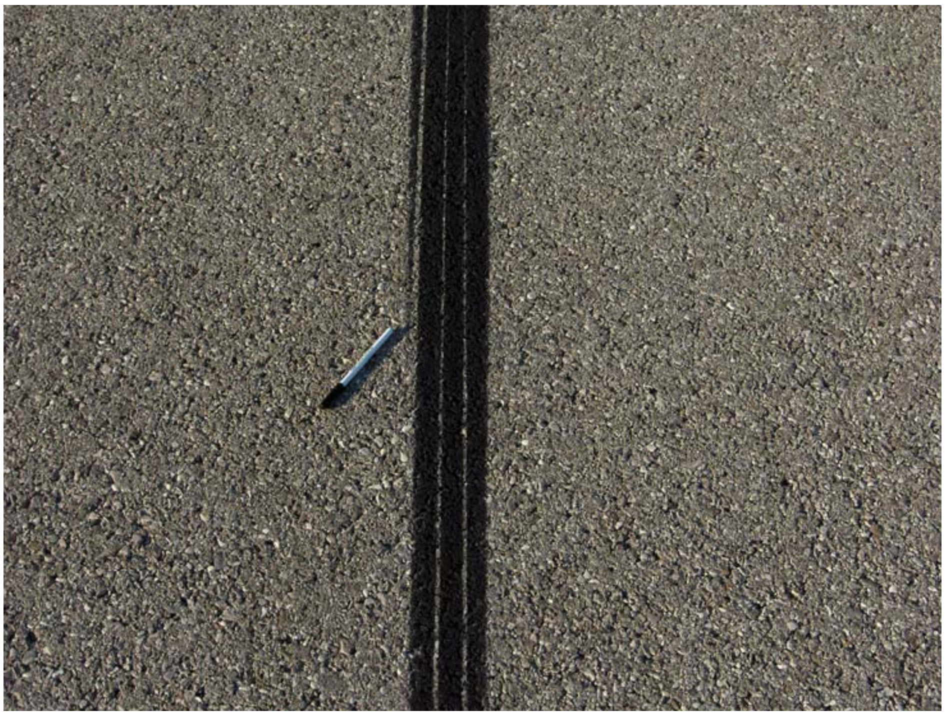

Figure 3 - Condition of SMA Surface with skid mark after 7 years.

C. Spangdahlem AB, Germany runway project

Based on the success with the Aviano runway, HQ USAFE utilized SMA to resurface the runway at Spangdahlem AB, Germany in July 2007. Prior to milling and overlay, the existing hot mix asphalt surface had a significant amount of random cracking as well as cracking in and adjacent to longitudinal joints (Figure 4). During hot weather moisture could often be seen migrating up through the cracks. The scope of this project was to mill and remove the 5 cm (2 inches) wearing course and replace with the same thickness of SMA in a total area of 117,000 square meters.

Figure 4 - Cracking with moisture migrating up through cracks.

SMA mix design for this project utilized the German standard SMA mix in accordance with ZTV Asphalt StB 01 and consisting of a 0 -11 mm high quality aggregate gradation with an asphalt content of approximately 7.0% The SMA was designed to have approximately 2.5 to 3.0% air voids and constructed to have approximately 3% air voids in-place. The mix was designed to provide a minimum mu factor of 0.7 at 100 Km/h measured by means of Stuttgard friction meter. (Granular chips were added to the surface of the SMA during construction so that the initial friction of the SMA would be satisfactory.) The asphalt bitumen was a polymer-modified bitumen PMB 45 A with fibers added to the mix to avoid draindown problems during temporary storage, transport, and placement. The contractor and the construction agency provided excellent quality control and quality assurance. All materials and workmanship met or exceeded the specifications.

Grooving was not specified on this project but sand spreading in accordance with ZTV Asphalt 01 requirements was included during the rolling operation to improve friction coefficients for the SMA until the asphalt film on the surface could wear off under traffic and weathering. After completion of compaction of the mixture, pressure washing of the surface was necessary to remove remaining loose sand to provide a FOD free surface for fighter aircraft operations.

Upon completion of milling and removal of the old wearing course, the area experienced heavy rains for over two weeks. The exposed surface that had been milled got completely saturated and even though precautions were taken to allow it to dry, some moisture remained trapped in this layer and is creating small diameter blisters on three small areas of the runway during periods of hot weather (Figure 5). If the surface is relatively porous then the moisture travels through the surface layer and appears on the pavement surface (Figure 6). The short term solution to the problem is to inspect the runway surface whenever ambient temperature reaches 25 degrees C., deflate blisters by drilling a small diameter hole and roll them to ensure bonding. The problem appears to be localized in small areas and the trapped moisture is expected to dissipate with time.

Figure 5 - Blister shown below straightedge.

Figure 6 - Water from underlying layers moving through surface in hot weather.

The cost of the installed SMA surface was approximately $9.40 per square meter and about $21.25 per square meter for the entire project which included the rough and fine milling, tack coat, electrical work, joint sealing, and markings. Total cost of the project was $2,855,700.

The milling and SMA placement was done in 10 days and the total project in 45 days including weather delays. For the paving operation the contractor used two asphalt plants, two pavers, and up to 8 rollers (Figure 7). Due to this effort the project was quickly constructed and the consistency of the in-place mixture was very good. The runway was opened to aircraft traffic on 1 Aug 2007 without any significant issues other than the blisters which are a minor nuisance. Good performance, similar to the SMA runway at Aviano, is expected from this SMA runway once the blister problem disappears.

Figure 7 - Pavers and Rollers used on SMA Project.

4. CONCLUSIONS

SMA has been providing excellent service since the 1960s on roads in various counties in Europe. It is now used by many state DOTs in the US and in many other countries in the World. In the last ten years, many commercial airports began using SMA also with excellent results. China has used SMA to overlay more than 10 of their commercial airport runways. Based on their experience, they plan to continue the use of SMA. A recent study tour of airfield pavement engineers from the US recently visited China to get more information on the status of SMA use there.

The high resistance to rutting makes SMA an excellent material for use on taxiways and runways where high pressure tire military aircraft operate. SMA mixtures have a longer life and its very low maintenance and repair cost more than compensate for its initial higher cost. It is generally believed that grooving is not required on SMA surfaces and this decision to not groove has resulted in a considerable savings when working on runways. Based on the results of these two HQ USAFE projects, it is anticipated that there will be more SMA project work on USAF airfields in the future.