Study of Stone Matrix Asphalt For The Flexible Pavement

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Abstract - **Stone Matrix Asphalt (SMA) was originally developed in Europe as an impervious/highly durable wearing surface for bridge decks. Based on its performance history, "splittmastixasphalt" began to be used as a surface layer for roadways carrying heavy truck traffic throughout Germany and other European countries. Today, it is the "pavement surface of choice" where long term performance and durability is needed. The highway traffic in India is increasing at a faster rate with the population and the road network has also expanded in different regions of India. Apart from the increase in truck traffic, there is also a huge difference in the maximum and minimum temperatures of the country. The maximum air temperature can reach even 50°°C in some parts of the country and the resulting pavement temperature can reach up to 60˚°C. With the increase in loading and temperatures, the pavements are subjected to various types of distresses. Rutting has been observed to be a major distress in flexible pavements and several studies were carried out across the globe to quantify mechanisms of rutting and to reduce the effective rut depth along the wheel path. The United Kingdom is currently resurfacing most all of its heavy traffic roadways with a SMA-type surface to provide a cost-effective surface treatment. Many countries are taking advantage of the quiet and smooth ride characteristics to address the public requirements**

Index Terms — **Advantages of SMA, Scope of SMA, Application of SMA, Design of SMA.**

I. INTRODUCTION

Stone Matrix Asphalt Pavement is hot mix asphalt consisting of two parts - a coarse aggregate skeleton and a binder rich mortar. It is made up of a mixture of crushed coarse and fine aggregates, mineral Filler, asphalt cement and a stabilizer for the binder, such as polymer or fibres. The philosophy of SMA is that the coarse aggregate skeleton stone portion provides a stone on stone contact to prevent rutting and provide skid resistance. The mix is held together with sufficient specialized mortar (the Matrix portion) to prevent draindown of the binder and to provide the mix with durability. SMA pavements are normally 2 inches thick when using a nominal ¾ inch (19 mm) aggregate size and have been placed at a 1½ or 1 inch thickness using a ½ inch (12.5 mm) or 3/8-inch (9.5 mm) nominal aggregate, respectively. All three nominal mix sizes have been successfully placed in Colorado. Bridge deck SMA overlays are normally 3 inches thick.

II. ADVANTAGES OF SMA

- It provides Resistance to rutting due to slow, heavy and high volume traffic.
- It provides Resistance to deformation at high pavement temperatures.
- Improved skid resistance& also improved resistance to fatigue effects and cracking at low temperatures.
- It results into Noise reduction over conventional alternative pavement surfaces.
- It increases durability&Reduces permeability and sensitivity to moisture.

III. SCOPE OF SMA

The scope of the present work involves the determination of various physical properties of the bitumen and aggregates used for SMA Mix. SMA samples are prepared by varying the binder content in Marshall Method and Super pave Gyratory Compactor (SGC). These specimens are analyzed for the density-voids and stability-flow. The optimum bitumen content for the mix with CRMB-55 and Terrasil treated aggregates are determined. The laboratory performances of the SMA mixes are checked for moisture susceptibility, rutting and repeated load tests. Drainage test was conducted to check for the binder drainage. Permeability tests were conducted to study permeable nature of SMA mixes with CRMB-55 and treated aggregates. Moisture susceptibility tests include the evaluation of Indirect Tensile Strength, Tensile Strength Ratio and boiling test for stripping.

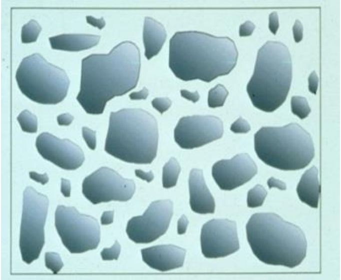
The rutting studies include determination of rutting depth by using Immersion Wheel Tracking Device (IWTD). Repeated load tests were carried out on SMA samples with CRMB-55 and treated aggregates to determine its fatigue life. Disposal of waste tires is a serious environmental concern in many countries. In order to solve this environmental problem partly and at the same time to improve the performance of Stone Matrix Asphalt (SMA), CRMB-55 was used for the investigation. Another attempt of SMA Mix using an anti-stripping additive was done. The objective of the present investigation is given below:

- To reduce anti-stripping by treating aggregates using anti-stripping agents. AlsoStudy the characteristics of SMA mixes using CRMB-55 binders and a mix using treated aggregates and VG-30.
- To evaluate the stability, flow value and volumetric properties of SMA mixes with CRMB-55 and treated aggregates by using Marshall Method and Superpave Gyratory Compactor.

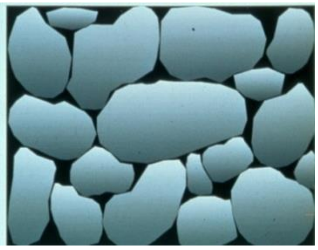
- To study the indirect tensile strength, permeability,Rut depth and amount of stripping of SMA mixes with CRMB-55 and treated aggregates.
- To study the performance of SMA mixes withCRMB-55 and treated aggregates under repeated loads.

IV. PROPOSED METHODOLOGY

Experimental studies were conducted in Laboratory as mentioned in the Scope.



Dense Graded Mix



SMA Mix

The Philosophy of The SMA - Concept

The philosophy of the SMA - concept can be summarized briefly as follows:

High stability to permanent deformation and high wear resistance by an excellent particle interlock and a high content of crushed premium aggregates.

Longevity and durability to premature cracking and ravelling by a very high content of bitumen and a void less mastic mortar which fills the voids of the stone skeleton and binds it together: high quality and quantity of bitumen are pre-requisite for a long useful service life.

Stabilizing additives assurances the homogeneity (no binder drainage) of the mix during the manufacturing, transportation and laying. As a side effect, they improve the stability.

High quality and high quantity of bitumen and coarse gap-graded aggregates are the essentials for a long service life of SMA.

Aggregates:

Double crushed tough premium aggregates of definite size, soundness, shape etc., e.g. max. 20% of flaky and elongated aggregates; all aggregates (aggregates, sand, filler) need to be under a permanent quality assurance, which is independent an from a third party.

Mineral-Type:

Granite, basalt etc. should be used as minerals. Limestone, sandstone and "soft" minerals shouldn't be used. Because the minerals/aggregates must have a high resistance to polishing and they also need to have a good aggregate abrasion value (LA 20). Furthermore, if available, the use of two different types of minerals can improve the performance and skid resistance.

Filler:Usually mineral filler (grounded limestone) is used.

Sand: 100% of the sand fraction must be crushed.

Gradation: Gap-graded (very high content of crushed coarse aggregates)

If you have no problems with the aggregates used in asphalt concrete, you will also have no problems in the SMA-mixture. If you have problems with the aggregates used in asphalt concrete you will have more problems using these aggregates in SMA.

Bitumen

The use of the particular bitumen quality predominantly depends on climate and traffic conditions. Paving grade bitumen and polymer modified bitumen is specified by Indian standard.

Additives: According to the specifications the following additives are permitted: Cellulose fibres,Polymers Artificial, siliceous material.

V. RANGE OF APPLICATION

SMA is adequate and it is recommended for any surface course. It is especially used for all heavy traffic roads. SMA is much more economical than asphalt concrete. Since the specifications were introduced in 1984, the use of SMA has significantly increased. The Stone Matrix Asphalt is appropriate for Highways, Rural roads, urban roads, Airports, Industrial areas. The choice of SMA mix design is at the discretion of the client when preparing the RFP (requirements for pavement). For the highway projects, SMA is the most favourite and acceptable asphalt mix and therefore - by experience – it is used intensively for these highway pavements.

By the selection of SMA, there is a strong tendency to a smaller top size, i.e. from 11 mm to 8 or 5 mm top size aggregates, because of the following reasons:

- Lower unit price per sq. m because of smaller thickness is necessary
- Less noise under traffic
- Better skid resistance
- A larger top size requires a greater thickness which means a higher unit price per sq. m,

- Larger top sizes generate more traffic noise; but there is a strong demand of public to reduce traffic noise.

Mix Design

There is no specific mix design method for SMA, but there are information sheets for initial suitability tests on hot mix asphalt. The steps of the evaluation of an appropriate job mix formula (JMF) according to the information sheet mentioned above are as follows: In accordance with the RFP (requirements for pavement) and with respect to its experiences with former JMFs, mixing, paving, performance during the time of warranty, and - last but not least - the price, the contractor selects the aggregates and the filler with the selected material (aggregates, sand, filler, additives) and on the basis of the feedback from other sites and JMFs, a tentative gradation is chosen. But there are requirements for abrasion value, polish stone value, freezing-thawing-test, etc. Mixes with the required minimum asphalt content and with three adjacent asphalt contents are prepared. Marshall specimen are prepared at 135/145 ± 5°C and by 50 blows on each side the Marshall tests are running for the evaluation of the air void content which must range from 3 to 5 % by volume (i.e depending on German climate conditions). If the required air void content is not achieved, the following alterations of the tentative mix within the enforceable limits of the specifications are recommended: Change total content or content of single sizes of crushed aggregates, Change filler content, Change mortar content.

Drain-down test: Additives are necessary to avoid drainage of binder from the coarse aggregates during mixing, transportation and paving. Therefore, a drain-down test must be performed for the evaluation of the appropriate and necessary content of the additive.

On the basis of the mix design results, the contractor decides on the JMF and submits it to the client for his approval.

Additives

Although fibres, polymers and siliceous materials are also permitted, cellulose fibres are used very extensively. By tests, trials and by experience, it was discovered that only the use of polymer is not adequate to avoid segregation of the gap-graded coarse aggregates and the high bitumen content. The additive has to be a bitumen carrier; polymer as a bitumen improver is not sufficient. All SMA-JMFs with polymers also had lower bitumen content than required or they had additionally fibres mixed in to achieve the requirements.Cellulose fibre shows no chemical reaction with the bitumen and it is inert to mixing temperatures and it works excellently. Because of the performance of the cellulose fibres, the technical assistance of the supplier and - last but not least - the relatively low price of the fibres, the usage and the market share of the different types of additives for SMA e.g. in Germany is as follows: Cellulose fibres 95%, the rest mineral fibres and other additives.

Mixing

Mixing and paving is neither specified in the specifications nor in the RFP. Method and equipment are within the assigned responsibility of the contractor. His technical expertise and accountability are essential.

Minimum and maximum temperature of SMA-mixture in °C	
Binder quality	**Stone Mastic Asphalt (SMA)**
50/70	150 – 190
70/100	140 – 180
25/55-55	150 – 190
45/80-50	140 – 180

- Drying of the unbound coarse material needs less heat than it is necessary for standard asphalt concrete (AC) and therefore the heat of the dryer must be reduced. Short term aging of the asphalt is very likely when it is mixed with too hot coarse aggregates. Drying of the minerals needs to be executed at such a temperature that the heat of the mix in the pug mill does not exceed 190°C. Mixing times depend on the type of plant.
- Paving and compaction procedure is similar to standard asphalt.
- Trucks must be covered until the SMA is discharged into the material hopper at the front of the road paver.
- Although the asphalt content of the SMA is very high, a tack coat is recommended to ensure and improve the bond between the layers.
- The temperature of the SMA in the road paver should be at least 150 (140) °C.
- An adapted pre-compaction of the asphalt paver is useful and should be achieved.

Compaction should be started as soon as possible and the roller should move as close to the paver as possible. Steel wheel rollers of approximately eight to ten tons for compaction are necessary. Vibrating should be executed mostly two or three times. There is a hazard of mortar enrichment on the surface, if using too much vibrating roller passes. The consequence is a very low initial skid resistance. Vibrating is not advisable on thin layers of approximately less than 25 mm thickness and at layer temperatures under 100°C. Since sucking up of the mortar is very likely compacting with a pneumatic roller can be a hazard.

Because of the high asphalt content, the initial skid resistance can be low and it can cause safety problems on high traffic highways. Therefore, a surface treatment is recommended by spreading 0.5 to 1.0 kg of fine crushed aggregates per sqm. After the first or second roller pass aggregates which are free of fines and 1/3 mm should be used.

During, the execution of the work there is a quality assurance by the client at every 6,000 sqm: SMA - samples are taken from the paver and tested.

VI. SALIENT-FINDINGS AND CONCLUSIONS

On the basis of analysis of results obtained in the present investigation, the following conclusions can be made:

- The results obtained from Marshall and SGC method provides similar results. Marginal difference in density values were observed for SMA samples prepared by SGC method because of its compactive effort.
- Addition of CRMB-55and modified aggregates improves the volumetric properties of SMA. The OBC of the SMA mixes with CRMB-55 and modified aggregates were 6.2% and 6% using Marshall and SGC respectively. From the results, it is clear that there is not much difference in the volumetric properties of SMA prepared using Marshall and 80 gyrations in SGC.
- The SMA mixes were found to be having good stone-on-stone contact. Addition of CRMB-55 and modified aggregates decreased the drain down value and hence the stabilizer additives can be avoided.
- The test proved that there is no stripping in the SMA mix prepared using modified aggregates and 10% stripping in the mix with CRMB-55.
- TSR was found to be more than 80% for all the SMA mixes used in the study. Higher TSR is obtained for SMA Mix using modified aggregates which indicate better cohesive strength of this mix as compared to SMA mix using CRMB-55.
- Test results indicate that the SMA specimen using CRMB-55 is less susceptible to permanent deformation (rutting) than that with modified aggregates.
- Repeated load test results prove that the fatigue life of SMA specimen using CRMB-55 was higher as compared to the fatigue life of SMA specimen using modified aggregates.

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