Study of Stone Matrix Asphalt(SMA)using Different Fillers

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Abstract— There are three major types of asphalt surfacing, characterized by a mixture of bitumen and stone aggregate. These are: Dense Graded asphalt (DGA); Stone Matrix Asphalt (SMA) and Open Graded Asphalt (OGA). Asphalt surfacing differs by the proportion of different size aggregate, the amount of bitumen added and the presence of other additives and material. The aim of this is to study the effect of different fillers on SMA Mix Design.
Key words: SMA, DGA, OGA

I. INTRODUCTION

A. SMA:

SMA was developed in Germany in the 1960s by Zichner of the Straubag-Bau AG central laboratory, to resist the damage caused by studded tires. As SMA showed excellent resistance to deformation by heavy traffic at high temperatures, its use continued even after the ban of studded tires. SMA is a gap graded mixture containing 70-80% coarse aggregate of total aggregate mass, 6-7% of binder, 8-12% of filler, and about 0.3-0.5% of fiber or modifier. The high amount of coarse aggregate in the mixture forms a skeleton-type structure providing a better stone-on-stone contact between the coarse aggregate particles, which offers high resistance to rutting. Aggregate to aggregate contact is also there in dense graded mixtures but it occurs within the fine aggregate particles as the coarse aggregate floats in the fine aggregate matrix, which don't give the same shear resistance as the coarse aggregate skeleton. Brown and Manglorkar (1993) reported that the traffic loads for SMA are carried by the coarse aggregate particles
instead of the fine aggregate asphalt-mortar. The higher binder content makes the mix durable. The fibers or modifier hold the binder in the mixture athigh temperature; prevent drainage during production, transportation and laying.

SMA is defined as "A gap graded aggregate hot mix asphalt that maximizes the binder content and coarse aggregate fraction and provides a stable stone-on-stone skeleton that is held together by a rich mixture of binder, filler and stabilizing additives". The deformation resistant capacity of SMA stems from a coarse stone skeleton providing more stone-on-stone contact than with conventional dense graded asphalt (DGA) mixes. Improved binder durability is a result of higher bitumen content, a thicker bitumen film, and lower air voids content. This high bitumen content also improves flexibility. Addition of a small quantity of cellulose or mineral fiber prevents drainage of bitumen during transport and placement. There are no precise design guidelines for SMA mixes. The essential features, which are the coarse aggregate skeleton and matrix composition, and the consequent surface texture and mixture stability, are largely determined by the selection of aggregate grading and the type and proportion of filler and binder.

B. Classification of Bituminous Mixtures: -

A bituminous mixture is a combination of bituminous materials (as binders), properly graded aggregates and additives. Bituminous mixtures used in pavement applications are classified either by their methods of production or by their composition and characteristics. .Bituminous mixtures can be classified by their method of composition and Characteristics as Dense-Graded HMA, Open-Graded HMA and Stone Matrix Asphalt(SMA). Dense-graded mixtures has a dense-graded aggregate gradation(aggregates are evenly distributed from coarse to fine) and have a relatively low air voids after placement and compaction. They are commonly used as surface and binder courses in bituminous pavements. The term bituminous concrete is commonly used to refer to a high-quality, dense-graded HMA mixture. A dense graded HMA mixture with maximum aggregate size of greater than 25 mm is called a large stone dense grade HMA mix, whereas a mix with 100% of the aggregate particles passing through the 9.5mm sieve is called a sand mix.

Unlike dense-graded mixes, an open-graded HMA mixture has a relatively larger size aggregate that contains very little or no fines, they are designed to be water permeable. Due to less aggregate surface area, these mixes have relatively lower bitumen content than that of a dense-graded HMA mix.

Stone Matrix Asphalt (SMA) is a gap graded bituminous mixture containing a high proportion of coarse aggregates and filler with relatively less medium sized aggregates. It has high binder content and low air voids with high levels of macro texture when laid resulting in waterproofing with good surface drainage. For a comparison, a view of a typical SMA mixture and a conventional dense graded mixture (NAPA, 1999). Cores from SMA mixtures (left) illustrate the greater percentage of fractured aggregate and higher percentage of
bitumen binder, compared to the conventional Hot Mix Asphalt (HMA) mixture (right) which contains a more uniform aggregate gradation and less bitumen binder.

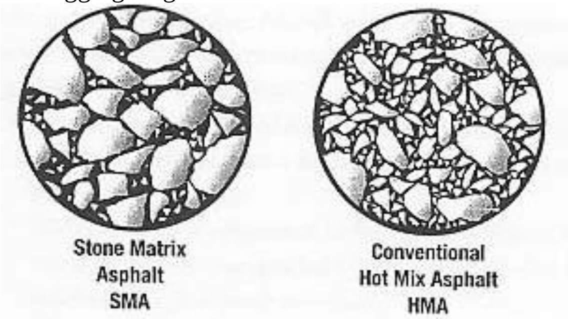


Fig. 1: comparison between SMA and conventional HMA

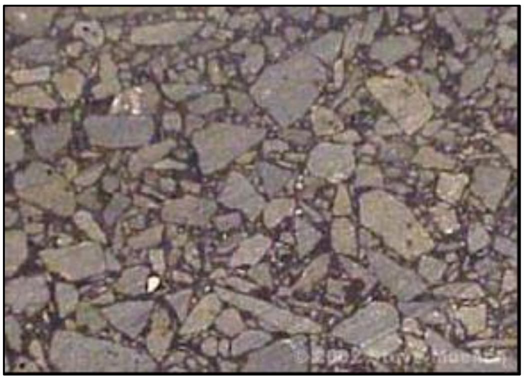


Fig. 2: Dense graded HMA


Fig. 3: Open graded HMA


Fig. 4: Stone matrix asphalt

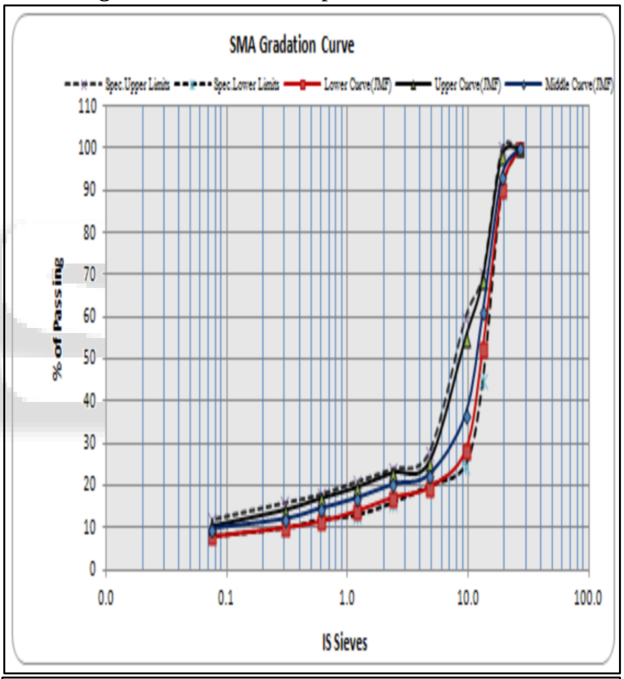
II. LITERATURE REVIEW

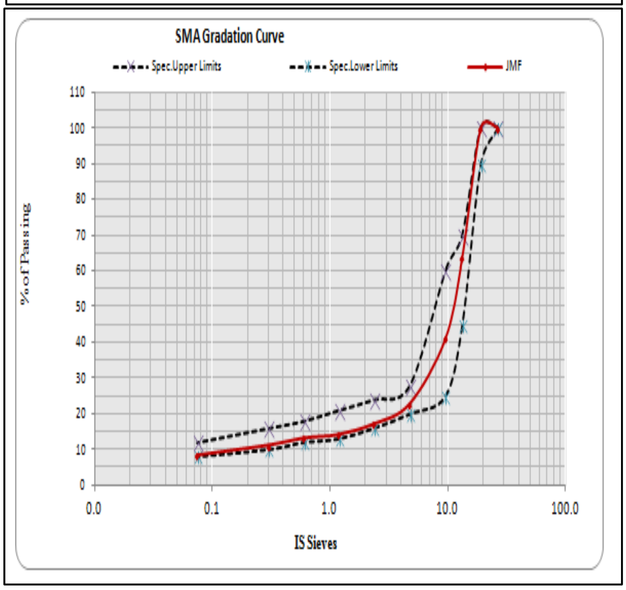
A. .(Salam Ridha Al-Etba ,Dr. P. Sravana & Amrendrakumar, 2013):

The effect of aggregate gradation and filler type in properties of SMA. Four of different aggregate gradations with two types of fillers, such as Hydrated Lime and Crushed Stone Dust have been tried for preparation of mixes. Hydrated Lime of SMA mixes has been improves air voids and Moisture Susceptibility in the same gradations of samples with Crushed Stone. They recommend to use the weight to change in grade to evaluate the resistance of aggregate particles to gradations in SMA mixes. The measurement of weight can be very valuable procedures to evaluate the resistance of aggregate. Four of different gradations with two types of fillers, Hydrated Lime and Crushed Stone have been tried for preparation of mixes. Crushed Stone has been improves the Marshall properties which is a low cost has Been used in the mixes had high Marshall Stability and unit weight values more than Hydrated Lime. Hydrated Lime of SMA mixes has been improves air voids and Moisture Susceptibility in the same gradations of samples with Crushed Stone. The optimum binder contents are found with Hydrated Lime is less, which is an important advantage from economy and quality point of view. It has been observed that the drain down and moisture susceptibility characteristics have improved by using Hydrated Lime filler in the mix. It creates multiple benefits for pavements:

- Hydrated lime acts as mineral filler, stiffening the asphalt binder and SMA.
- It improves resistance to fracture growth (i.e., it improves fracture toughness) at low temperatures.
- It favourably alters oxidation kinetics and interacts with products of oxidation to reduce their deleterious effects.

Hydrated lime is an additive that increases pavement life and performance through multiple mechanisms. It is also found that Crushed Stone increases the stability value and tensile strength ratio of mixes. Both of lower and upper curve were failed to get the optimum binder content in both types of filler used, middle curve behaviour same to modified curve but lower in result values. From the overall discussion of the test results on SMA mixes, it can be concluded that all the mixes made with middle curve and modified curve content of both filler types perform satisfactorily and can be used in mixes in the wearing courses of flexible pavements.





B. (Ratnasamymuniandy, Elataheraburkaba, Lamyam.J Mahdi, 2013):

They study and examines four types of industrial and by-product wastes filler, namely; limestone as reference filler, ceramic waste, coal fly ash, and steel slag. One filler content consists of 10% by total weight of aggregate with three proportions; 100% passing 75micron (µm), 50/50 % passing 75µm/20µm, and100% passing 20µm was used. Laboratory tests were performed to determine the impact of different filler types and filler particle size on some properties of asphalt-filler matrix and Stone Matrix Asphalt mixture (SMA). The results indicate that the application of industrial and byproducts wastes as filler improves the properties of asphalt-filler matrix and SMA mixtures. The increased stiffness, due to addition of the filler, is represented by an increase in softening point, in viscosity, stability and resilient modulus as well as a decrease in penetration. The optimum asphalt content at given filler to asphalt ratio increased with the decrease in filler particle size regardless filler type. It was also determined that the filler type and particle size has significant effect on the mixture property. Among these three proportions, the samples prepared with the filler size proportion of 100% passing the 75microm gave the best value in terms of Marshall Quotient, the filler size proportion of 50/50 gave the best value in terms of Resilient Modulus while Stability vary depends on filler type.

Their main objective of study was to facilitate decisions concerning the effectiveness of using new filler types with different particle size obtained from by-product wastes to improve the engineering properties of paving mixtures to enhance pavement performance. The reported improvement in the engineering properties of the paving mixtures containing ceramic waste, coal fly ash, and steel slag can be attributed to the bonding and cementations properties of the fillers. This tends to increase the viscosity of the filler-asphalt matrix and the particles texture of the fillers which tends to increase the frictional resistance among the aggregate particles and increase the stability of the mix. From the investigation reported in their study, using different types of fillers with different particle size, the following conclusions can be summarized as follow:

- Filler type and particle size plays an important role on the engineering properties of the asphalt mixtures.
- The filler component, in addition to filling the voids, interacts with the binder present in the mix making it stiff and brittle. The change in mix properties is very much related to the properties of the filler.
- The major finding of this study, is that ceramic waste and steel slag as a filler were found to be effective in improving the Marshall Stability, Resilient Modulus, and Marshall Stiffness Index or Marshall Quotient (MQ) as compared to limestone filler. Coal Fly Ash had the lowest optimum asphalt content. On the other hand, it had little improvement in Marshall Stability and the Resilient Modulus value compared to the reference filler.
- In this study; a general trend was observed that, the properties of the asphalt-filler matrixes and SMA mixtures increased by increases the filler particle size at a given asphalt/filler ratio regardless filler type.
- The results of the laboratory tests on the ceramic waste and steel slag fillers were found to improve the overall mixture properties. The use of these special filler improves the pavement performance, thus reducing the maintenance and rehabilitation cost of the pavement.
- It can be concluded that utilization of industrial and by-product wastes in SMA results in the improvement of the engineering properties and reduction in the optimum asphalt content. The reduction in optimum asphalt content results in significant cost saving.

C. (A. Behnood And M.Ameri, 2012):

Significant quantities of steel slag are produced as by-product every year from steel industries in Iran. Although it can be used as an artificial source of aggregates, it is sent to landfills for disposal. The disposal of steel slag occupies a significant portion of landfills and causes many serious environmental problems. This study aims to investigate the feasibility of utilizing steel slag aggregates in Stone Matrix Asphalt (SMA) mixtures. The results show that the use of steel slag as the coarse portion of aggregates can enhance Marshall stability, resilient modulus, tensile strength, resistance to moisture damage and resistance to the permanent deformation of SMA mixtures.

They found that According to the results obtained from Marshall stability, indirect tensile strength, and resilient modulus tests, it should be noted that mixtures with steel slag have shown encouraging results in comparison with those containing limestone. Also, replacing the coarse portion of limestone aggregate with steel slag leads to better results in comparison with mixtures that contain steel slag as the fine portion. Steel slag used as the coarse portion in SMA mixtures increased Marshall stability and decreased flow values. Hence, mixtures with steel slag coarse aggregate have higher MQ values, which is an indicator of high stiffness and resistance to permanent deformation.

MSR and TSR values obtained from the loss of Marshall and moisture susceptibility tests, respectively, indicated that utilizing steel slag as the coarse portion of aggregates can enhance the resistance of mixtures To moisture damage.

Dynamic creep test results indicated that mixtures containing steel slag as the coarse portion are more resistant to permanent deformation and have lower rut depth.

D. (Deprizonsyamsunur, NazahathNaeem and Eric Loh, 2013):

In their study, cockle shell ash was used as a filler material in Stone Matrix Asphalt (SMA) mix to verify the appropriateness and feasibility for the highly traffic roads. SMA is one of the new generations of asphaltic mix and adopted in many countries due to its excellent performance. The main objective of their study is to determine whether the cockle shell as a filler material can improve their performances of Stone Matrix Asphalt on its stability and flow. The manual compaction was carried out to obtain the shell ash and exploited to evaluate the volumetric properties of the design mix. The aggregate gradation of SMA 20 was utilized as the aggregates and 25% increment of cockle shell ash was added as a filler material in their study. The results were compared to conventional or 0% of cockle shell to check the suitability of the materials. The results obtained are adequate and meet the requirement of the standard for SMA Mix.

This study investigates the potential and suitability of shell ash as a filler material in SMA 20 Mix by Marshall

Test parameters. The results proved that cockle shell ash can be exploited as mineral filler in SMA design as it meets the standard requirement. The other local materials such as coal fly ash, steel slag, limestone dust can be applicable as a filler material in SMA Mix by meeting the criteria from the laboratory test. The stability values concluded that the increments of cockle shell ash declines the stability values of the design. The maximum stability values are obtained at the conventional and stability rate decline with increments of bitumen content. However, the stability values meet the standard requirements and cockle shell ash can be utilized as a filler material for SMA design. The additional filler material showed that the low flow values compared to conventional specimens and the peak occurred at 6.5% of bitumen. There are variation in 75 and 100% of shell ash which might be because of manual compaction, maintain of the temperature during sample preparation etc. Though, the result met the requirement as it lies in the range of 2-3 mm and is appropriate for the filler material.

Void in Mineral Aggregates results are above the standard requirements for SMA specification. The results of additional mineral filler are lower than the conventional specimen and optimum is obtained at 6.5% of bitumen content. There is slight variation of VMA in normal specimen and specimen with cockle shell ash as filler material, although, this can be adequate to utilize as a filler material. The net result conclude, it can be appropriate as the filler materials in SMA Mixtures while it has lower volumetric properties compare to specimen of normal or 0% of shell ash as filler materials as it showed the adequate result for parameters according to the standard.

III. Conclusion

From above study it can be conclude that steel slag, fly ash, cockle shell, stone dust, hydrated lime, ceramic waste can be used in SMA mix design as filler material. The fillers can be add in mix in range of 8-12%. These fillers are significantly affect the SMA mix design and helps to improve the strength of bituminous mix. The mixes with cement and fly ash results in less drain down. Using low cost fillers which are by product of industries can be reduce the cost of total road construction.

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