A Study on Properties of Stone Mix Asphlat by Using Cellulose as Fiber and Copper Slag as Partial Replacement to Aggregates

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Abstract— Generally, Aggregates are used in addition with bitumen throughout the world in construction & maintenance of flexible pavements. Aggregates with uniform, close, well, or dense perform well with normal bitumen in heavily trafficked roads when designed and executed properly and also commonly used in paving industry. But it is not always possible to arrange dense aggregates available at the site positions. In such situations, bituminous mix known as stone matrix asphalt (SMA) that is basically consisting of gap graded aggregate, can be attempted. SMA (stone matrix asphalt or stone mastic asphalt) was originally developed in European and German countries as impervious or highly durable wearing surface for bridge decks. But today, it is pavement surface of choice. It consists of two parts, a coarse aggregate and a binder rich mortar. It is made by a mixture of crushed coarse and fine aggregates, stabilizer such as fibers or polymers, mineral filler, cement. In present study, an attempt has been made to study the properties of SMA mixes with cellulose fiber and Copper slag in partial replacement of stone aggregates as coarse and fine aggregate grades. This research project was done to check the usage of Copper slag in SMA mixture by conducting Marshall test in the laboratory in which stability value and flow values was examined along with other properties of mixtures. Here IRC -SP-79 specification, aggregate gradation is taken for stone matrix asphalt. Binder used is 60/70 penetration grade bitumen. Binder content is varied as 4%, 5%, 5.5%, 6%, and 7% by weight of aggregates and fiber used is optimum fiber content at 0.3% by weight of aggregate. Maximum stability value is obtained for copper slag as coarse aggregate i.e. 17.77 KN at 5.5% bitumen content when compare to stone as coarse aggregate. SMA Mix with Copper slag material shows less flow value in comparison with stone aggregate. The air voids with Copper slag shows more value than stone aggregate. Copper slag shows optimum binder content of 5.5% whereas SMA Mix with only stone aggregates gives optimum binder content of 5%.

Keywords: SMA, Copper Slag, Cellulose Fiber, Marshall Stability Introduction

I. INTRODUCTION

Stone matrix asphalt has been proved, most expensive when compare to the dense graded mixes for high volume roads. Brown (1992) observed that many number of factor influenced the performance of SMA mixtures, as change in binder source and grade of mix, types of aggregates, environmental conditions, production and methods of construction etc. The FHWA SMA Technical Working Group defined SMA as "A gap graded aggregate hot mix asphalt which will maximize the binder content and coarse aggregate fraction and provides a stable stone-on-stone skeleton that is held together by a rich mixture of filler, binder and stabilizing additives".

A. Advantages

- It improves skid resistance, reduces noise when compared to conventional alternative pavement surfaces.
- SMA also shows improved resistance to fatigue effects and cracking at low temperatures, also increases durability, and reduces permeability and sensitivity to moisture.
- SMA provides excellent resistance to rutting due to slow, heavy and high volume traffic, and resistance to deformation at high pavement temperatures.
- SMA has a rough texture which gives good friction properties after the upper surface film of the binder is removed by the traffic.
- Higher strength, durability, reduced moisture permeability and longevity of SMA over conventional mixes.

B. Disadvantages:

- Increased cost associated with higher binder and filler contents, and fiber Additive.
- High filler content in SMA may result in reduced productivity. This may Be overcome by suitable plant modifications Possible delays in opening to traffic as SMA mix should be cooled to 40 oC to prevent flushing of the binder surface.
- Initial skid resistance may be low until the thick binder film is worn off the top of the surface by traffic.

C. Objective of the Project

- The main objective of this project is to check the suitability of preparing SMA mixes using fiber and to study their effect on various properties of SMA.
- Preparation of several Marshall Specimens and to achieve optimum binder content by using Marshall Method.
- To compare the various engineering properties of the SMA samples with other similar type test results.

II. LITERATURE REVIEW

Al-Qadi and Imad L (2007) tried to develop an understanding of the interaction between aged and virgin asphalt binders in RAP. Based on this understanding, they determined the appropriate level of contribution that should be given to the residual asphalt binder in RAP. The level of interaction between aged and virgin binders will then be used to investigate the influence on the performance and the durability of the mixtures as compared to virgin HMA. RAP material into hot-mix asphalt (HMA) since 1980, RAP HMA design provides 100% contribution for the residual asphalt binder from the RAP based on solvent extractions.

This means that the amount of virgin asphalt binder is reduced by the full amount of asphalt binder in the RAP for the percentage specified. This has recently been reported to be inaccurate and could result in an erroneous HMA job mix formula and may cause dry HMA. Hence, the HMA may become vulnerable to durability cracking and premature failure.

Yue Huang and Roger N.Bird studied on construction and maintenance of UK roads consumes large amounts of quarried aggregates. The use of secondary (recycled), instead of primary (virgin), materials helps easing landfill pressures and reducing demand of extraction. However, concerns over inferior road performance and additional costs have hindered the widespread use of secondary aggregates in such applications. This is especially the case in surface layers of asphalt pavements that may represent a value application for recycled solid waste materials (SWM). Waste glass, steel slag, tires and plastics are selected for technical requirements, as well as the performance of asphalt pavements constructed using such recycled materials. Waste arising and management indicates that although there is a large potential for supplying secondary materials, a few factors have effectively depressed such recycling activities. Such barriers are described and may also apply to the secondary use of other SWM. After identifying and quantifying such barriers a brief discussion suggests ways of theirremoval.

Kandhal, P S (1997) studied on brief overview of the recycling of asphalt pavements. Five recycling methods are present: (1) cold planning; (2) hot recycling; (3) hot in-place recycling; (4) cold in-place recycling; and (5) full depth reclamation. Strategies for selecting an appropriate recycling method and also performance of different recycling processes have been explained. Economics, legislation/specification limits, and structural design associated with recycling of asphalt pavement are explained. Brown and Haddock (1997) has remarked that, due to the fact that the strength of SMArelies mostly on the stone-on-stone aggregate skeleton, steps should be taken as to design the mixand place it with a strong coarse aggregate skeleton that would provide the desired strength and stability to the mix.

Kumar Pawan, Chandra Satish and Bose Sunil (2007) tried to use an indigenous fiber in SMA Mix by taking low viscosity binder coated jute fiber instead of the traditionally used fibers and compared the result with the imported cellulose fiber, using 60/70 grade bitumen and found optimum fiber percentage as 0.3% of the mixture. Jute fiber showed equivalent results to imported patented fibers as indicated by Marshall stability test, permanent deformation test and fatigue life test. Aging index of the mix prepared with jute fiber showed better result than patented fiber.

Bradely et.al. (2004) studied on Utilization of waste fibers in stone matrix asphalt mixtures. They used carpet, tire and polyester fibers and other materials to improve the strength and stability of mixture compared to cellulose fiber. They found no difference in the moisture susceptibility and permanent deformation in SMA Mix containing waste fibers as compared to the SMA Mix which contains cellulose or mineral fiber.

Punith V.S., Sridhar R., Bose Sunil, Kumar K.K., Veera ragavan A (2004) adopted Marshall mix design at 60^0C, using 50 blows of compaction per side and did a comparative study of SMA with asphalt concrete mix utilizing reclaimed polythene in the form of LDPE carry bags as stabilizing agent (3 mm size and 0.4%) .The test results indicated that the mix properties of both SMA and AC mixture are getting enhanced by the addition of reclaimed polythene as stabilizer showing better rut resistance, resistance to moisture damage, rutting, creep, aging and better drain-down properties aswell.

III. EXPERIMENTAL INVESTIGATION

A. Materials Used:

The following materials are used for conduction this experimental work

- Copper Slag as Stone Aggregate and fine aggregate.
- Mineral filler-Stone Dust
- Binder (Bitumen of penetration grade60/70)
- Stabilizers (cellulose fiber)

B. Mineral aggregates

Copper slag is a by-product obtained during smelting and refining of copper. The waste copper slag can be used as abrasive tools, road construction, and ballast. Despite increasing rate of reusing copper slag, the huge amount of its annual production is disposed in dumps or stockpiles to date. One of the greatest potential applications for reusing copper slag is in cement and concrete production. Many researchers have investigated the use of copper slag in the production of cement, mortar, and concrete as mixed with lime stone powder, dust, cement replacement, use as partial replacement of coarse, and fine aggregates. Apart from using as replacement in cement concrete, it will also be used in stone mix Asphalt mixes.

Fig. 1: Copper Slag

Properties	Value	
	Stone Aggregate	Copper Slag
Coarse aggregate		
Soundness in (%)	4.5	3.5
Water absorption (%)	0.5	1.9
BULK sp. Gr.(gr/ cm^3	2.64	3.12
L.A. abrasion (%)	15.6	21.7

Apparent sp. Gr. (gr/ cm^3)	2.79	3.53
Plasticity index	Non plastic	Non plastic
Fine Aggregate		
Bulk sp. Gr	2.43	2.89
Apparent sp. Gr	2.77	3.58

C. Binder:-

Many researchers used various types of binders one being, conventional 60/70 penetration grade bitumen and other modified binders like Polymer Modified Binder (PMB), Crumb Rubber Modified Binder (CRMB) and Natural Rubber Modified Binder (NRMB) etc.
In this research work 60/70 bitumen is used as binder.

D. Filler:-

In SMA Mix, filler is used for the proper binding of materials. Fillers such as slag dust, rock dust, stone dust, hydrated lime, hydraulic cement, mineral filler, fly ash etc. are used in SMA Mix. We can even use fine aggregate less than 75 micron as filler. But in this research work, stone dust and cement is taken as filler which gives proper binding with fiber, bitumen and aggregate.

E. Stabilizer:-

SMA is gap graded mix, which means it has more air void content and high concentration of binder. So to prevent them stabilizing additives are added to the mixture such as cellulose fiber, mineral fibers and many polymers, waste materials such as tires, carpet fibers, natural fiber etc. are used in various SMA mixes. Here in this research work Cellulose fiber is used as stabilizing agent.

F. Mixdesign:-

The main objective of bitumen mix is

- To promote good frost ,thaw resistance and to prevent shrinkage cracks sufficient flexibility is required
- To ensure durability of pavement enough bitumen is required
- Sufficient flexibility is needed to avid premature cracking of pavement caused due to repeated bending by traffic.
- To allow further additional compaction by imposed load caused due to traffic sufficient air void in compacted bitumen is required.

1) Preparation of Mixes:-

1) 1) First sieving is done to coarse and fine aggregates. Sampling of coarse and fine aggregates is carried out for 13mm STONE MATRIX ASPHALT composition as specified by IRC:SP-79.2 2) Total sample weight is 1200gm including filler, binder .After sampling is done the sample was allowed to be heated in an oven at 160 degree Celsius for 12 hours.
2) It is then taken out, mixed with bitumen and is compacted with a hammer with a falling weight of 4.54kg falling from a height of 40cms, by giving 50 blows on each side for compaction.
3) The sample is allowed to dry for the next 24 hr. and then it is taken out of the mould with the help of Sample Ejector. Its weight in air, radii and thickness/ height is calculated and then a Wax coating is put over them.
4) Before conducting the Marshall test, each of the samples was kept in hot water bath for 30 min. at 60 degree temperature.
5) 6)Weight in water also Calculated.2 Samples each of 4%, 5%, 5.5%, 6% and 7% bitumen were prepared respectively for bituminous course and Marshall Test was carried out to calculate their Stability

The various samples are:-

- Sample with fiber using stone as coarse aggregate and fine aggregate.
- Sample with fiber using Copper slag as coarse aggregate and fine aggregate.

IV. Analysis of Results

In this project work, Experimental studies are conducted for two types of samples are prepared. They are: -

1) Sample with fiber using stone as coarse aggregate and fine aggregate.
2) Sample with fiber using Copper slag as coarse aggregate and fine aggregate.

A. Marshall Stability: -

Stability value increases with increase in bitumen content upto some point theoretically and then decreases .The reason is due to increase in bitumen content there will be high bonding with aggregate and gets strong, but with further increase in bitumen, the applied load is transmitted and hydrostatic pressure keeps the aggregates immobilized. By this it makes weak against plastic deformation and stability decreases. Stability value increases with fiber than without fiber. Here fiber acts as stabilizer in mix, fiber not only fill the voids but also reduces the drain down and hold with binder and gives good result.

B. Flow Value:-

Flow value defined as deformation of sample where failure occurs. Flow value increases with increase in bitumen content using with fiber or without fiber. Generally increase is slow, but later with increase in bitumen content flow value increases. Flow value prepared with fibers how low when compare to without fiber. But in some situations, flow value increases with fiber due to formation of lumps of bitumen and fiber.

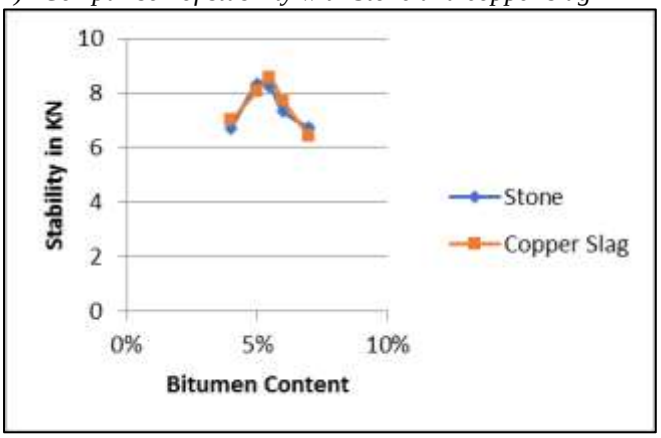
C. Air Voids

While preparing the samples, due to improper compaction and heating air voids are formed between the samples. Here air voids goes on decreasing on increasing the bitumen content. This is due to increase in bitumen content air voids get filled up. The air voids with fiber shows less than without fiber due to fibers fill up some voids in sample.

D. Voids in Mineral Aggregates

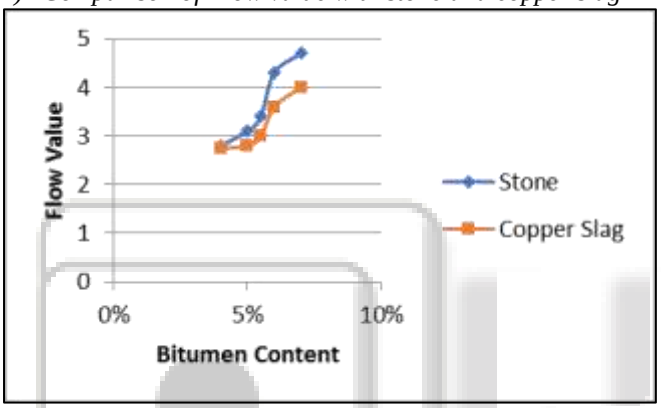
With increase in bitumen content, VMA goes on slowly decreasing and then it remains constant, and then finally increases with increase in bitumen. The slowly decreasing in VMA is due to reorientation of aggregates in bitumen. Whereas at high bitumen content, due to a thick bitumen film repels the aggregates and increases the VMA value theoretically.

1) Comparison of stability with Stone and copper slag



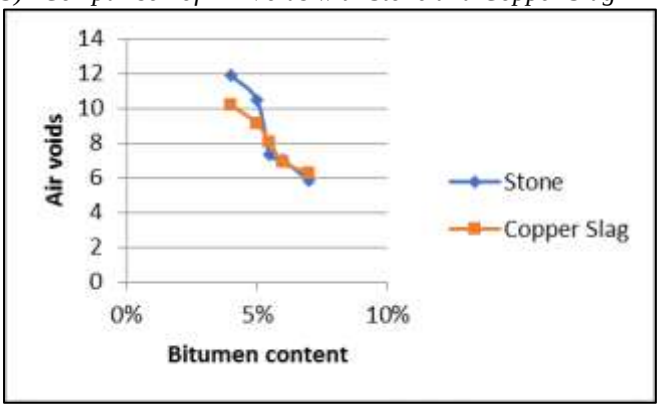
The maximum stability value is obtained for copper slag i.e. 8.55KN at 5.5% bitumen content when compare to stone coarse aggregate.

2) Comparison of Flow value with stone and copper slag



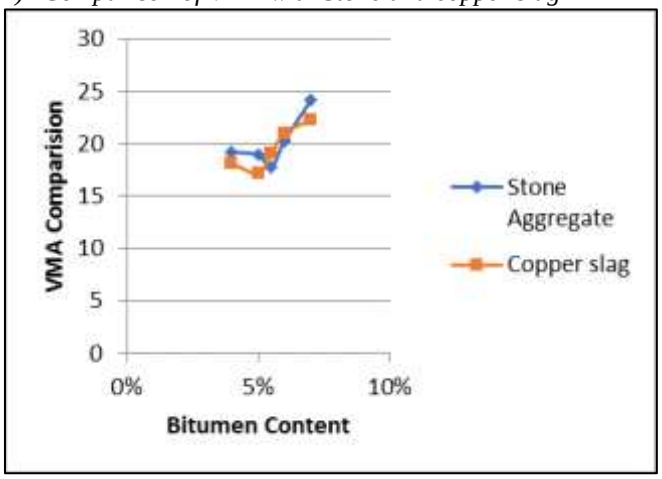
Flow value increases with increase in bitumen content. Generally increase is slow, but later with increase in bitumen content flow value increases. SMA mix Copper slag shows less flow value in comparison with SMA mix with stone aggregate.

3) Comparison of Air Voids with Stone and Copper Slag



While preparing the samples, due to improper compaction and heating air voids are formed between the samples. Here air voids goes on decreasing on increasing the bitumen content. This is due to increase in bitumen content air voids get filled up. The air voids with Copper slag shows more value than Mix with stone aggregate.

4) Comparison of VMA with Stone and copper slag



The VMA value, for a given aggregate should theoretically remain constant. However, in this case, it is sometimes observed that, at low bitumen content, VMA slowly decreases with the increase in bitumen content, then remains constant over a range, and finally increases at high bitumen content. At very high bitumen content, due to a thicker bitumen film, the aggregates slightly moves apart resulting in an increase in VMA.

V. Conclusions

A. Marshall Stability: -

The maximum stability value is obtained for copper slag i.e. 8.55KN at 5.5% bitumen content when compare to stone coarse aggregate.

B. Flow Value: -

Flow value increases with increase in bitumen content. Generally, increase is slow, but later with increase in bitumen content flow value increases. SMA mix Copper slag shows less flow value in comparison with SMA mix with stone aggregate.

C. Air Voids: -

While preparing the samples, due to improper compaction and heating air voids are formed between the samples. Here air voids goes on decreasing on increasing the bitumen content. This is due to increase in bitumen content air voids get filled up. The air voids with Copper slag shows more value than Mix with stone aggregate.

D. Voids in mineral Aggregates: -

The VMA value, for a given aggregate should theoretically remain constant. However, in this case, it is sometimes observed that, at low bitumen content, VMA slowly decreases with the increase in bitumen content, then remains constant over a range, and finally increases at high bitumen content. At very high bitumen content, due to a thicker bitumen film, the aggregates slightly move apart resulting in an increase in VMA.

E. Optimum Binder Content: -

The optimum binder content of the SMA mix, based on the results of Marshall test taking 3 % air voids as the main criteria are observed to be increasing with the increase in

stiffness of the binder. Copper slag shows optimum binder content of 5.5% whereas SMA Mix with only stone aggregates gives optimum binder content of 5%.

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