Assessment of suitability of Coconut Shell charcoal as a Filler in Stone Mastic Asphalt

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Abstract_ Use of asphalt material and its mixture are used to improve the durability and performance of pavements. SMA requires stabilizing additives composed of cellulose fibres or mineral fibres to prevent draindown of mix. SMA was first implemented in European countries. The stone mastic asphalt is a gap graded mixture consisting of coarse aggregate, fine aggregate, stabilizers and binders. In the project work the main objective is to compare the results obtained by the fillers stone dust and coconut shell charcoal. The binder content has been varied from 4-6%. Binder of 60/70 penetration grade bitumen is used. For minimizing the cost and increasing efficiency different waste materials are used as fillers, coconut shell charcoal is one among them. It possesses properties such as resistance to crushing, resistance to freezing, surface moisture etc. Stability flow parameters and air void ratio are compared among the fillers. Marshall test method is used for carrying out this project.

Index Terms_ Binder, Coconut shell charcoal, Filler, Marshall test, SMA mix, Stability, Stabilizer.

1 INTRODUCTION

Highway construction involves huge outlay of investment. Bitumen is used for covering surface in most of the Indian highways. For the construction and maintenance of flexible pavements, aggregates mixed with bitumen are widely used. SMA is a mixture of coarse aggregate fine aggregates, mineral filler, and bitumen. Well graded aggregates and mineral filler resulting in maximum density when mixed with optimum quantity of bitumen results in a mix with very high stability. Desirable properties of SMA mix are stability (enough resistance to deformation under sustained or repeated loads), durability (resistance disintegration by weathering or abrasive forces of traffic), skid resistance (offer enough resistance to the skidding of tires).

SMA shows rut resistance and resistance to deformation caused by heavy traffic. SMA is a gap graded mixture consisting of 70-80% coarse aggregate of total mass, 6-7% of binder, 8-12% of filler, and 0.3-0.5% of stabilizers or additives. For residential streets and highways SMA is used as a durable surfacing option. The deformation resistance capacity of SMA stems from a coarse stone skeleton providing more stone-on-stone contact than with conventional dense graded asphalt mixes. The high bitumen content also improves flexibility. There are no precise design guidelines for SMA mixes. The essential features, which are the coarse aggregate skeleton and mastic 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. It has good fatigue and tensile strength. Materials used for SMA are gap graded aggregate, modified asphalt binder, fiber filler.

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Fillers are fine particles passing through 2.36mm sieve and retained in 0.075mm sieve. Generally the filler that are used are produced from industries or from any natural products to reduce the cost and increase its workability and durability. The fillers that are used in project work are :

Stone dust: Stone are the cheapest material. It is basically obtained by crushing the stones such that the size of the stone particles are retained in 0.075mm sieve.

Coconut Shell Charcoal: Concrete pavements suffer from a perception that they contribute a considerable amount of carbon dioxide (CO2) to the atmosphere due to the use of Coconut shell Charcoal it binds the aggregates together.

Cellulose fiber: Cellulose fiber is used as a stabilizer in the present project. It is mixed with SMA mix so that it can bind the bitumen with the aggregate properly. It also provides better strength to the sample. It generally spread throughout the sample when heat is applied to it. The amount of Fiber that is used during experiment is about 0.3% - 0.5% of the total weight.

Binder used: Different types of binder like convectional 60/70 or 80/100 penetration grade bitumen are used nowadays. Also many modified binder which are used by different researchers for their work are: Polymer Modified Bitumen (PMB), Crumb Rubber Modified Bitumen (CRMB) Natural Rubber Modified Bitumen (NRMB).In this research project work 60/70 penetration grade bitumen is used in SMA mix and different results are obtained.

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2 MATERIALS USED

- Coarse aggregate
- Fine aggregate
- Mineral filler – stone dust and Coconut shell charcoal.
- Binder – bitumen of penetration grade 60/70
- Stabilizer – Cellulose fibre (0.3% - 0.5%)

2.1 Materials details

Coarse aggregate: The coarse aggregate should be crushed rocks which should pass through 19mm sieve and retained in 4.75 mm sieve. The rocks should be well graded, cubic shape and rough surface for good compaction. The hardness should be such that it can resist the traffic load.

Fine aggregate: Fine aggregates are generally stone crusher dusts with fractions passing through 4.75 mm and retained on 0.075 mm IS sieve. The fine aggregate should consist of 100% fine crushed stone dust which should be clean, hard to resist pressure, durable for long period, cubic shape and free from soft pieces.

Mineral filler: Aggregate which pass through 0.075mm sieve are called filler. Mineral fillers have significant impact over the properties of SMA mixes.

- It increases stiffness of asphalt & mortar matrix.
- It helps to reduce drain-down in the mix which improves the longevity of the mix by using required amount of asphalt in the mix.
- It maintains adequate amount of void in the mix.

Binder: Bitumen acts as binding agent to the Coarse and fine aggregates and stabilizers in SMA mixtures. SMA mixes are very rich in mortar binder which increases the aging of the mix. Properties of bitumen depend on temperature. Bitumen shows viscous as well as elastic property. Bitumen used for the experiment is of 60/70 penetration grade.

Stabilizers: Stabilizers are used to reduce the air void present between the aggregates and also to bind them together so that no bleeding of bitumen can occur. Due to which Compaction increases and drain down of bitumen decreases. Cellulose fiber is used as stabilizer in the experiment. Cellulose fiber is obtained from chemical farm and then cleaned properly. It is then cut into pieces of 10-15mm for proper mixing with aggregates. The important stabilizing additives used in the SMA mixes can be classified into four different groups:

- Fiber (Cellulose Fiber, Chemical Fiber and Mineral Fiber)
- Polymer
- Powder and flour like materials (Special Filler and Silicic acid)
- Plastics (Polymer Powder/Pellets)

2.2 Material testing

The materials should be tested with all standard tests for coarse aggregate, fine aggregate and bitumen. The test results should conform to IS Specifications and IRC recommendations.

3. EXPERIMENTAL PROCEDURE

3.1 Preparation of mixes

Samples of coarse and fine aggregate are carried out for 13mm SMA composition as specified by IRC: SP-79.

Table 1: The Composition of SMA mix as per **IRC: SP-79**.

IS SIEVE	Cummulative %	mean	% retained	4%	5%	5.5%	6%
19	100	100	0	0	0	0	0
13.2	90-100	95	5	57.6	57	56.6	56
9.5	50-75	67.5	32.5	374	370.5	373	369.4
4.75	20-28	24	38.5	443	438.9	436.5	435.1
2.36	16-24	70	4	45.8	45.6	45.4	45.1
1.18	13-21	17	3	34.5	34.2	34	33.7
0.6	12-18	15	2	23	22.8	22.5	22.2
0.3	10-12	15	3	34.5	34.2	34.0	33.7
0.075	8-12	10	2	23	22.8	22.5	22.4
Total				1152	1140	1134	1128
Binder used				48	60	66	72

According to the composition, the total weight of each sample is 1200gm.

3.2 Sieving:

The coarse and fine aggregates are properly cleaned and dried. Then by Sieving the aggregates are separated according to the Standard Composition of SMA mix. The aggregates are sieved through 19mm to 0.075mm and kept separately.

3.3 Mixing:

The aggregates are mixed thoroughly so that the gap between the aggregates reduces so as to provide better compaction. The sample is mixed for 5 minutes. Then the sample is kept in the heating oven at 160^{o}c for 1 hour. Then the sample is mixed with bitumen.

3.4 Moulding:

The sample mixed with bitumen is then compacted by using Marshall Compaction Moulds. The compaction is

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done using a hammer of 4.54 kg which is allowed to fall from a height of 40cm. The sample is compacted with 50 blows on each side. The sample is allowed to dry for 24 hours. The sample is taken out from mould with a help of Sample Ejector.

3.5 **Weighing:**

The sample Weight, Radius and Height is measured. Then the sample is Coated with Paraffin/Wax and again measured. The sample weight in water is measured.

3.6 **Hot water bath:**

The sample is then kept in hotwater bath at 60^{o}C for 30mins. Care should be taken so that the specimen should not be heated more than 60^{o}C or kept for more than 30mins. If such condition occurs, then the bitumen which is used for binding will be worthless and could not be used for Marshall Test. Because when the load will be applied it can hold the pressure due to looseness of bitumen.

3.7 Marshall test:

The basic concepts of the Marshall mix design method were originally developed by Bruce Marshall of the Mississippi Highway Department around 1939 and then refined by the U.S. Army. The Marshall stability of the mix design is defined as a maximum load carried by a compacted specimen at a standard temperature of 60 ^{o}C. The total maximum load (kN) taken by the Specimen where failure occurs is taken as Marshall Stability. The stability value obtained is corrected by using correlation ratio table. The total amount of deformation which occur at maximum load is recorded as Flow Value whose unit is 0.25mm.

4 RESULTS

Marshall stability: The stability of the specimen is derived by the load taken by it and then multiplying with the correlation ratio which is obtained from thickness/height or volume of the sample. Theoretically with increase in Bitumen content, the stability also increases up to a certain point and then gradually decreases.

This is due to with increase in bitumen content, the bond between the aggregate and the bitumen increases but with further increase, the strength between them decreases as the contact point between the aggregates become immobilize. Due to which mix become weak against plastic deformation. Simultaneously the stability Values also decreases.

Flow value: Flow Value is defined as deformation caused when maximum load is applied where usually failure occurs. The flow value increases with increase in bitumen content. But the flow is gradually slow where stabilizers are not used. The flow increases very slowly initially but with increase in bitumen content, the flow value increases theoretically.

Air voids: The air void is the gap present between the aggregates. The void decreases with increase in bitumen. Bitumen fills the gap present and increases the compatibility. Theoretically the air voids decreases slowly initially and with increase in bitumen percentage the air voids decreases very quickly. With addition of stabilizers, it also helps to fill the void along with bitumen

Table 2: Results using stone dust as filler

Sample No	Bitumen content	Measured Stability,kg	Corrected Stability,kg	Flow Value, mm
1	4	810	882.9	2.8
2	4	760	828.4	2.7
Average	4		855.65	
1	5	810	923.4	3.1
2	5	760	866.4	3.2
Average	5		894.9	
1	5.5	840	999.6	3.6
2	5.5	880	959.2	3.8
Average	5.5		979.4	
1	6	740	843.6	4.1
2	6	750	892.5	4.2
Average	6		868.05	

Table 3: Results using coconut shell charcoal as filler

Sample No	Bitumen content	Measured Stability,kg	Corrected Stability,kg	Flow Value, mm
1	4	740	880.6	2.9
2	4	720	820.8	3.1
Average	4		850.7	3
1	5	850	926.6	3.1
2	5	820	975.8	3.4
Average	5		951.2	3.25
1	5.5	910	1037.4	3.2
2	5.5	850	969	3.4
Average	5.5		1003.2	3.3
1	6	790	861.1	4.2
2	6	820	893.8	4.4
Average	6		877.45	4.3

4.1 Comparison of results

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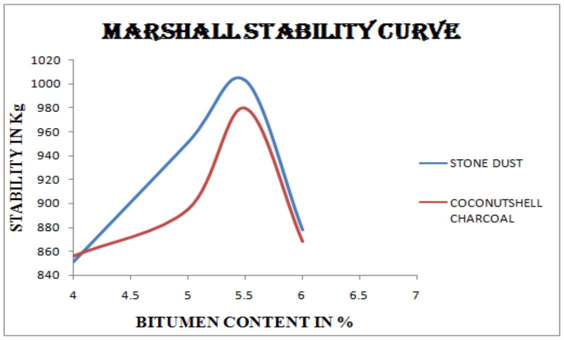

Fig 1: Average stability value comparison graph with different bitumen content

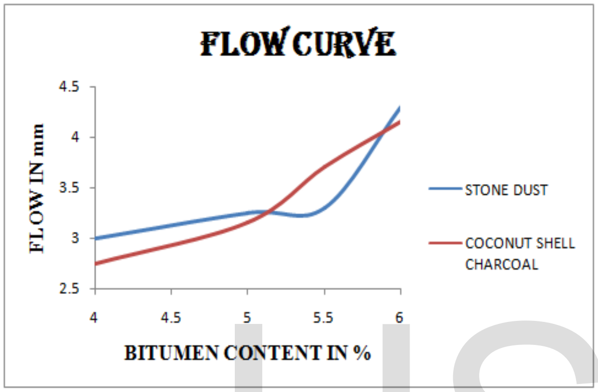

Fig 2: Average flow value comparison graph with different bitumen content

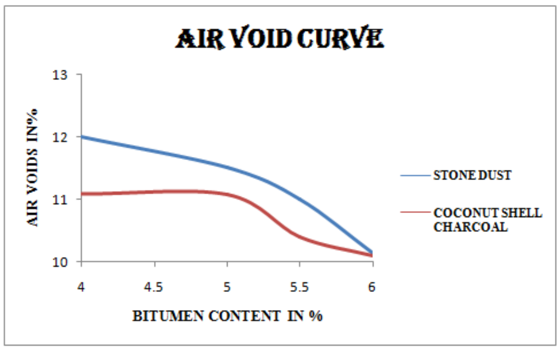

Fig 3: VA comparison graph with different bitumen content

4.2 Equations used

$$VA = [1 - G_{mb}/G_{mm}] * 100$$

G_{mb} = Bulk Specific Gravity Of the mix
= Mmix / Bulk Vol.of mix.

G_{mm} = Theoretical max. specific Gravity of Mix
= Mmix / Vol. of (mix – air voids)

By using the formula, the air void (VA) is found out.

5 CONCLUSIONS

Marshall stability

The maximum Stability Value obtained is 1037.4 kg by using Stone dust as Filler at Optimum binder of 5.5% . Using Coconut Shell charcoal as filler, an average Stability is obtained which is 975.8 kg. As the difference in Stability value is less which is 3.61% therefore Coconut shell charcoal can be used as a substitute as filler.

Flow value

The Flow value increases with increase in bitumen percentage. The maximum increase is shown by Coconut shell charcoal as filler. It is found that Flow Value increases very slowly at first.

Air voids

The VA decreases very slowly initially . With increases in bitumen content, the VA decreases very quickly. The maximum decrease in the VA is obtained when Stone dust is used as filler. The decrease is steady in case of Coconut shell charcoal as filler

Optimum bitumen content

At 5.5% bitumen content, the maximum stability is obtained which is 1037.4 kg for stone dust filler sample. Optimum bitumen content does not depend in filler type as the size of the fine particles is 0.075mm.

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