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ASSESSMENT OF THE SUITABILITY OF COCONUT CHARCOAL AS FILLER IN STONE MATRIX ASPHALT

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ABSTRACT

For improvement of pavement of road, the use of asphalt material and its mixture are usedso that their durability and performance can be enhanced. For which the suitable mixture that is been adopted is SMA Mix (Stone mastic asphalt or Stone matrix asphalt) which is better than bituminous Concrete or dense graded mix (DGM). It was first implemented in European Countries and North America. The Stone Mix asphalt is gap- graded mixture Consisting of Stone or Slag as Coarse aggregate, different binders are used (natural or artificial) as stabilizers and high bitumen Content. For Minimizing the Cost and increasingthe efficiency of roads, many different alternative are used for improvement by-using different waste materials as fillers among them Coconut shell charcoal is one of them. In the Research work, the main objective is to compare the results obtained by using fillers like Stone dust, Portland cement, Fly ash with Coconut Shell charcoal. The Properties thatCoconut shell Charcoal possesses are resistance to crushing, absorption, surface moisture, grading, resistance to freezing, light weight, heating and synthetic resin glues which is most important for pavement of roads. Therefore its Stability and flow parameters and Air Voidratio are obtained so that it can be compared with different typesof Fillers. From that we can establish a perfect combination so that it can be useful as a substitute as a filler for improving the quality and durability of pavement of roads. Therefore aggregate gradation taken as per IRC-SP-79 specification for SMA mix. The Binder Content are varied as 4%,5%, 5.5%, 6%, 7% by weight of aggregates. 0.3% by weight of aggregate is used as Optimum Binder Content. Binder of 60/70 penetration grade bitumen is used. For carrying out the experiment, Marshall test method is used for obtaining better results.

Keywords: SMA Mix, Coconut shell charcoal, Filler, Binder, Marshall Test.

I. INTRODUCTION

Generally aggregates are mixed with bitumen are widely used all over the world for construction & maintenance of flexible pavements. The close and well-uniform , or dense graded aggregates mixed with normal bitumen generally perform very well in heavily trafficked roads therefore they are very common in paving industries. Basically to form dense graded aggregate, it is very difficult to arrange aggregates of different size whichare found in sites. In such a situation, bituminous mix known as stone matrix asphalt(SMA) consisting of gap graded aggregates can be used.

SMA is gap graded mixture consisting of 70-80% coarse aggregate of total mass, 6-7% of binder, 8-12% of filler, and about 0.3-0.5% of fiber or stabilizer or additives. It provides a deformation resistant, durable surfacing material, suitable for heavily trafficked roads. SMA is defined as a gap-graded Hot Mix Asphalt designed to maximize deformation (rutting) resistance & durability by using stone-on-stone contact Structure. As aggregate are all in contact, rut resistance depends on aggregates property rather than asphalt binder property. Since the aggregate do not deform much as asphalt binders, the stone-on- stone contact significantly reduces the rutting under loading.

Figure 1: SMA Sample

A. Fillers used

Basically Filler are the fine particles which when passed through 2.36mm sieve and retained in 0.075mm sieve. Generally the Filler that we have used are waste materials that are produced from industries or from any natural products to reduce the cost and increase its workability and durability. As filler are used to reduces the gaps i.e Voids so that the compaction between Coarse and Fine aggregate increases to provide better Stability to the pavement. The fillers that are used in experimental process are as follows:

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.

Portland Cement: Cement can be used as a filler due to its lump property due to which it can bind the particles properly.

Fly Ash: Fly Ash are the waste materials produced from the industries which can used as a replacement for fillers and also the cost is very low. The Fly Ash that is used in the project Work is obtained from Adhunik.

Coconut Shell Charcoal: Concrete pavements suffer from a perception that they contribute a considerable amount of carbon dioxide (CO_2) to the atmosphere due to the use of Coconut shell Charcoal it binds the aggregates together.

Extraction of coconut shell charcoal:

The Process used for extraction of Coconut shell charcoal are as follows:

- Cutting: First the Coconut is cut down from the tree and dried for somedays.
- Ripping: Then the Cover is ripped out such that the shell can be visible properly.
- Burning: charcoal.

Properties of coconut shell charcoal:

- High Strength property than other fillers due to its hardness and low specific weight.
- It shows high modulus Property.
- High lignin Content as it has high resistance to different weather and thereforesuitable material for construction of road.
- It shows good durability and abrasion resistance Characteristics.
- It has low Cellulose Content.

B. 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.

C. 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 project work 60/70 penetration grade bitumen is used in SMA mix and different results are obtained.

II. LITERATURE REVIEW

Gradation with high amount of fines (either naturally occurring or caused by excessive abrasion) may cause distortion in mixtures as the large amount of fine particles tend to push the larger particles apart and act as lubricating ball-bearings between these larger particles, and this in turns problem in deformation resistance of mixtures under traffic loading.

Mineral fillers are added to asphalt paving mixtures to fill voids in the aggregate and reduce the voids in the mixture. However, addition of mineral fillers has dual purpose when added to asphalt mixtures. A portion of the mineral filler that is finer than the asphalt film thickness mixed with asphalt binder forms a mortar or mastic and contributes to improved stiffening of mix. This modification to the binder that may take place due to addition of mineral fillers could affect asphalt mixture properties such as rutting and cracking. The other portion of fillers larger than the asphalt film thickness behave as a mineral aggregate and serves to fill the voids between aggregate particles, thereby increasing the density and strength of the compacted mixture. In general, filler have various purposes among which, they fill voids and hence reduce optimum asphalt content and increase stability, meet specifications for aggregate gradation, and improve bond between asphalt cement and aggregate.

Ramzi et al. have evaluated the use of cement bypass dust (CBPD) as filler in asphalt mixtures. They have both investigated the effect of adding either lime or CBPD in different proportion on binder and Marshal Properties. From their test data, they have made the conclusions were : For any filler type (lime or CBPD), penetration and ductility of the filler-binder mortar generally decreased as filler content was increased. However, such decrease was steeper and more pronounced when lime rather than CBPD was used as filler. On the other hand,softening point increased with the filler content where more significant increment was observed when lime rather than CBPD. When considering the Marshal properties, the substitution of 5% CBPD for lime as a filler would be the optimum value used in asphalt concrete mixtures. Any percentages higher than 5% CBPD would require more asphalt binder and thus produce an uneconomical mix.

III. OJECTIVES

- Determine the marshall stability, flow and air voids for conventional stone matrix asphalt.
- Comparative study on stone dust, fly ash and coconut charcoal as filler material using as stone matrix asphalt.
- Comparison of air voids, marshall flow and stability properties with stone dust, fly ash and coconut charcoal as filler material using as stone matrix asphalt.

IV. EXPERIMENTAL INVESTIGATION

A. Materials used

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

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. Itis 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)

Figure 2: Topcel Cellulose Fiber

As per MORTH specification usually 0.3%-0.5% fiber is used in SMA mixtures.

Table 1: Properties of the Fiber

Property	Value
Density gm / cm^3	1.5
Elongation (%)	2-3
Cellulose (%)	65-80
Lignin (%)	10-15
Moisture Content (%)	10.5-22.5
Ph	10-15
Tensile Strength(Mpa)	500-1000

Young Modulus(Mpa)	2.5-9.5

B. Experimental procedure

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

Table 2: the Composition of SMA mix as per IRC: SP-79

IS SIEVE	Cummulative %	mean	% retained	4%	5%	5.5%	6%	7%
19	100	100	0	0	0	0	0	0
13.2	90-100	95	5	57.6	57	56.6	56	55.8
9.5	50-75	67.5	32.5	374	370.5	373	369.4	362.8
4.75	20-28	24	38.5	443	438.9	436.5	435.1	434.1
2.36	16-24	70	4	45.8	45.6	45.4	45.1	45.12
1.18	13-21	17	3	34.5	34.2	34	33.7	33.5
0.6	12-18	15	2	23	22.8	22.5	22.2	22.3
0.3	10-12	15	3	34.5	34.2	34.0	33.7	33.5
0.075	8-12	10	2	23	22.8	22.5	22.4	22.3
Total				1152	1140	1134	1128	1116
Binder used				48	60	66	72	84

According to the composition, the total weight of each sample is 1200gm.3 samples each of 4%, 5%, 5.5%, 6% and 7% bitumen were prepared respectively andMarshall test was carried out to calculate their Stability, flow and VA respectively. The Samples prepared using slag as coarse aggregate and stone as fine aggregate with different fillers are as Stone dust, Coconut Shell Charcoal, Fly ash. The Samples prepared using Stone as coarse aggregate and fine aggregate with differentfillers are Portland Cement and Stone dust. 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. The aggregates are mixed thoroughly so that the gap between the aggregates reduces so asto provide better compaction. The sample is mixed for 5 minutes. Then the sample is keptin the heating oven at 160˚ C for 1 hour. Then the sample is mixed with bitumen accordingto the requirement.

Figure 3: Mixing aggregates with Bitumen

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

Figure 4: Sample Before & After Coating

The sample is then kept in hot water bath at 60˚ C for 30mins. Care should be taken so thatthe specimen should not be heated more than 60˚ 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 pressuredue to looseness of bitumen.

Marshall Mix design is generally used worldwide for conducting different test regarding

Stability and flow Characteristics of the mix sample. It is also available at low cost. The sample is taken out of Hot water bath and placed in the Marshall Stability testing machine and loading is done at a constant rate of 5 mm per minute of deformation until failure.

- 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 occurs at maximum load is recorded as Flow Value whose unit is 0.25mm.

Figure 5: Marshall Test Machine

V. ANALYSIS OF RESULT

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 usuallyfailure 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 withbitumen.

Different results of slag as coarse aggregate and stone asfine aggregate with cellulose fiber as stabilizer.

Table 3: Results using Stone dust as filler

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S.No.	Bitumen Content (%)	Wt. before Coating (gm)	Wt. after Coating (gm)	Wt. in water (gm)	Height (cm)	Flow (mm)	Load Taken (KN)	Stability (KN)
1	4%	1188	1201	747	5.6	2.9	240	7.4
2	4%	1186	1200	744	5.5	3.1	260	7.2
3	5%	1195	1204	750	5.4	3.1	280	8.5
4	5%	1180	1193	751	5.8	3.4	260	8.2
5	5.5%	1185	1192	734	5.8	3.2	300	9.1
6	5.5%	1186	1193	736	5.6	3.4	280	8.5
7	6%	1192	1198	771	5.4	4.2	230	7.9
8	6%	1188	1194	767	5.2	4.4	250	8.2
9	7%	1195	1196	738	5.2	4.3	260	8.3
10	7%	1183	1197	735	5.2	4.6	240	7.6

Table 4: Results using Fly ash as filler

S. No.	Bitumen Content (%)	Wt. before Coating (gm)	Wt. after Coating (gm)	Wt. in water (gm)	Height(cm)	Flow (mm)	Load Taken (KN)	Stability(KN)
1	4%	1185	1201	736	5.8	2.3	320	7.92
2	4%	1188	1205	741	5.7	2.4	260	7.6
3	5%	1184	1204	742	5.6	2.5	350	8.48
4	5%	1183	1192	744	5.8	2.7	260	7.64
5	5.5%	1185	1200	744	5.8	3.0	390	8.91
6	5.5%	1184	1198	736	5.6	2.9	360	8.7
7	6%	1181	1198	756	5.4	3.1	340	8.44
8	6%	1182	1191	748	5.6	3.3	305	7.92
9	7%	1187	1205	761	5.6	3.9	320	8.1
10	7%	1185	1197	758	5.6	3.8	260	7.6

Table 5: Results using Coconut shell charcoal as filler

S. No.	Bitumen Content (%)	Wt. before Coating (gm)	Wt. after Coating (gm)	Wt. in water (gm)	Height(cm)	Flow (mm)	Load Taken (KN)	Stability(KN)
1	4%	1144	1174	681	5.7	2.8	270	8.1
2	4%	1187	1215	682	5.6	2.7	250	7.6
3	5%	1181	1198	672	5.6	3.1	270	8.1
4	5%	1186	1206	684	5.7	3.2	250	7.6
5	5.5%	1201	1214	686	5.7	3.6	280	8.2
6	5.5%	1182	1193	690	5.6	3.8	305	8.6
7	6%	1194	1201	693	5.6	4.1	230	7.4
8	6%	1184	1180	692	5.7	4.2	238	7.5
9	7%	1170	1207	669	5.8	4.6	210	6.8
10	7%	1190	1197	680	5.6	4.5	205	6.6

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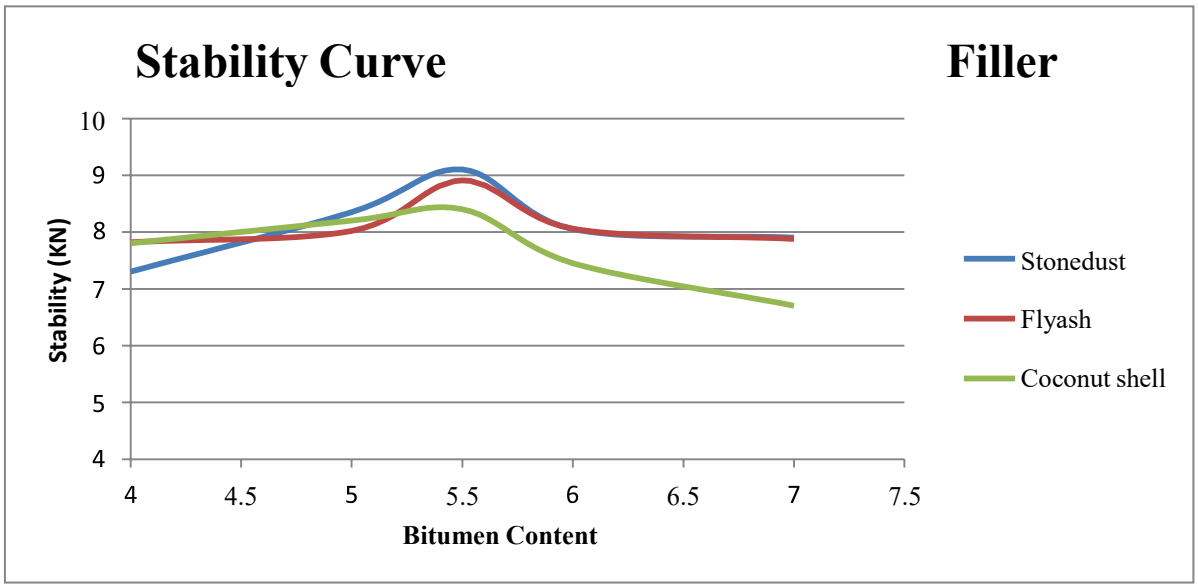
A. Comparison of results:

a. Stability value comparison using different fillers:

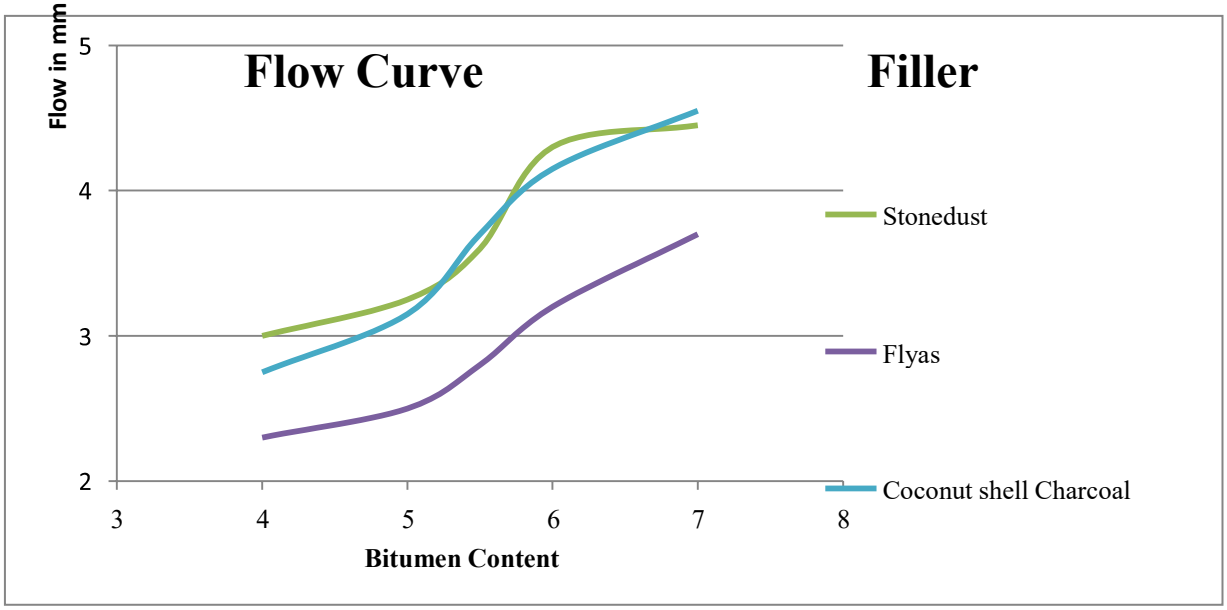


Graph 1: Average Stability Value Comparison Graph with different Bitumen Content

Table 6: Average Stability Value using different Fillers

	Bitumen content (%)	Stone dust as filler	Fly Ash as filler	Coconut shell Charcoal as filler
STABILITY (KN)	4%	7.3	7.82	7.8
	5%	8.35	8.02	8.2
	5.5%	9.1	8.91	8.4
	6%	8.05	8.06	7.45
	7%	7.9	7.88	6.7

b. Flow value comparison using different fillers:



Graph 2: Average Flow value comparison Graph with different Bitumen Content

Table 7: Average Flow Value using different Fillers

	Bitumen content (%)	Stone dust as filler	Fly Ash as filler	Coconut shell Charcoal as filler
FLOW VALUE (mm)	4%	3.0	2.3	2.75
	5%	3.25	2.5	3.15
	5.5%	3.6	2.8	3.7
	6%	4.3	3.2	4.15
	7%	4.45	3.7	4.55

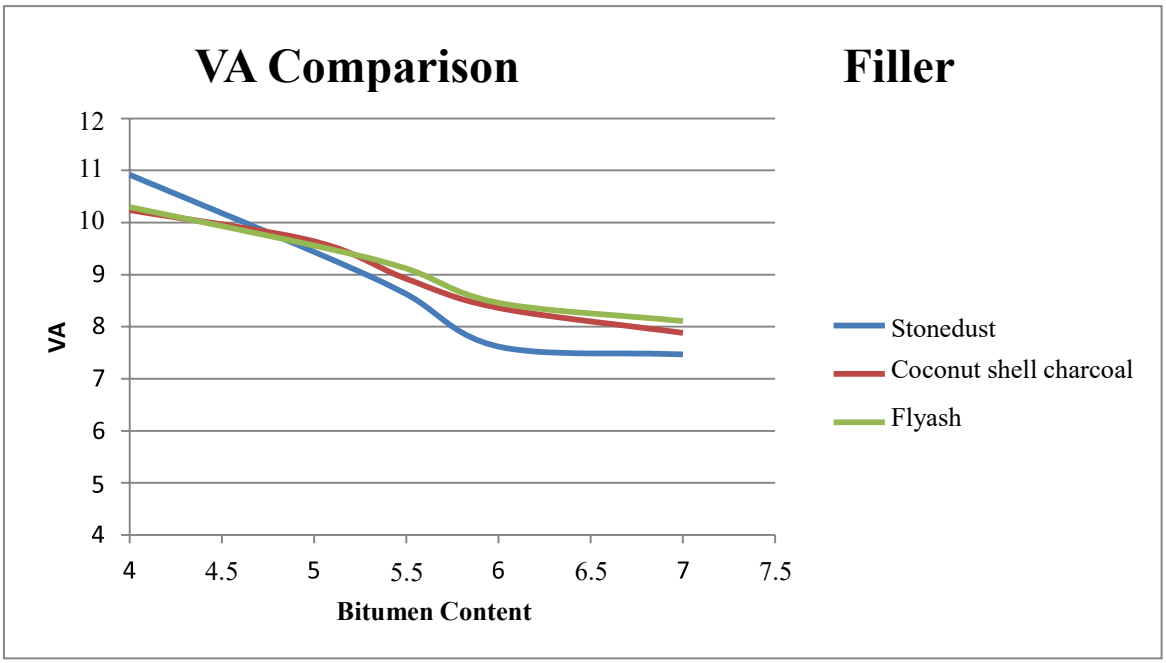
c. Air void (va) comparison using different fillers:

VA= [1 - Gmb/Gmm] *100

Gmb = Bulk Specific Gravity Of the mix = Mmix / Bulk Vol.of mix.

Gmm = Theoretical max. specific Gravity of Mix = Mmix / Vol. of (mix – air voids)

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



Graph 3: VA Comparison Graph with different bitumen Content

Table 8: Air void (VA) using different fillers

	Bitumen content (%)	Stone dust as filler	Fly Ash as filler	Coconut shell Charcoal as filler
STABILITY	4%	10.9	10.37.94	10.2

(KN)	5%	9.44	9.56	9.64
	5.5%	8.63	9.12	8.92
	6%	7.62	8.46	8.36
	7%	7.47	8.11	7.88

VI. SUMMARY

Marshall stability:

By using different bitumen content of 4%, 5%, 5.5%, 6% & 7%, the Optimum Stability of the SMA Mix is found out. It is observed from the graph that the Stability value increases with increase in bitumen content and the decreases gradually which helps us to find out the performance of different fillers used in SMA mix at corresponding bitumen content (%). From the graph, it is found that

- The maximum Stability Value obtained is 9.1 KN by using Stone dust as Filler at Optimum binder of 5.5% seconded by fly ash filler with stability value of 8.91kN.
- Using Coconut Shell charcoal as filler, an average Stability is obtained which is 8.4 KN.
- As the difference in Stability value is less which is 9.68% therefore Coconut shell charcoal can be used as a substitute as filler.

Therefore it is proved that with increase in bitumen content, the Stability Value also increase but up to certain point i.e 5.5% of bitumen content. After that the stability Value decreases due to excess use of bitumen which decreases the strength of the Mix.

Flow value:

Theoretically it is found that with increase in bitumen content, the Flow Value increasesfor different types of fillers. The results obtained from the experiment is :

- The Flow value increases with increase in bitumen percentage as the maximum increase is shown by Coconut shell charcoal as filler.

- The Flow Value is least in case of fly ash fillers .
- From the graph it is found that Flow Value increases very slowly at first but with increase in Bitumen content it increases very quickly because as % of bitumen increases, the sample mould loses its uniformity, strength and also stability decreases as a result deformation increases when load is applies on the sample specimen.

Air voids (va) :

Theoretically we know that the Voids that are present between the aggregate due to irregular shape decreases the strength of the mix. So to avoid this, Bitumen along with fillers and stabilisers is added to it so that voids gets filled up and also it acts as a sticky material so that the aggregates are closely packed among themselves. So, with increase in bitumen content the air voids decreases.

- From the graph, it is observed that the VA decreases very slowly initially but 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 (obc) :

The Optimum bitumen content is obtained where the maximum Stability occurs.

- According to the graph, at 5.5% bitumen content, the maximum stability isobtained which is 9.1 KN for stone dust filler sample.
- Optimum bitumen content does not depend in filler type as the size of the fine particles is 0.075mm.

VII. CONCLUSIONS

- The maximum stability obtained is 9.1 KN in case of Stone dust used as filler andthe stability value obtained for coconut shell charcoal is 8.4 KN.
- As the Stability value is more than 8 KN in case of coconut shell charcoal asfiller, it can be used as filler in SMA mix for pavement of roads.
- Flow increases with increase in bitumen content in case of all fillers used in the

sample.

- Air voids decreases with increase in bitumen content for all the fillers used in the sample.
- From the experiment, it can be concluded that coconut shell charcoal can be usedas a substitute for filler as it satisfies all the criteria to be used as a filler.

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