An Experimental Study on M-Sand and Coconut Shell Charcoal as Filler Material in Bituminous Concrete Mix

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Abstract **-** A precise engineering design may save considerable investment as well as reliable performance in highway can be achieved. A good design of Bituminous mix is expected to result in mix which is strong, durable, rutting resistance, at the same time environment friendly and economical. Use of asphalt material and its mixture are used to improve the durability and performance of pavements. In this project work the main objective is to compare the results obtained by the fillers Quarry dust, M-sand and partial replacement of coconut shell charcoal. From that we can achieve a perfect combination so that it can be used as a filler for improving quality and durability of roads. Therefore, aggregate gradation taken as per MORTH 5th revision and the binder content used is VG30 grade. For minimizing the cost and increasing efficiency different waste materials are used as fillers, coconut shell charcoal powder 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 - Bituminous Concrete Mix, Coconut Shell Charcoal, M-Sand, Marshall test, Quarry dust.

I. INTRODUCTION

Generally, aggregates mixed with bitumen are widely used all over the world for construction and maintenance of flexible pavements. The close and well-uniform, or dense graded aggregates mixed with normal bitumen generally perform very well in heavy traffic roads therefore they are very common in paving industries.

Bituminous mix known as Bituminous Concrete (BC) consisting of well graded aggregates which will be used. As BC mix showed excellent rutting resistance and resistance to deformation caused by heavy traffic at high temperatures, its use became popular even after the ban of studded tires. BC mix is well graded mixture consisting of 50-60% coarse aggregate of total mass, 5-6% of binder, 8-12% of filler. It provides a deformation resistant, durable surfacing material, suitable for heavy traffic roads. BC mix is used as a durable asphalt surfacing option for residential streets and highways. BC mix forms an interlock between coarse aggregate to form a stone skeleton which can sustain permanent deformation.

The stone skeleton is fully filled with bitumen and along with filler so that it can bind them properly so as to prevent drainage of binder and not to cause any problem while transportation and while placing. As the Coarse aggregate content is high in BC Mix, it forms a skeleton- type structure which provide good resistance for rutting. The higher content of binder makes the mix durable.

II. RESEARCH ELABORATION

A. Materials Used

1) Coarse aggregate
2) Fine aggregate
3) Mineral filler – Quarry Dust, M-Sand and Coconut Shell Charcoal.
4) Binder – VG30 grade bitumen

B. Material 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 passes through 0.075mm sieve are called filler. Mineral fillers have significant impact over the properties of SMA mixes. Different types of mineral fillers that are used in the SMA mixes are Quarry dust, M-Sand and Coconut shell charcoal.

Binder - Bitumen acts as binding agent to the Coarse and fine aggregates and stabilizers in BC mixtures. BC 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.

The main objective of the experiment is that by using different filler with BC mix and comparing the results obtained by which we can find, the most suitable filler for BC mix.

III. EXPERIMENTAL PROCEDURE

A. Preperation of Mixes

Samples of coarse and fine aggregate are carried out for 13mm Bituminous Concrete Mix composition as specified by MORTH-5th revision. According to the composition, the total weight of each sample is 1200gm. 3 samples each of 2%, 3%, 4%, 5% of coconut shell charcoal replaced in M-Sand prepared respectively and Marshall 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 Quarry dust, M-Sand and Coconut shell charcoal.

B. 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.

C. 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 160^0C for 1 hr. Then the sample is mixed with the bitumen according to the requirement.

D. Moulding

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.

E. 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 also measured.

F. Hot Water Bath

The sample is kept in the hot water bath at 60^0C for 30 mins. care should be taken so that specimen should not be heated more than 60^0C or kept for more than 30 mins. If such condition occurs, then the bitumen which is used for binding will be worthless and could not be used for Marshall Test.

G. Marshall Test

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 5mm 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 occur at maximum load is recorded as Flow Value whose unit is 0.25mm.

IV. RESULTS AND DISCUSSION

A. 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.

B. 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.

C. 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 decrease very quickly. With addition of stabilizers, it also helps to fill the void along with bitumen.

Table.1 Testing of Materials

S.No.	Description	Obtained Result	Limitations	IS Code
1.	Water Absorption Test (CA)	0.5%	Not more than 2%	IS 2386 (part 3)
2.	Aggregate Crushing Test (CA)	21%	Not more than 30%	IS 2386 (part 4)
3.	Aggregate Impact Test (CA)	18%	Not more than 24%	IS 2386 (part 4)
4.	Specific Gravity Test (CA)	2.55	2.5 - 3	IS 2386 (part 3)
5.	Specific Gravity Test (FA)	2.65	2.6 - 2.7	IS 2386 (part 3)
6.	Softening Point Test (BITUMEN)	49	Not less than 47	IS 1205
7.	Penetration Test (BITUMEN)	59	50 - 70	IS 1203
8.	Ductility Test (BITUMEN)	67cm	Not less than 40cm	IS 1208

Table.2 Job Chart

JOB CARD

Design of 40 mm thick Bituminous Concrete Mix (BC) for the work of

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Quantity of materials required for 10 m^2 area

Materials		Vol in m^3
13.2	and down size aggregate	0.133
6.0mm	and down size aggregate	0.115
2.36 mm	and down size aggregate	0.103
	Agg dust (M – Sand)	0.086
60/70	penetration grade bitumen	39 (in kg)

Permissible Variation from Job Mix Formula

1. Aggregate passing 19.0 mm & larger sieve	+/- 7
2. Aggregate passing 13.2 mm & 9.5 mm sieve	+/- 6
3. Aggregate passing 4.75 mm sieve	+/- 5
4. Aggregate passing 2.36mm, 1.18mm & 0.6 mm sieve	+/- 4
5. Aggregate passing 0.3mm & 0.15 mm sieve	+/- 3
6. Aggregate passing 0.075 mm sieve	+/- 1.5
7. Binder 60/70 grade bitumen	+/- 0.3
8. Mixing Temperature	+/- 10^0c

S.No	Sieve Size	Coarse Aggregate						Fine Aggregate		Combined Grading	Job Grading		Specification
		13.2	28%	6.0mm	24%	2.36 mm	26%	Agg dust	22%	100%			
1	19.0 mm	100.00	28.00	100.00	24.00	100.00	26.00	100.00	22.00	100.00	(or)	100	100
2	13.2 mm	70.00	19.60	100.00	24.00	100.00	26.00	100.00	22.00	91.60	(or)	92	90-100
3	9.50 mm	38.00	10.64	100.00	24.00	100.00	26.00	100.00	22.00	82.64	(or)	83	70 - 88
4	4.75 mm	6.00	1.68	80.00	19.20	100.00	26.00	100.00	22.00	68.88	(or)	69	53 - 71
5	2.36 mm	0.00	0.00	35.00	8.40	90.00	23.40	100.00	22.00	53.80	(or)	54	42 - 58
6	1.18 mm	0.00	0.00	0.00	0.00	80.00	20.80	81.00	17.82	38.62	(or)	39	34 - 48
7	600 mic	0.00	0.00	0.00	0.00	55.00	14.30	65.00	14.30	28.60	(or)	29	26 - 38
8	300 mic	0.00	0.00	0.00	0.00	32.00	8.32	0.00	0.00	19.98	(or)	20	18 - 28
9	150 mic	0.00	0.00	0.00	0.00	22.00	5.72	35.00	7.70	13.42	(or)	13	12 - 20
10	75 mic	0.00	0.00	0.00	0.00	0.00	0.00	21.00	4.62	4.62	(or)	5	4 - 10

Table.3 Result using Quarry Dust as filler

Filler	Bitumen	Wt. in Air	Wt. in Water	Saturated	Volume	Density (gm/cc)	Marshall (KN)
Quarry dust	5%	1260.0	750.0	1211.0	510.0	2.470	12.35
Quarry dust	5%	1261.0	751.0	1212.0	510.0	2.472	12.37
Quarry dust	5%	1262.0	752.0	1213.0	510.0	2.474	12.33
Average						**2.472**	**12.35**

Table.4 Result using M-Sand as filler

Filler	Bitumen	Wt. in Air	Wt. in Water	Saturated	Volume	Density (gm/cc)	Marshall (KN)
M-Sand	5%	1232.0	710.0	1221.0	522.0	2.360	9.45
M-Sand	5%	1233.0	710.0	1222.0	522.0	2.370	9.48
M-Sand	5%	1234.0	710.0	1223.0	522.0	2.380	9.42
Average						**2.373**	**9.45**

Table.5 Result using 2% Coconut Shell Charcoal as partial filler

Filler % used	Bitumen	Wt. in Air	Wt. in water	Saturated	Volume	Density (gm/cc)	Marshall (KN)
2%	5%	1232.0	710.0	1235.0	525.0	2.347	9.18
2%	5%	1234.0	711.0	1237.0	526.0	2.346	9.21
2%	5%	1235.0	712.0	1238.0	526.0	2.346	9.24
Average						**2.351**	**9.21**

Table.6 Result using 3% Coconut Shell Charcoal as partial filler

Filler % used	Bitumen	Wt. in Air	Wt. in water	Saturated	Volume	Density (gm/cc)	Marshall (KN)
3%	5%	1242.0	719.0	1242.0	523.0	2.371	10.51
3%	5%	1240.0	718.0	1244.0	526.0	2.361	10.54
3%	5%	1239.0	717.0	1241.0	525.0	2.365	10.57
Average						**2.366**	**10.54**

Table.7 Result using 4% Coconut Shell Charcoal as partial filler

Filler % used	Bitumen	Wt. in Air	Wt. in water	Saturated	Volume	Density (gm/cc)	Marshall (KN)
4%	5%	1250.0	715.0	1255.0	540.0	2.315	8.52
4%	5%	1252.0	716.0	1257.0	541.0	2.314	8.55
4%	5%	1251.0	714.0	1256.0	542.0	2.308	8.58
Average						**2.315**	**8.55**

Table.8 Result using 5% Coconut Shell Charcoal as partial filler

Filler % used	Bitumen	Wt. in Air	Wt. in water	Saturated	Volume	Density (gm/cc)	Marshall (KN)
5%	5%	1204.0	676.0	1211.0	535.0	2.250	7.86
5%	5%	1205.0	677.0	1212.0	535.0	2.252	7.89
5%	5%	1206.0	678.0	1213.0	535.0	2.254	7.92
Average						**2.255**	**7.89**

Table.9 Stability Value using different fillers

Filler Materials		Marshall Stability Value (KN)
Quarry Dust		12.35
M-Sand		9.45
Coconut Shell Charcoal	2%	9.21
	3%	**10.54**
	4%	8.55
	5%	7.89

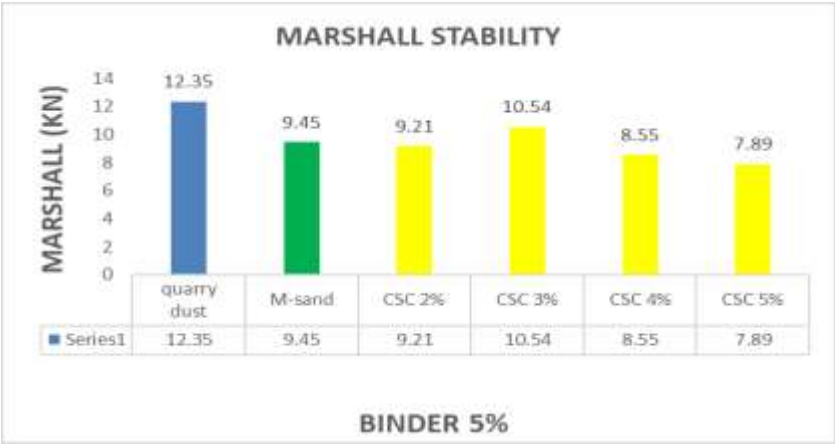

Fig.1 Stability Value comparison graph with different fillers

From the above graph, when **3% Coconut Shell Charcoal** is used the stability value is higher than M-Sand. This Stability Value is acceptable and it can be used as partial replacement as filler material in M-Sand.

Table.10 Density Value using different fillers

Filler Materials		Density Value (gm/cc)
Quarry Dust		2.472
M-Sand		2.373
Coconut Shell Charcoal	2%	2.351
	3%	**2.366**
	4%	2.315
	5%	2.255

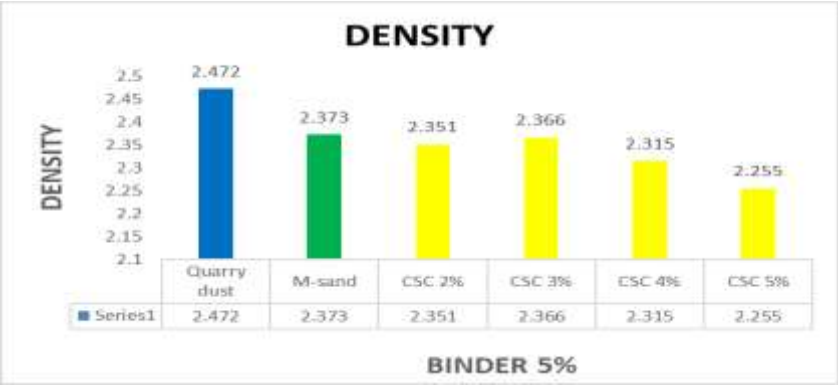

Fig.2 Density Value comparison graph with different fillers

From the above graph Density Value is more less equal to quarry dust and M-Sand when 3% coconut shell charcoal is used. So **3% of coconut shell charcoal** can be used as partial replacement in M-sand.

Table.11 Air Voids value using different fillers

Filler Materials		Air Voids (%)
Quarry Dust		5.10
M-Sand		5.60
Coconut Shell Charcoal	2%	5.32
	3%	**5.20**
	4%	5.18
	5%	5.16

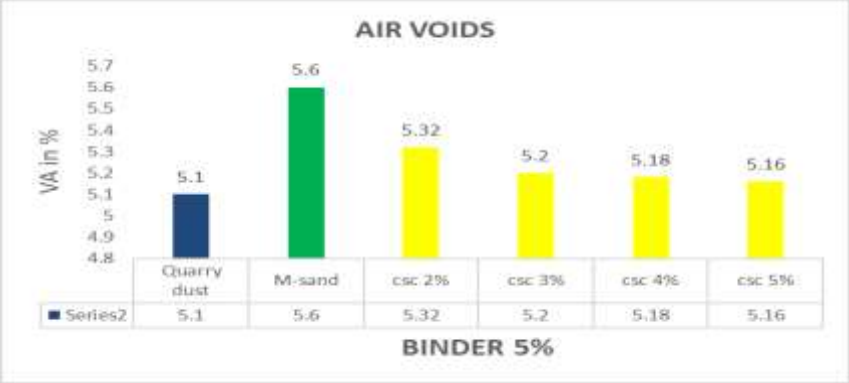

Fig.3 Air Voids comparison graph with different fillers

From the above graph Air Voids is less, when **3% coconut shell charcoal** is used as partial replacement of M-Sand. The value is nearer to quarrye dust so it can be used as filler material.

Table.11 Flow Value using different fillers

Filler Materials		Flow Value (mm)
Quarry Dust		3.51
M-Sand		3.11
Coconut Shell Charcoal	2%	3.20
	3%	**3.31**
	4%	3.15
	5%	3.10

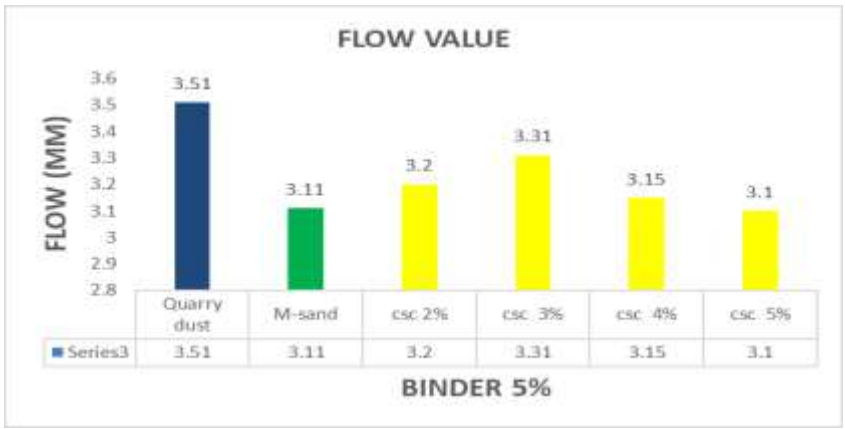

Fig.4 Flow Value comparison graph with different fillers

From the above graph Flow Value is higher, when **3% coconut shell charcoal** is used. So this partial replacement can be used as filler material in BC Mix.

V. CONCLUSION

A. Marshall Stability

By using different fillers like Quarry dust, M-Sand, Coconut Shell Charcoal powder (2%, 3%, 4% & 5%) with M-Sand, the stability of BC mix is found out. It is observed from the graph that the stability value decreases and increases when 3% of Coconut Shell Charcoal power is used with M-Sand which helps us to find the performance of the filler used in BC mix at bitumen content of 5%.

From the graph, it is found that

1) The maximum Stability Value obtained is 12.35 KN by using Quarry dust as Filler at Optimum binder of 5% seconded by 3% of Coconut Shell Charcoal powder with M-Sand as filler with stability value of 10.54 KN.
2) Using Coconut Shell Charcoal as filler, an average Stability is obtained which is 9.04 KN.
3) As the difference in Stability value is less therefore Coconut Shell Charcoal with M-Sand can be used as a substitute as filler.

B. Flow Value

Theoretically it is found that, the Flow Value increases for different types of fillers.

The results obtained from the experiment is:

1) The Flow value increases in Quarry dust as filler followed by 3% coconut shell charcoal powder with M-Sand.
2) The Flow Value is least in case of 5% Coconut Shell Charcoal powder with M-Sand used as filler.
3) From the graph it is found that Flow Value decreases and increases when 3% of coconut charcoal with M-Sand is used as filler and then gradually it decreases, the sample mould loses its uniformity, strength and also stability decreases as a result deformation increases when load is applied on the sample specimen.

C. Air Voids

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 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.

1) From the graph, it is observed that the VA increases and then decreases gradually, in usage of Coconut Shell Charcoal powder with M-Sand.
2) The maximum decrease in the VA is obtained when Quarry dust is used as filler.
3) The decrease is steady in case of Coconut Shell Charcoal with M-Sand as filler.

D. Concluding Remarks

1) The maximum stability obtained is 12.35 KN in case of Quarry dust used as filler and the stability value obtained for 3% Coconut Shell Charcoal with M-Sand is 10.54 KN.
2) As per MORTH 5TH REVISION the Stability value is more than 9 KN in case of 3% Coconut Shell Charcoal as filler, it can be used as filler in BC mix for pavement of roads.
3) Flow increases when stone dust used as filler and followed by 3% Coconut Shell Charcoal with M-Sand as fillers used in the sample.
4) Air voids decreases when Quarry dust is used as filler and decreases gradually in Coconut Shell Charcoal when it is used.
5) From the experiment, it can be concluded that 3% Coconut Shell Charcoal with M-Sand can be used as a substitute for filler as it satisfies all the criteria to be used as a filler.

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