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BITUMEN MODIFICATION USING CRUMB RUBBER AND PARTIAL REPLACEMENT OF FINE AGGREGATES USING COCONUT SHELL CHARCOAL

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ABSTRACT
The purpose of this paper is to modify bitumen using crumb rubber and simultaneously partially replace fine aggregates using coconut shell charcoal in the base course of a flexible pavement. The samples are made with different combinations of bitumen modified with 5%, 10% and 15% crumb rubber by weight of bitumen while simultaneously replacing the fine aggregates with 5%, 10% and 15% coconut shell charcoal by weight of fine aggregates. The samples are tested for maximum stability using the Marshall stability test. The sample providing the maximum stability is taken as the result of this paper.
KEYWORDS: Bitumen, Crumb Rubber, Coconut shell charcoal, Marshall test

I. INTRODUCTION :

A flexible pavement is defined as a pavement layer comprising of a mixture of aggregates and bitumen, heated and mixed properly and then laid and compacted on a bed of granular layer. A typical flexible pavement consists of a bituminous surface course over a base course and a sub base course. Base course of a flexible pavement is the one which lies below the surface course or wearing course and above the sub base course. This layer provides additional load distribution and contributes to drainage and frost resistance in pavement. Base course are usuallyconstructed out of aggregates or HMA (Hot Mix Asphalt).

Crumb rubber is recycled rubber produced from automotive and truck scrap tyres. During the recycling process, steel and tyre cord are removed, leaving tyre rubber with agranular consistency.An immense problem affecting environmental pollution is the increase of waste tyre from vehicles. In an attempt to decrease the magnitude of this issue, crumb rubber obtained from the waste tyre rubber is used as a modifier for bitumen. By using crumb rubber as a bitumen modifier, it is considered to be a smart solution for sustainable development by reusing waste materials and is believed to improve the performance properties of HMA.

Coconut shell charcoal (CSC) is a by – product of agriculture obtained by burning coconut shells in a limited supply of oxygen. It is widely known for its use as a domestic and industrial fuel. Coconut shell charcoal can be used as a source of replacement for fine aggregate in the construction of flexible pavement when broken down into suitable size.

II. OBJECTIVE :

The paper aims to use waste materials such as crumb rubber and coconut shell charcoal in road pavement construction as a bitumen modifier and aggregate replacement respectively.

The results obtained are expected;

- To reduce the amount of waste materials by proper use.
- To increase the strength and stability of road.
- To reduce the cost of construction.
- To reduce ill effect of waste material.
- To save the environment.

III. MATERIALS :

VG-30 bitumen, 30 mesh size crumb rubber, 20mm nominal size aggregates, coconut shell charcoal.

IV. EXPERIMENTAL PROCEDURE :

PRELIMINARY TESTS ON PLAIN BITUMEN

Preliminary tests such as the ductility test, softening point, penetration, viscosity, specific gravity and stripping were conducted on plain bitumen as per IS 73-2013.The results (Table 1) obtained are as per IS 73-2013 requirements.

PRELIMINARY TEST ON AGGREGATES

Common preliminary tests such as impact test, crushing test, Los Angeles abrasion test, shape test, specific gravity and water absorption test were conducted for aggregates as per IS 2386 part(I), (III) and (IV). The results (Table 2) obtained are as per requirements of MORT & H specifications.

PREPARATION OF BITUMINOUS MIX

For thispaper Bituminous mix gradation was used following specifications stated by MORT & H. Aggregates are oven dried and sieved according to BC gradation and separated.The amount of each size of fraction required to produce a mixed aggregate of 1200gm as per gradation is to be weighed. The required height of specimen is 63.5(+/-1).

Bitumen and aggregate is heated separately to 160 °C and 150 °C respectively. Then bitumen is poured in aggregate as required. Then the mixture is thoroughly mixed till a uniform coating is obtained on aggregate when the mixture is being heated together maintained at around 170 °C. The specimen moulds and compaction hammer are cleanedthoroughly and mould assembly is heated in hot air oven to a temperature about 150 °C. A little grease isto be applied to the mould before the mix is placed. The mould is assembled and the mix is transferred and tampered using spatula. Then 75 blows are applied on either sides of the mould manually.

Then the specimen is extracted after 24 hours.

MARSHALL STABILITY TEST

Before testing the moulds their dimensions is measured to note the volume and their weight in air and weight in water are taken. After that they are kept in water bath maintained at 25^{0}C for 30 minutes. The moulds are tested within 3 to 4 minutes after taking out from the water bath. The mould is placed on the Marshall apparatus and Marshall Stability and flow dial gauge readings are then recorded.

DENSITY AND AIR VOID ANALYSIS

The following quantities are worked out by carrying out density and air voids analysis: Bulk specific gravity of Compacted Mixture, Theoretical specific Gravity, Percent air voids, Percent air voids in Mineralaggregates (VMA), Percent aggregate voids filled with bitumen (VFB).

Bulk Specific Gravity (Gm)

$= [W_m / (W_m - W_w)]$

Where;

W_m = Weight in grams of the specimen in air.

W_w = Weight in grams, of specimen suspended in water

TheoreticalSpecific Gravity (G_t) = $(W_1+W_2+W_3+W_b)$
$W_1/G_1+W_2/G_2+W_3/G_3+W_b/G_b$

Where;

W_1 = Weight of coarse aggregate

W_2 = Weight of fine aggregate

W_3 = Weight of filler

W_b = Weight of bitumen

G_1 = Specific gravity of coarse aggregate

G_2 = Specific gravity of fine aggregate

G_3 = Specific gravity of filler

G_b = Specific gravity of bitumen

% Air voids (V_v) $= \frac{G_t - G_m}{G_t} \times 100$

Where;

G_m = bulk specific gravity

G_t = theoretical specific gravity

Volume of bitumen (V_b)

$= \frac{W_b / G_b}{\frac{W_1+W_2+W_3+W_b}{G_m}}$

Where;

W_b = Weight of bitumen

G_b = Specific gravity of bitumen

W_1 = Weight of coarse aggregate

W_2 = Weight of fine aggregate

W_3 = Weight of filler

G_m = bulk specific gravity

Voids in mineral aggregate (VMA)$=V_v + V_b$

Where;

V_v = % Air voids

V_b = Volume of bitumen

Voids Filled With Bitumen (VFB) = $(V_b/VMA) \times 100$

Where;

V_b = Volume of bitumen

VMA = Voids in mineral aggregate

Further, the following graphs are to be plotted;

Marshall stability v/s bitumen content

Flow value v/s bitumen content

Bulk density v/s bitumen content

Percent air voids v/s bitumen content

VFB v/s bitumen content

From the graphs, bitumen content corresponding to maximum stability, maximum bulk density and 4% air voids is taken and the average is taken as the optimum bitumen content (OBC). With that OBC the Marshall tests are repeated for the specimens made using bitumen modified using crumb rubber and fine aggregates partially replaced with coconut shell charcoal. And the results are analysed and compared to identify the proportion which gives maximum stability.

PREPARATION OF MODIFIED BITUMINOUS MIX

Bitumen is modified by mixing 5% crumb rubber by weight of bitumen and heated till the rubber melts into bitumen.Aggregates are oven dried and sieved according to BC gradation and separated. The amount of each size of fraction required to produce a mixed aggregate of 1200gm as per gradation is to be weighed. From this, 5% of fine aggregate (4.75mm passing to 0.075mm retaining) is replaced by coconut shell charcoal by weight of fine aggregate.

The required height of specimen is 63.5(+/-1). Modified bitumen and aggregate replaced with CSC is heated separately to 160 °C and 150 °C respectively. Then modified bitumen ispoured into aggregate as per requirement. Then the mixture is mixed thoroughly till a uniform coating is obtained on aggregate while the mixture is being heated together maintained at around 170 °C. The specimens mould and compaction hammer are cleaned and mould assembly is heated in hot air oven to a temperature about 150 °C. A little grease is applied to the mould before the mix is poured into it. The mould is assembled and the mix is transferred and tampered using spatula. Then 75 blows are applied on either sides of the mould manually. Then the specimen is extracted after 24 hours.

This procedure is repeated for following proportions;
5% crumb rubber with
10% coconut shell charcoal
15% coconut shell charcoal
10% crumb rubber with
5% coconut shell charcoal
10% coconut shell charcoal
15% coconut shell charcoal
15% crumb rubber with
5% coconut shell charcoal
10% coconut shell charcoal
15% coconut shell charcoal

4.7. Marshall stability test on modified bituminous samples

Before testing the moulds are kept in water bath maintained at 25^{0}C for 30 minutes. The moulds are tested within 3 to 4 minutes after taken out from the water bath. The mould is put out on Marshall Apparatus and Marshall Stability and flow dial gauge readings are recorded.

V. RESULTS :

Preliminary test results of plain bitumen

Sl No.	Test particulars	Test Results
1	Penetration at 25^{0}C (mm)	66
2	Softening point (^{0}C)	41.9
3	Ductility at 27^{0}C (cm)	78
4	Specific gravity	1
5	Viscosity (sec)	28
6	Stripping value (%)	0

Table 1.Plain bitumen test Preliminary results test results of aggregate

Sl.No.	Test Particulars		Test results obtained
1	Aggregate impact value, %		13.55
2	Aggregate crushing value, %		28.28
3	Los Angeles abrasion value, %		35.9
4	Flakiness index, %		20.6
	Elongation index, %		12.8
5	Water absorption, %		0.7
6	Aggregate specific gravity	Coarse aggregate	2.715
		Fine aggregate	2.715
		Filler	2.715

Table 2. Aggregate test results

Marshall test results

BITUMEN PERCENT	5%			5.5%			6%		
	Sample			Sample			Sample		
	1	2	3	1	2	3	1	2	3
Weight of coarse aggregates, W1 (g)	998	998	998	993	993	993	987	987	987
Weight of fine aggregates, W2 (g)	82	82	82	81	81	81	81	81	81
Weight of filler, W3 (g)	60	60	60	60	60	60	60	60	60
Weight of bitumen, Wb (g)	60	60	60	66	66	66	72	72	72
Weight of specimen in air, Wm (g)	1242	1240	1248	1124	1125	1127	1206	1204	1210
Weight of specimen suspended in water, Ww (g)	715	710	720	644	647	656	700	698	704
Marshall stability; kN	16.03	15.57	15.72	16.34	16.65	17.11	14.18	14.49	14.34
Average stability (kN)	15.77			16.70			14.33		
Flow value (mm)	5.5	5.65	5.42	6.2	6.3	6.24	7.04	7.10	7.08
Average flow (mm)	5.52			6.24			7.07		
Gt	2.5			2.48			2.46		
Gm	2.35	2.33	2.36	2.34	2.35	2.39	2.38	2.37	2.39
Vv (%)	6	6.8	5.6	5.6	4.43	3.6	3.25	3.65	2.84
Vb (%)	11.75	11.65	11.8	12.87	12.92	13.14	14.28	14.22	14.34
VMA (%)	17.75	18.45	17.4	18.47	17.35	16.74	17.53	17.87	17.18
VFB (%)	66.19	63.14	67.81	69.68	74.47	78.49	81.46	79.57	83.46

Table 3. Marshall test results tofind OBC

Marshall test graphs

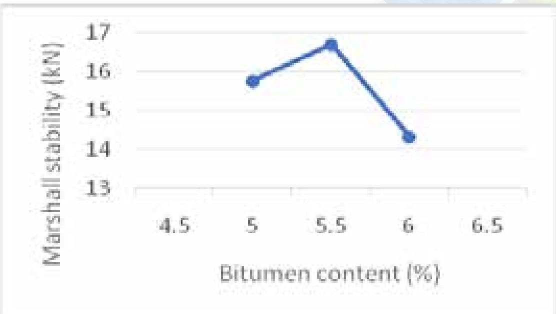

Fig 1. Marshall stability v/s Bitumen content

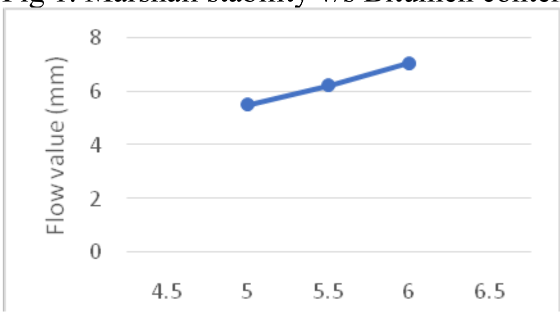

Fig 2. Flow value v/s Bitumen content

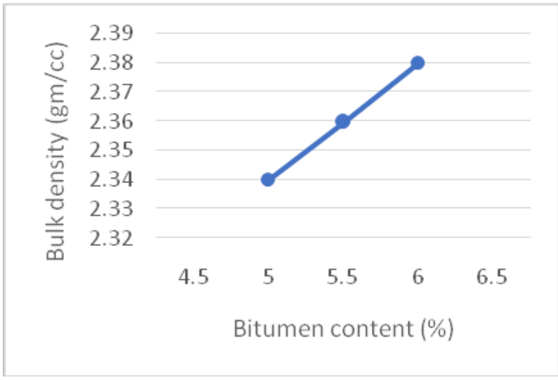

Fig 3. Bulk density v/s Bitumen content

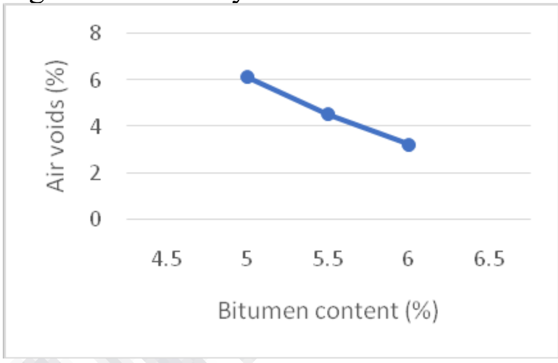

Fig 4.% Air voids v/s Bitumen content

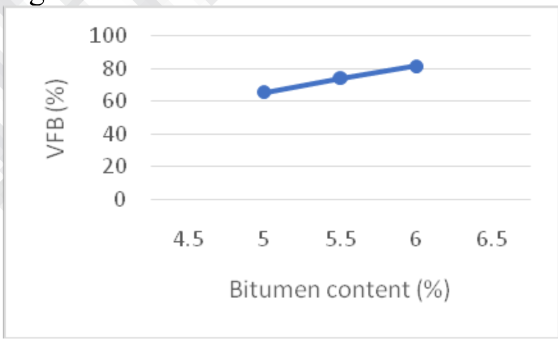

Fig 5.VFB v/s Bitumen content

From the curves;

Bitumen content for maximum Marshall stability is 5.5%, maximum bulk density is at 6% and 4% air voids is at 5.7%. Optimum bitumen content is the average of above values. So, optimum bitumen content is 5.7%.

Marshall test results for modified bituminous samples

CSC Crumb rubber	5%	10%	15%
5%	18.04	22.59	18.27

10%	16.96	15.26	12.18
15%	13.56	16.49	13.87

Table 4.Marshall stability values for modified bituminous samples

CSC Crumb rubber	**5%**	**10%**	**15%**
5%	6.4	6	7.95
10%	3	6.8	7.9
15%	8.9	9	7.9

Table 5. Marshall flow values for modified bituminous samples

Marshall graphs for modified bituminous samples

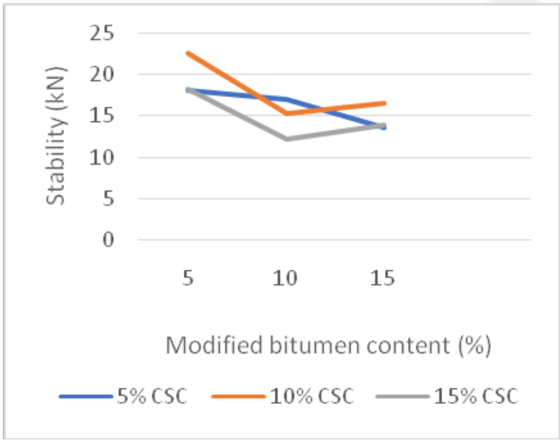

Fig 6. Marshall stability curve for modified bituminous mix

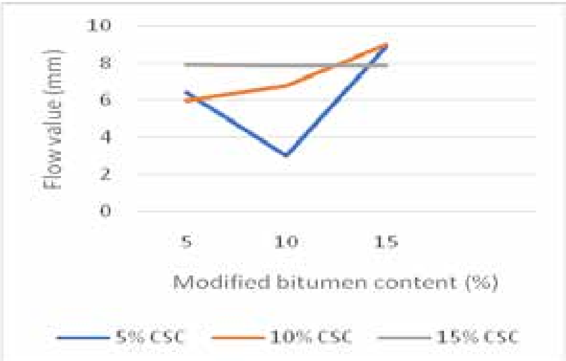

Fig 7.Marshall flow curve for modified bituminous mix

VI. CONCLUSION :

By studying the test results of common laboratory tests on plain bitumen and aggregate it is concluded that the raw materials used are of required quality. From Marshall test on plain bituminous mix samples, 5.7% bitumen content was found to be the optimum bitumen content.

The OBC was used in making specimens with bitumen modified using crumb rubber while partially replacing fine aggregates with coconut shell charcoal. From the results obtained from Marshall stability test on these modified bituminous mix samples, it is observed that the specimen prepared using 5% crumb rubber and 10% coconut shell charcoal gives the highest stability value of 22.59 kN and have a flow value of 6mm. Finally it can be concluded that crumb rubber and coconut shell charcoal can be used in construction of road pavement as bitumen modifier and aggregate replacement respectively. This ensures reduction of waste materials by proper usage while increasing the strength and stability of the road pavement and reducing the cost of construction.

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