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Utilization of Sugarcane Bagasse Ash with Fly Ash as Alternative Fillers in Bituminous Concrete

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Abstract- Most of the roads in India are paved with bituminous concrete due to its low cost initial investment with respect to cement concrete pavement. Bituminous concrete is a dense mixture of coarse aggregate, fine aggregate, fillers and bitumen as binder. It requires frequently maintenance work. Performance of bituminous concrete depends upon its density and gradation. Its density and stability can be increased by filling its very fine voids. These voids are generally filled with filler materials, like stone dust or silica fume. Fillers are very effective in stability and rut resistance properties in bituminous concrete. Sugarcane bagasse ash is waste material, which is generally disposed in open land after burning sugarcane bagasse in Sugar mills. It is a locally available material and can be utilized as a filler material. In this paper, three different bitumen concrete grade II mixes with Sugarcane bagasse ash as filler (BCSBA), with Fly ash as filler (BCFA) and with both Fly ash and Sugarcane bagasse ash (BCSBFA) were prepared at 5%, 5.5%, 6%, 6.5% and 7% bitumen content. Content of fly ash and sugarcane bagasse ash were decided as per blending requirement of bituminous concrete grade II. Performance of bituminous concrete with fly ash and sugarcane bagasse ash were tested by Marshall stability Test. The laboratory result showed that sugarcane bagasse ash can be used as filler with fly ash without significant reduction of stability of bituminous concrete. It was also found that excess addition of sugarcane bagasse ash can increase flow value. This type of study can be a solution of sugarcane bagasse ash disposal problem.

Keywords: **Fly Ash, Optimum bitumen content, Sugarcane bagasse ash, Stability.**

I. INTRODUCTION

Bituminous roads are mainly preferred in developing countries to develop an efficient large road network with availability of less funds. Bituminous pavement is basically multiple layer system. In which, surface layer is constructed by bituminous material, sometimes base layer also. Bituminous concrete is a dense mixture of coarse aggregate, fine aggregate, filler and bitumen as binder. Well graded aggregate mix is preferred for high strength mix, which gradation is given in IRC 111:2009 [1]. Fine aggregates fills the voids of coarse aggregate and fillers are used to fill voids of fine aggregate. Fillers also reduces the quantity of bitumen, which could be filled in voids. Conventionally, stone dust, cement, lime are being used as filler. But now a days, Fly Ash is being used as filler and different fine solid wastes like brick dust, marble dusts, ashes like rice husk ash, sugarcane bagasse ash etc. are also being tested to check their suitability as fillers in bituminous concrete. These types of waste dust and ashes are freely available in quarry sites and agricultural areas. Disposal of these type of ashes and dust are one of the major problem, which leads to environmental pollution. Utilization of these types of waste in road construction can give a better solution for disposal of these wastes, reduction of pollution and also reduction of cost of road construction.

Conventional fillers like cement, stone dust and lime have proved their suitability in bituminous concrete. But some researcher have also checked their effects in combination or also conducted comparative study. For example-Replacement of 50% stone dust by fly Ash reduced optimum binder content and increased the stability of bituminous mix [2]. Improvement in rutting resistance was found by dynamic shear and static indentation test. As per comparative study of Cement, Stone dust and fly ash as filler, it was concluded that cement can give better stability than others, but fly ash provided better temperature stability [3]. Study showed that 25% replacement of stone dust by fly ash as filler give better stability at lower binder content [4].

Researches on fine solid waste like Marble dust, Brick dust and Glass powder as filler also gave satisfactory results. Comparative study of Marble dust and stone dust showed that higher stability was achieved at 5.5% of Marble Dust with 4.6% bitumen and also there was increment in resilient modulus [5]. Experimental investigation of on brick dust [6] and concrete dust [7] concluded that brick dust gave nearly same stability values like other fillers, but optimum bitumen content were also increased. Glass powder as filler in bituminous mix also showed similar results like conventional filler like lime, cement [8]. Agricultural waste are generally used as bio fuel in local factories and produces large quantity of ashes. Example of these ashes are Rice husk ash, Rice straw ash, Sugarcane bagasse ash etc.

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A study on hydrated lime, rice husk ash and fly ash as filler in different proportion in Dense Bituminous Macadam suggested that 4% Rice husk and 4% Fly ash can give better results in the context of optimum bitumen content and indirect tensile strength and better stiffness than hydrated lime [9]. Rice husk ash and slag as filler compared to stone dust increased optimum asphalt content from 5.5% to 5.83% but gave better retained stability of asphalt concrete [10]. Bitumen concrete mix with 50% Rice Husk Ash and 50% Lime Stone of 5 % filler content also showed better result [11]. Rice straw ash as filler as compare with conventional mixes can also increase 2-4% stability, but higher content of filler can also reduce the stability and flow value [12]. Sugarcane bagasse ash had also showed 0.34 % content of Sugarcane bagasse ash increases the Marshall stability by 0.6%, flow value by 4.9% and Resilient Modulus by 17.4% compared to ordinary hot mix asphalt [13].

Strength of mix and asphalt interaction with filler depends upon filler particle size, asphaltene and resin content in asphalt, filler volume fraction and its SiO_2 content. Better results can be found by filler with stronger alkalinity and higher asphaltene and resin content of asphalt [14].

Since Sugarcane bagasse ash is one of the abundantly locally available material in the area of sugar production. Therefore, in this experimental investigation, effect of utilization of sugarcane bagasse ash with or without fly ash was studied.

II. EXPERIMENTAL INVESTIGATION

In this experimental study, All constituents material were tested to check their appropriateness as road material. Three different mineral aggregate mixes, Bituminous concrete with Fly Ash (BCFA), Bituminous concrete with Sugarcane bagasse Ash (BCSBA) and Bituminous concrete with both Fly Ash & Sugarcane bagasse ash (BCSBFA) were prepared. Three samples of each mixes with five different bitumen content were casted and Marshall Test was performed on those prepared samples.

A. Material

Coarse aggregate (size 20mm-10mm and 10mm-4.75mm), Fine aggregate (River Sand passing from 4.75mm), Fly ash from Kanti Thermal Power plant, Muzaffarpur, Bihar, Sugarcane bagasse ash (ash of residue of sugarcane, which is used as biofuel) from Hindustan Petroleum Corporation Ltd. (HPCL) Biofuel Sugarcane factory, Sugauli, Bihar and bitumen were collected. All materials were tested in laboratory as per IS Code to check its suitability for bituminous concrete grade II. Test Result and composition of constituent material was shown in Table I, Table II, Table III and Table IV.

Table-I: Properties of coarse aggregate

Test	*Results*	*Standard Results*
Maximum Size(mm)	20 mm	20 mm
Water absorption	0.35%	<2%
Crushing strength	22.4%	<30%
Aggregate impact value	11.45%	20 to 30%
Los Angeles Abrasion test	25.6%	<35%
Specific gravity	2.70	2.5- 3
Flakiness vale	10.11%	25%
Elongation test	11.30%	Combined flakiness+ Elongation index<30%

Table-II: Properties of fine aggregate

Test	*Results*	*Standard Results*
Specific gravity	2.61	2-3
Water absorption	1%	<2%
Sieve analysis	Fineness modulus 2.53	2.2-2.9

Table-III: Bitumen Test Result

Test	Results	Standard Results
Penetration Test	95	80-100
Ductility Test	79 cm	Min 75 cm
Specific gravity	1.02 g/cc	Near about 1 g/cc
Softening Point	52°C	Min 40°C

Table-IV: Specific gravity of Filler

Filler	Specific gravity
Fly Ash	2.07
Sugarcane Bagasse Ash	1.94

Table-V: Chemical Composition Of Sugarcane Bagasse Ash [15]

Chemical Properties	Chemical Composition (%)
Silicon Dioxide (SiO_2)	62.43
Aluminium Oxide (Al_2O_3)	4.38
Ferro Oxide (Fe_2O_3)	6.98
Calcium Oxide (CaO)	11.80
Magnesium Oxide (MgO)	2.51
Sulphur Trioxide (SO_3)	1.48
Potassium Oxide (K_2O)	3.53
Loss On Ignition (LOI)	4.73

B. Blending Of Aggregate

Proportion of constituent material was taken by trial. Grain size distribution of sample mixes were calculated and compared by range of grain size distribution of bituminous concrete mix grade II [1]. After several trail mix constituent proportion was decided, which fulfill the criteria of bituminous concrete mix II. After mixing all aggregate, following gradation of mineral aggregate were obtained for mixes BCFA, BCSBA and BCSBFA.

Table-VI: Grain size distribution in different mixes

sieve size (mm)	Bituminous concrete grade II		Grain Size distribution		
	Min	Max	Mix with Fly ash	Mix with sugarcane bagasse ash	Mix with both sugarcane bagasse ash and fly ash
19	100	100	100.00	100	100.00
13.2	79	100	82.54	81.94	84.72
9.5	70	88	72.74	73.77	74.96
4.75	53	71	56.69	58.65	60.32

2.36	42	58	53.75	56.23	57.76
1.18	42	58	47.94	51.37	38.84
0.6	26	38	31.07	28.19	26.57
0.3	18	28	23.42	17.48	18.18
0.15	12	20	12.10	12.12	11.67
0.075	4	10	4.86	4.39	4.18

C. Sample Mix Preparation

Aggregates were weighted as per determined proportion, heated and thoroughly mixed in laboratory bitumen hot mixer with bitumen at temperature 160^{o}C. Three cylindrical samples (dia 10.16cm and average height 6.36 cm) of five different bitumen content 5%, 5.5%, 6%, 6.5% & 7% and for three different mixes BCFA, BCSBA, BCSBFA were casted on Marshall Compactor by 75 blows of hammer on both faces of sample as per ASTM D1559. Fig.1 shows the whole process of preparation and testing of samples.

Fig.1: Methodology of preparation of sample

III. RESULT & DISCUSSION

Bulk density (G_b) and theoretical density (G_t) of all specimen were determined. After determination of bulk density, air voids (Vv) and volume filled by bitumen (VFB) were determined. Stability and flow value were determined on Marshall Stability test apparatus after heating in water bath at 60^{o}C for 35 minutes. Average value of all results were shown in Table VII to Table X and Fig. 2 to 6.

Table-VII: Marshall Stability result of BCFA

Bitumen content	Bulk Density	Vv	VFB	STABILITY	Flow value
5	2.08	5.62	64.904	14.32	3.6
5.5	2.107	3.891	74.850	18.89	3.8
6	2.113	3.205	79.804	19.65	4.5
6.5	2.101	3.11	81.207	18.75	4.7
7	2.069	3.19	77.772	17.16	5.1

Table-VIII: Marshall Stability result of BCSBFA

Bitumen content	Bulk Density	Vv	VFB	STABILITY	Flow value
5	2.071	7.05	55.138	13.16	4.4
5.5	2.09	5.51	61.913	16.86	4.8
6	2.11	4.267	68.735	18.85	5.1
6.5	2.108	3.76	72.720	19.11	5.8
7	2.089	3.21	72.396	16.78	6.4

Table-IX: Marshall Stability result of BCSBA

Bitumen content	Bulk Density	Vv	VFB	STABILITY	Flow Value
5	2.06	7.42	56.128	13.24	4.6
5.5	2.083	5.788	63.74	15.67	5.1
6	2.105	5.037	71.571	16.53	5.8
6.5	2.104	3.85	74.454	17.11	6.3
7	2.073	3.61	72.693	15.32	7.6

A. Density of Bitumen Sample

Average density of all three bitumen concrete mix samples was determined and it was found that it increases by the increment of bitumen content at certain level and then start reducing.

Bitumen helps to arrange mineral aggregate to make a dense mix, due to which, density increases. Since, specific gravity of bitumen is very less than other ingredient, therefore after a certain limit, it starts reducing. Highest bulk density was found for BCFA specimen at less bitumen content about 6 %. While maximum density of BCSBFA and BCSBA were found at 6% and 6.25% respectively, as shown in Fig. 2.

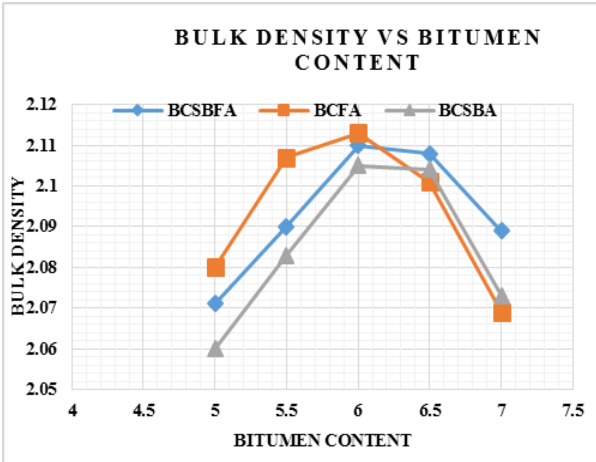

Fig.2- Bulk Density Vs Bitumen Content

B. Percentage Volume of Voids

Volume of air voids was determined with the help of theoretical and practical bulk density. Graph between percentage air voids and bitumen content shows that as the bitumen content increases, percentage air voids decreases. BCFA specimen had least voids, as shown in Fig. 3.

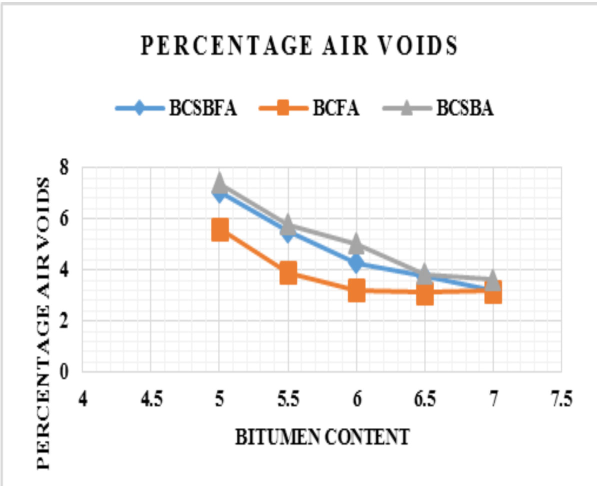

Fig.3:Air voids Vs Bitumen Content

C. Voids Filled By Bitumen

Air voids of the sample should be filled to achieve higher density. Bitumen fills the remaining air voids after voids filled by fillers. In case of BCFA mix, it was found that 81.2 % of air voids was filled by bitumen as compared to other mixes. Sugarcane bagasse ash also showed nearby similar property, shown in Fig.4.

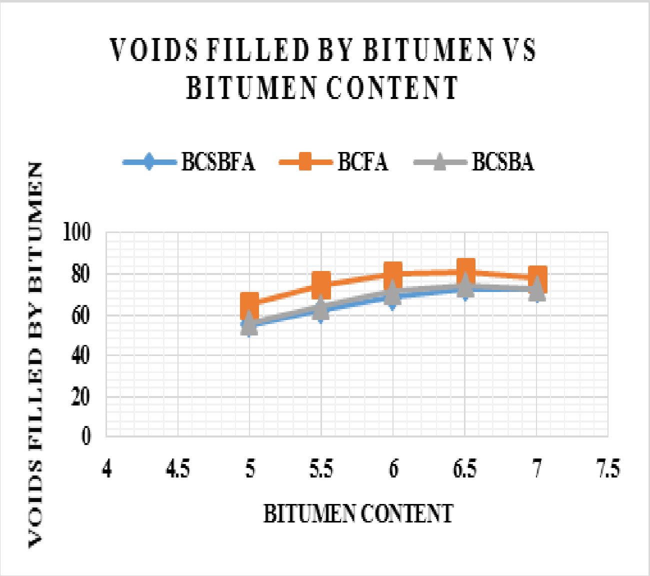

Fig.-4 : Voids filled by Bitumen Vs Bitumen Content

D. Stability

Marshall Stability test was conducted on the prepared samples to determine Stability of bitumen sample. Results showed that there were very less variation in stability of BCFA, BCSBA and BCSFA. But still BCFA showed better results at 6 % bitumen content. Use of Sugarcane bagasse ash reduced stability and increase optimum bitumen content by very small amount.

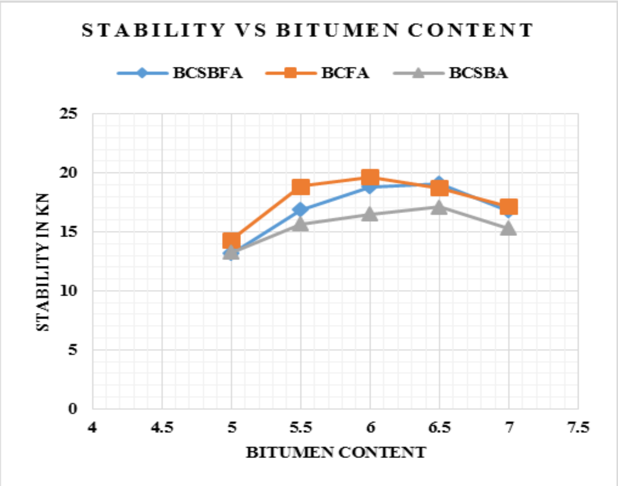

Fig.-5 : Stability Vs Bitumen Content

E. Flow Value

Flow value of Bitumen sample was determined by Marshall Stability test. Graph was drawn between bitumen content and flow value, which showed that BCSBA slightly increased the flow value in comparison of BCFA and BCSBFA, but it was under permissible limit.

F. Optimum Bitumen Content

Best results was foundat different bitumen content in various test. Therefore, average of three bitumen content (Bitumen content at maximum stability, maximum bulk density and at designed air voids 4%) is taken as optimum bitumen content, which are given in following table.

Table-X: Optimum bitumen content calculation

Mix	At Max stability	At Max. Density	At 4% air voids	Average
BCFA	6	6	5.5	5.83
BCSBA	6.5	6.25	6.5	6.42
BCSBFA	6.5	6	6.25	6.25

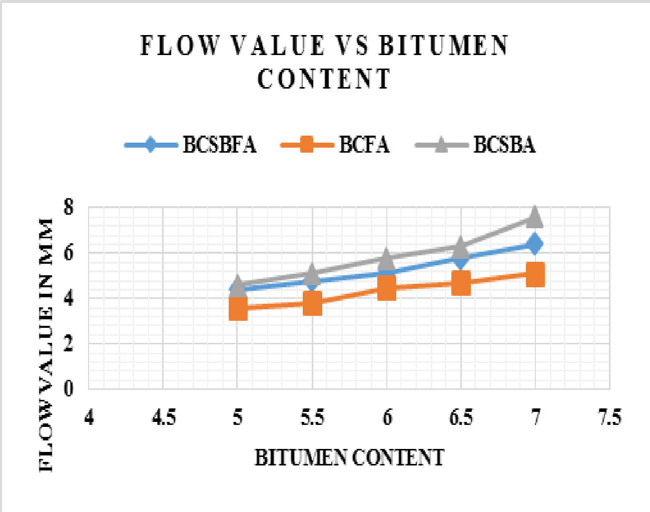

Fig.6: Flow Value Vs Bitumen Content

IV. CONCLUSION

Marshall Stability test results on various specimens with filler fly ash and sugarcane bagasse ash was also give the idea of the behavior of fillers in mixes. Sugarcane bagasse ash reduced the mix density slightly due to its less specific gravity. Fly ash was found more efficient to reduce air void content. While sugar bagasse ash has also nearly same characteristics. Due to less voids filled by bitumen with sugar cane bagasse ash, it can be concluded that it resists flow of bitumen in voids. Fly ash was more efficient to provide stability. Sugarcane bagasse ash reduces the stability and also due its adsorption nature, its binder content at maximum stability was more. More flow value with Sugarcane bagasse ash also suggests that fly ash is efficient to fill voids and create also friction to flow. Optimum bitumen content was found least 5.83 % for BCFA and more 6.42% for BCSBA. It can be concluded that utilization of sugarcane bagasse ash can give an alternative filler material for bituminous concrete and also a solution of disposal problem of this type of waste. It was suggested that use sugarcane bagasse ash with other filler, for less reduction of stability and less increment in optimum bitumen content.

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