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Study of Fibre Reinforced Bituminous Concrete

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Abstract: The proposed work presents the studies on stability, flow and volumetric properties of fibre reinforced bituminous concrete in comparison with the properties of conventional bituminous concrete. Marshall's stability tests were conducted to determine the optimum binder content. By varying the amount of 10 mm polypropylene fibres (4%, 6%, 8% and 10% by weight of bitumen), optimum fibre content was obtained. The results indicate that the addition of PP fibres increases the stability but decreases the flow value.

Keywords: Fibre reinforced, PP fibres, FRBC, Marshall's test, OBC.

I. INTRODUCTION

A good roadway infrastructure is an essential component of a strong and stable economy. Bituminous Concrete (BC), a mixture of bitumen and aggregate is a widely employed material for pavement construction. As the modern highway transportation has high speed, high traffic density, heavy load and channelized traffic, bituminous concrete pavements are subjected to various types of distress such as fatigue cracking, rutting and ravelling. Use of modified binders with additives like crumb rubber, natural rubber, polymers, etc., is gaining popularity as means of controlling pavement distresses.

The merits and demerits of fibre reinforcement in bituminous concrete have been studied extensively over the past few years. A comprehensive literature review shows that coir, polypropylene, polyester and glass fibres are the most commonly used fibres in Fibre Reinforced Bituminous Concrete (FRBC). Polypropylene (PP) fibers, however, are preferred due to their low-cost and good consistency with bituminous pavement [1]. These fibres have been found to reduce crack intensities and reflective cracking in pavements. PP fibre modified mixtures are also slightly stiffer and show improved fatigue life [1]. The use of PP fibres increases the Marshall Stability value while it decreases the flow value.

This paper aims at studying the effect of polypropylene fibres as reinforcement in bituminous pavements. The optimum binder content was determined for the selected aggregate gradation and then commercially available PP fibers of graded length were added to the obtained optimum binder content. Different percentages of PP fibres (4%, 6%, 8% and 10% by weight of bituminous binder) were added to different samples. Marshall's stability tests were conducted on these specimens and Marshall Stability value and flow value were found out. From the obtained data, optimum fibre content was determined.

II. LITERATURE REVIEW

According to Abtahi, Kunt, Hejazi and Ebrahimi**[1],** polypropylene fibre modified bituminous concrete samples exhibits superior performance compared to other fibre reinforced samples. Polypropylene fibres decreases penetration and ductility of modified bitumen while the softening point value is increased compared unmodified bitumen specimen. They also suggested that Polypropylene (PP) fibres are preferred due to their low-cost and good consistency with bituminous pavement.

K. Thulasirajan and V.L. Narsimha**[2]** undertook a comparative study of BC and FRBC and concluded that addition of fibres enhances the properties of bituminous mixtures by increasing its stability and air voids and decreasing the flow value. Addition of coir fibres led to an increase in stability by 49% and decrease in flow value by 11%. Coir fibres were also found to improve the compressibility of mix.

Kaloush and Zeiada**[3]** inferred from laboratory experimental program that fibres in bituminous concrete improved the mixtures performance against the anticipated major pavement distresses like permanent deformation , fatigue cracking and thermal cracking.

Literature survey was conducted regarding addition of polypropylene , aramid, coir, Recron 3s, nylon fibres etc.

III. METHODOLOGY

IV. MATERIAL PROPERTIES

The tests were conducted to ascertain various properties of selected aggregates and VG-30 bitumen. The results are shown in Tables 1 and 2:

Table 1. Properties of Aggregates

Sl. No.	Property	Test Results	Remarks
1	Aggregate Crushing Value	30.8%	Satisfactory
2	Impact value	30%	Satisfactory
3	Specific gravity	2.7	Satisfactory
4	Los Angeles Abrasion value	32.3%	Satisfactory
5	Flakiness index	13.48%	Satisfactory
6	Elongation index	8.87%	Satisfactory
7	Soundness	10%	Satisfactory

Table 2. Properties of Vg-30 Bitumen

Sl. No.	Property	Test Results	Remarks
1	Softening Point of bitumen	41°C	Satisfactory
2	Ductility Value	82cm	Satisfactory
3	Specific gravity of bitumen	1.00	Satisfactory
4	Penetration value of bitumen	75	Satisfactory
5	Viscosity of bitumen	72sec	Satisfactory

Polypropylene fibres were selected for obtaining FRBC. The fibres were 100% virgin homo-polymer containing no reprocessed olefin material and were specifically engineered and manufactured in an ISO 9002 facility (Refer Table 3).

Table 3. Physical and Chemica L Properties of Polypropylene Fibres

Properties	Results
Absorption	Nil
Fibre Length	10mm
Melt Point	324°F
Thermal Conductivity	Low
Acid and Salt Resistance	High
Specific Gravity	0.91
Modulus (Young's)	0.5 (3.5 kN/mm)
Ignition Point	1,100°F
Electrical Conductivity	Low
Alkali Resistance	Alkali Proof

V. MIX DESIGN

The following steps were adopted for the rational design of bituminous mix:

A. *Gradation of aggregate*

Aggregates which posses sufficient strength, hardness, toughness were chosen, keeping in view the availability and economic consideration. Aggregates of size 20mm (A), 12mm (B), 6mm (C) and M -sand were selected and graded.

Based on the individual grading of aggregates, a suitable gradation for the mix was arrived upon as shown in Table 4. Fig.1. shows the gradation curve of the selected proportion of aggregates.

Table 4. Final Gradation of Aggregates

Sieve size(mm)	%finer	MORTH specifications
26.5	100	100
19	95.04	79-100
13.2	76.29	59-79
9.5	65.39	52-72
4.75	46.14	35-55
2.36	37.87	28-44
1.18mm	30.02	20-34
0.6mm	23.72	15-27
0.3mm	14.32	20-10
0.15mm	7.70	13-5
0.075mm	3.28	2-8
pan	0	0

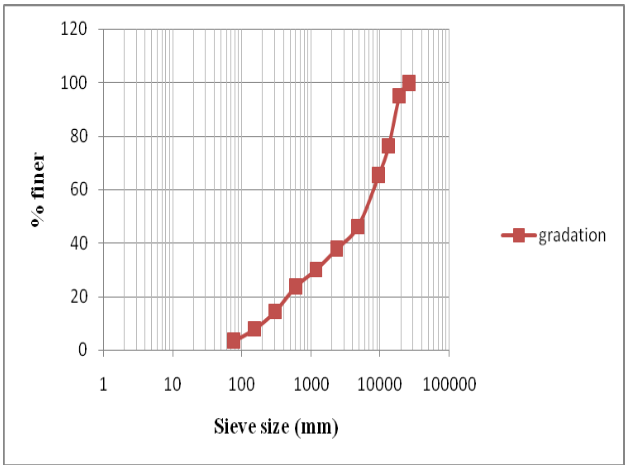

Fig.1. Final gradation curve

The following proportions were obtained:
Aggregate A- **15%**
Aggregate B- **25%**
Aggregate C- **15%**
Aggregate D- **45%**

B. *Marshall test method- ordinary mix*

To obtain the Optimum Bitumen Content for the selected gradation of aggregates, test specimens were prepared with binder contents 4.5, 5, 5.5 and 6% by weight of mix. For each binder content , 3 specimens were prepared.

The graded aggregates were heated to a temperature of 150°C- 170°C and the required proportions of bitumen by weight of aggregates were also heated to a temperature of 150°C -160°C. The heated bitumen and aggregates were mixed at a temperature of 160°C. The test specimens were then cast and tested under specified conditions.

Table 5. Correction Factors For Marshall Stability Values

Volume of specimen (cc)	Thickness of specimen (mm)	Correction factor
457-470	57.1	1.19
471-482	58.7	1.14
483-495	60.3	1.09
496-508	61.9	1.04
509-522	63.5	1.00
523-535	65.1	0.96
536-546	66.7	0.93
547-559	68.3	0.89
560-573	69.9	0.86

Applying the correction factors as per Table 5, the Marshall Stability values and flow values were obtained and are tabulated in Table 6. Marshall properties of the samples are shown in Table 7.

Table 6. Marshall's Test Results

Bitumen by weight of mix (in %)	Bitumen by weight of aggregate	Marshall value (in kg)				Flow(mm)	
		Observed	Correction	Corrected	Average	Observed	Average
4.5	4.71	1407.8	0.93	1309.2	1440.53	4.9	4.42
		1498.7	0.93	1393.8		4.2	
		1735.1	0.93	1613.6		4.15	
5	5.26	1558.4	0.93	1449.3	1472.33	4.4	4.57
		1610.38	0.93	1497.65		4.8	
		1580.7	0.93	1470.1		4.52	
5.5	5.82	1062.3	0.96	1019.8	1122.1	4.9	4.75
		1207.8	0.96	1159.5		4.7	
		1236.36	0.96	1186.9		4.65	
6	6.38	1029.9	0.96	988.7	1040.2	4.85	4.86
		1168.8	0.96	1122.04		4.45	
		1051.9	0.96	1009.8		5.3	

Table. 7. Marshall Properties of Ordinary Mix

Bitumen by weight of mix (in %)	Weight		Bulk volume	Specific Gravity.			Volume % total	Voids (in %)		
	In air	In water		Bulk	Bulk average	Theoretical maximum	Bitumen	In aggregate (VMA)	Filled with bitumen (VFB)	Voids In mix (Vv)
4.5	1192 1207 1195	690 697 695	502 510 500	2.37 2.37 2.39	2.838	2.56	10.25	17.81	57.55	7.56
5	1195 1200 1205	702 727 700	493 473 505	2.42 2.54 2.39	2.45	2.54	11.67	15.34	76.07	3.67
5.5	1205 1210 1185	707 705 682	498 505 503	2.42 2.39 2.36	2.39	2.52	12.46	17.90	69.61	5.44
6	1202 1210 1205	680 686 700	522 524 505	2.30 2.31 2.39	2.33	2.50	13.19	20.48	64.40	7.29

C. ***Marshall test method- Fibre reinforced mix***

PP fibres were added by employing the wet mixing technique. Aggregates were preheated to a temperature of 160°C and they were placed in asphalt mixer where the temperature was maintained. Simultaneously bitumen was also heated to a temperature of 160°C and fibres were added to it and manually stirred for 5 minutes. This mixture was then added to asphalt mixer and thorough mixing was done for 10 minutes after which specimens were cast.

To determine the optimum fibre content , two specimens each with optimum binder content but varying fibre content of 4%, 6%, 8% and 10% by weight of optimum binder content respectively were cast and the Marshall's test was conducted on them. The results are given in Table 8 and Table 9.

Table 8. Marshall's Test Results of FRBC

Fibre by weight of bitumen (in %)	Bitumen by weight of aggregate	Marshall value (in kg).				Flow (mm)	
		Observed	Correction	Corrected	Average	Observed	Average
4	4.83	2820.78	0.86	2425.00	2749.33	4.7	4.72
		3574.02	0.86	3073.66		4.75	
6	4.83	3740.26	0.93	3478.44	3600.43	4.34	5.32
		4002.60	0.93	3722.42		6.3	
8	4.83	3537.66	0.89	3147.93	3227.98	4.5	4.15
		3716.88	0.89	3308.02		3.8	
10	4.83	2850	0.93	2700.62	2675.56	5.36	5.48
		2903.89	0.93	2650.50		5.60	

Fig.2. PP fibres mixed with bitumen

Fig.3. Asphalt mixer

Table. 9. Marshall Properties for FRBC

Fibre by weight of bitumen (In %)	Weight		Bulk volume	Specific Gravity.			Volume % total	Voids (in %)		
	In air	In water		Bulk	Bulk average	Theoretical maximum	Bitumen	In aggregate (VMA)	Filled with bitumen (VFB)	In mix (Vv)
4.0	1200 1200	725 705	475 495	2.53 2.42	2.47	2.54	12.53	14.96	83.75	2.43
6.0	1200 1200	725 725	475 475	2.53 2.53	2.53	2.54	11.65	12.04	96.76	0.39
8.0	1200 1200	675 725	525 475	2.28 2.53	2.41	2.54	11.06	16.89	65.48	5.83
10	1272 1269	750 750	522 519	2.44 2.44	2.44	2.54	11.19	15.28	73.23	4.09

VI. RESULTS

Graphs were plotted for ordinary mix and FRBC with bitumen content and fibre content respectively on X-axis and following values on Y-axis (Fig.4 to Fig.13):

1. Percentage voids in total mix.
2. Unit weight.
3. Percentage voids filled with bitumen (VFB).
4. Marshall Stability value.
5. Flow value.

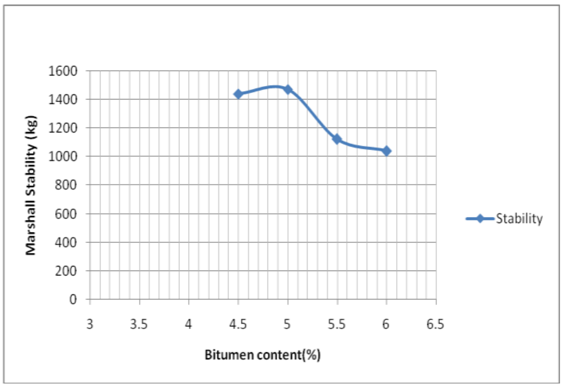

Fig.4. Stability v/s Bitumen content

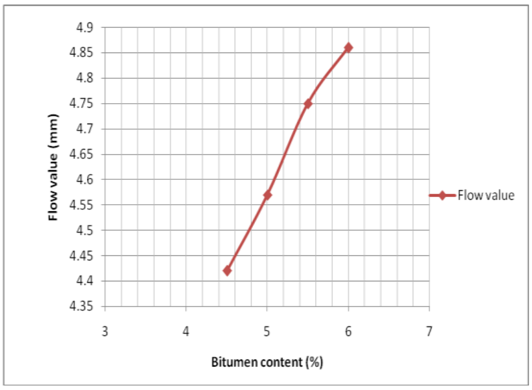

Fig.5. Flow value v/s Bitumen content

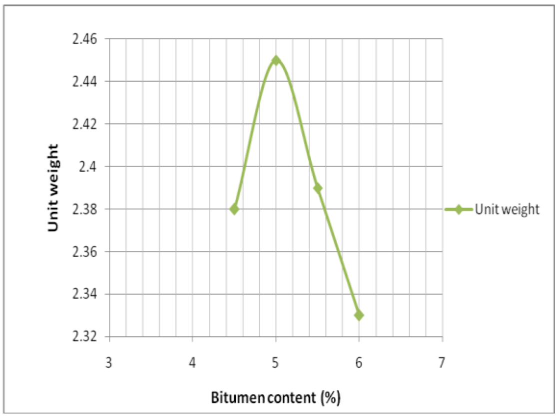

Fig.6. Unit weight v/s Bitumen content

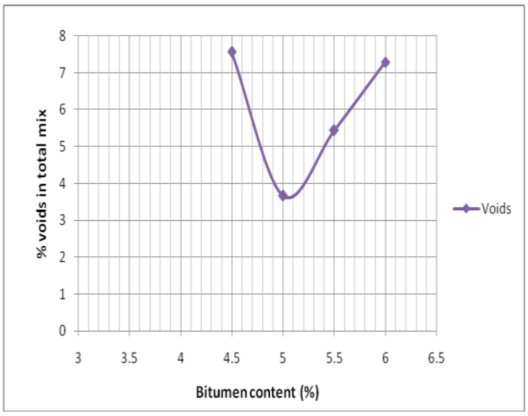

Fig.7. % Voids in mix v/s Bitumen content

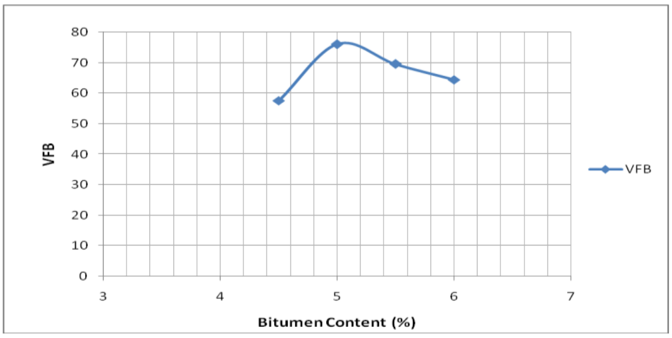

Fig.8. VFB v/s Bitumen content

The optimum bitumen content for the mix is calculated by taking the average value of the bitumen content found from the previous graphs:

1. Bitumen content corresponding to maximum stability.
2. Bitumen content corresponding to maximum unit weight.
3. Bitumen content corresponding to median of the percent of air voids in total mix.

The optimum binder content is 4.83% by weight of mix.

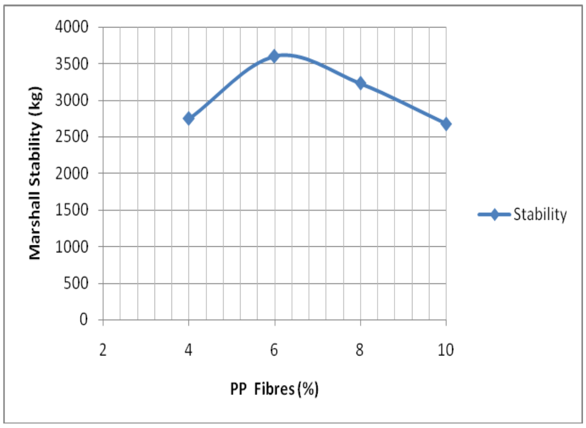

Fig. 9. Stability v/s PP fibres (%)

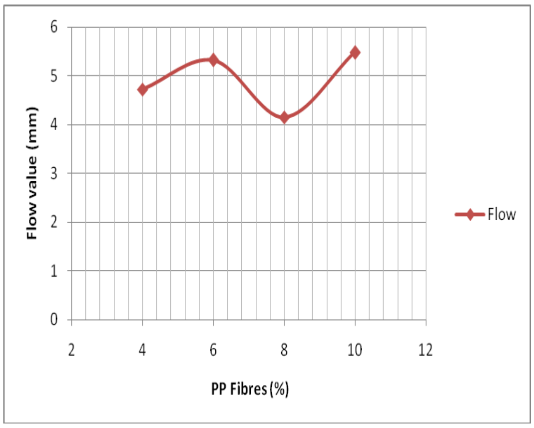

Fig.10. Flow value v/s PP fibres (%)

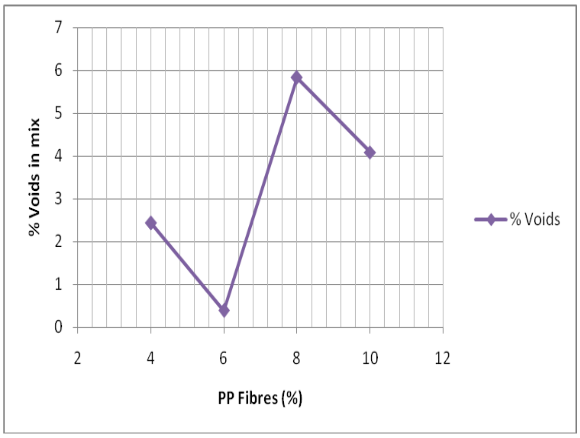

Fig. 11. % voids in mix v/s PP fibres(%)

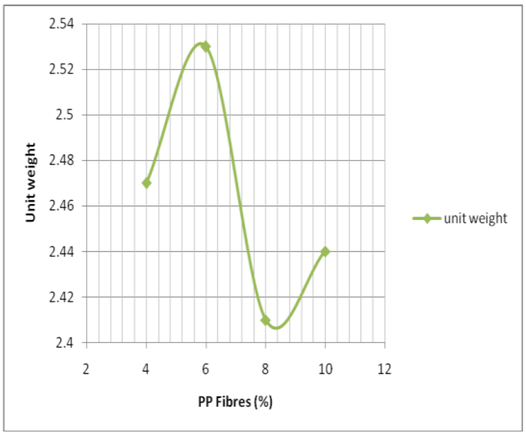

Fig.12. Unit weight v/s PP fibres (%)

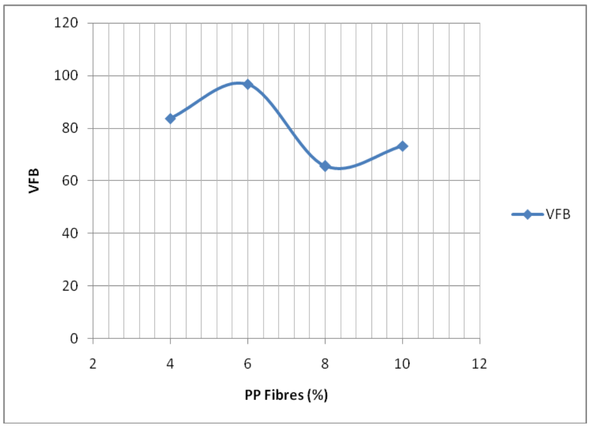

Fig.13. VFB v/s PP fibres(%)

To determine the optimum fibre content, the average of the following three fibre content is taken:

1. The fibre content corresponding to maximum stability values.
2. The fibre content corresponding to maximum unit weight.
3. The fibre content corresponding to the median of the percentage of air voids in the total mix.

The optimum fibre content is 5.33% by weight of bitumen.

VII. CONCLUSION

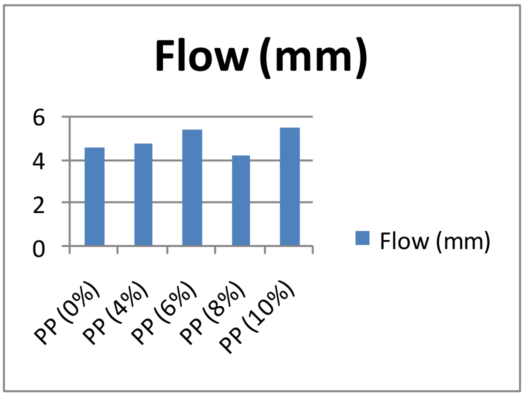

Fig. 14. Variation of flow value

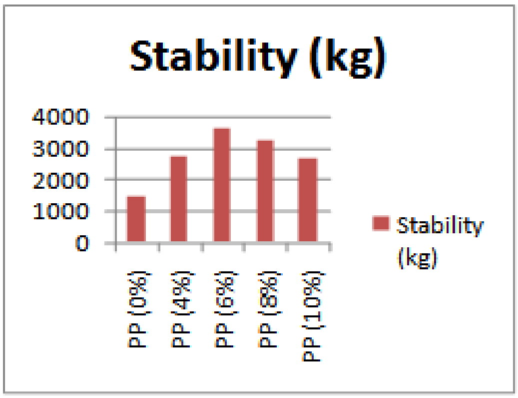

Fig .15. Variation in Marshall Stability value

The addition of PP fibres to bituminous mixtures increased the Marshall Stability value and decreased the flow value as depicted in Fig. 14 and Fig. 15. A fibre content of 5.33% and a binder content of 4.83% provide good stability and volumetric properties. The variation in stability and flow values improves the structural resistance of bituminous concrete to distresses occurring in flexible pavements.

REFRENCES

[1]. K.Thulasiraja, V.L. Narasimha, "Studies on Coir Fibre Reinforced bituminous concrete", *International Journal of Earth Sciences and Engineering*, ISSN 0974-5904.

[2]. Sayyed Mahdi Abthai, Saman Esfandiarpour, Mehmet Kunt, Sayyed Mahdi Hejazi, Milad Ghorban Ebrahimi, "Hybrid Reinforcement of Asphalt Concrete mixtures using Glass and Polypropylene fibres", *Journal of Engineered Fibres and Fabrics.*

[3]. T. Subramani, "Experimental Investigations on Coir fibre reinforced bituminous mixes", *International Journal of Engineering Research and Applications.*

[4]. Kamil E Kaloush, Waleed A Zeiade, "Evaluation of Fibre Reinforced Asphalt mixtures using advanced material characterization tests".

[5]. J. Murali Krishnan "Asphalt Mix Design", HINCOL Training Program – 2013.

[6]. Amit Goel,Animesh Das, " Emerging road materials and innovative applications", *National conference on materials and their application in Civil Engg*,2004.

[7]. Highway Research Record No. 38, "General Report on Road Research Work Done In India during 2010-11", *IRC Highway Research Board,* New Delhi.

[8]. Gomaa K. Moussa, "Effect of addition of short fibres of poly-acrylic and polyamide to asphalt mixtures", *Alexandria Engineering Journal*, 42(3), 329-336, (2003).