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Experimental Study on Addition of Polypropylene Fiber & Crumb Rubber in Bituminous Concrete Mix

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Abstract: Bitumen is used in road pavement as the binder of aggregate in a great extent all around the world. Fibres and waste materials like plastics, rubber tyres can be used to improve the mechanical properties of bituminous mixture in road pavements are known as bituminous mix modifier[2]. Use of this innovative technology not only strengthens the road construction but also increases the road life as well as help to improve the environment. In this present study, an attempt has been made to use polypropylene fiber and crumb rubber to enhance with flexible pavement quality. The main objective of this paper consists of evaluating the advantages of using modified bituminous mixtures in laboratory which are compared with the conventional bituminous mix.
Keywords : bituminous mix modifier; polypropylene fiber crumb rubber; flexible pavement.

1.0 Introduction

Highway was a fundamental infrastructure in national economy and social welfare, since they provide mobility and accessibility for motorists and loads. It must undergo heavy load and unfavorable environmental conditions for an acceptable period of time. So the roads are to be maintained in good condition. The quality of roads depends on materials used for construction. In the construction of flexible pavement, bitumen plays the role of binding the aggregate together by coating over the aggregate. It also helps to improve the strength of the road. High temperature rutting, poor water resistance and low temperature cracking are most considerable limitations of unmodified and pure bitumen. A common method to improve the quality of bituminous mix is by modifying the Engineering properties of bituminous mix by blending with organic synthetic polymers like rubber and fibers. In this paper, usage of polypropylene fiber and crumb rubber in flexible pavement is studied. Polymer modified bituminous mix and crumb rubber modified bituminous mix should be used only in wearing coarse depending upon the requirements of extreme climatic variation[1].

A. Polypropylene fiber:

The addition of polypropylene fiber in bituminous mix typically increases the stiffness of the bitumen which improves the rutting resistance of the mixture in hot climates. Polypropylene fibres act as reinforcement in the bituminous concrete mix. A polypropylene modified bituminous binder also shows improved adhesion and cohesion properties [3].

B. Crumb rubber:

Crumb rubber is a term usually applied for recycled rubber from automotive and truck scrap tires which is a particular material free of fiber and steel. The addition of rubber in bituminous mix increases the flexibility and flexural strength of carpet layer of highway[4,5].

C. Objective of the project:

- The present study aimed to find out the stability when polypropylene and crumb rubber is added to the mixture.
- To find out the optimum percentage of polypropylene and then optimum crumb rubber percentage to be used in the mix of optimum polypropylene.
- To find the Marshall stability and flow value of the optimum percentage

D. Outline of the project:

Experimental phase of this research starts with the unmodified bitumen and aggregate quality test. The optimum bitumen content is then worked out using Marshall Stability mix design process on control sample. Polypropylene fiber modified sample are prepared by adding polypropylene fiber in the mix in different percentages and the optimum polypropylene content is determined by using of Marshall Stability criterion. Then crumb rubber is added in various percentages with the constant optimum value of polypropylene fiber and the specimen is prepared and tested in Marshall Stability apparatus to find out optimum percentage of crumb rubber.

2.0 Materials

E. Bitumen:

80/100 grade bitumen was used in this investigation to prepare the samples. Table 1 shows the test results of basic properties of bitumen.

Table 1: Basic properties of Bitumen

Properties	Result
Specific gravity	1.02
Penetration	8.2mm
Softening point	55°C
Ductility	68cm

F. Coarse Aggregate:

Aggregate of size 10mm were used as coarse aggregate. Table 2 shows the basic properties if coarse aggregate.

Table 2: Basic properties of Coarse aggregate

Properties	Result
Specific gravity	2.66
Water absorption	0.45%
Impact strength	20.625%
Crushing strength	28.57%
Abrasion	25.1%

G. Fine aggregate:

Quarry dust is taken as fine aggregate for mix. Table 3 shows the basic properties of Quarry dust.

Table 3: Basic properties of Fine aggregate

Properties	Result
Specific gravity	**2.6**

H. Mineral filler:

Fly ash is taken as mineral filler in our paper. Table 4 shows the basic properties of fly ash.

Table 4: Basic properties of fly ash

Properties	Result
Specific gravity	2.2

I. Polypropylene fiber:

Table 5 shows the basic properties of polypropylene.

Table 5: Basic properties of polypropylene fiber

Properties	Result
Specific gravity	0.887
Length	12mm
Thickness	7.5µm
Slenderness ratio	1600

J. Crumb rubber:

Rubber shredded into pieces of uniform size was used in the study. Table 6 shows the basic properties of modifiers used.

Table 6: Basic properties of crumb rubber

Properties	Result
Specific gravity	1.15
Size	2.36mm

3.0 Experimental Methods

K. Marshall stability test:

The experimental work carried out in this present investigation is the Marshall Stability test. The original Marshall method is applicable only to bitumen paving mixes, with a maximum aggregates with maximum size of 25mm. Marshall Stability test is empirical in nature. Hence no modifications can be affected to the standard procedure, such as reheating of mix for preparing specimens, conducting Marshall Test on field compacted sample etc. The Marshall test uses standard test specimens of 64mm (2.5 inches) height and 102 mm (4 inches) mm diameter. They are prepared using a specific procedure for proportioning materials heating, mixing and compaction of the bitumen mixture. Marshall Stability test involves mainly 2 processes:

- Preparation of Marshall samples
- Marshall Test on samples

L. Sample preparation:

The mixing of ingredients was done as per the following procedure.

- Required quantities of coarse aggregate, fine aggregate & mineral fillers were taken in an iron pan.
- This was kept in an oven at temperature 160°C for 2 hours. This is because the aggregate and bitumen are to be mixed in heated state so preheating is required.
- The bitumen was also heated up to its melting point prior to the mixing.
- The required amount of bitumen modifier was weighed and kept in a separate container.
- The bitumen (60 gm) 5% by weight of whole mix was heated on a controlled gas stove for a few minutes maintaining the above temperature.
- The aggregate was added to the bitumen and was mixed for 2 minutes.
- Now bitumen modifier (polypropylene, crumb rubber) added to this mix and the whole mix was stirred uniformly and homogenously. This was continued for 15-20 minutes till they were properly mixed which was evident from the uniform color throughout the mix.
- Then the mix was transferred to a casting mould.
- This mix was then compacted by the Marshall Hammer. The specification of this hammer, weight 4.86kg and the height of release is 45cm.
- 75 no. Of blows were given per each side of the sample so subtotal of 150 no. of blows was given per sample.
- Then these samples with moulds were kept separately and marked.

M. Marshall test on samples:

In this method, the resistance to plastic deformation of a compacted cylindrical specimen of bituminous mixture is measured when the specimen is loaded diametrically at a deformation rate of 50 mm/min. The Marshall stability of the mix is defined as the maximum load carried by the specimen at a standard test temperature of 60°C. The flow value is the deformation that the test specimen undergoes during loading up to the maximum load. In India, it is a very popular method of characterization of bituminous mixes due to its simplicity and low cost. In the present study the Marshall properties such as stability, flow value, unit weight and air voids were studied to obtain the optimum binder contents (OBC) and then compare mixes to check addition of which of the additive mentioned gives more stability.

N. Stability and flow test:

Stability value is defined as the maximum load at which the specimen fails under the application of the vertical load. Generally, the load was increased until it reaches the maximum & then when the load just began to reduce, the loading was stopped and the maximum load recorded by the proving ring was observed. Table 7 & chart 1 show the stability and flow value of polypropylene modified bituminous mix specimen.

Table 7: Marshall Stability of polypropylene modified bituminous mix specimen.

% Bitumen	%Polypropylene	Stability value (kN)	% increase in stability
5	0	5.2174	--
	1	8.5201	38.7636
	2	13.1485	60.3194
	3	19.4430	73.1656
	4	15.9219	67.2312

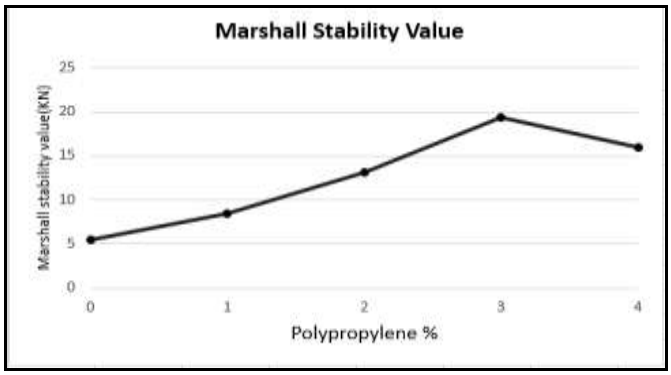

Chart 1: Marshall Stability Value Vs Polypropylene content

The flow value is defined as the deformation undergoes by the specimen at the maximum load where the failure occurs. Table 8 & chart 2 shows the Marshall Flow value when polypropylene fiber is added to the bituminous mix.

Table 8: Marshall Flow value of polypropylene modified bituminous mix

% Bitumen	% Polypropylene	Flow value(mm)	% decrease in flow value
5	0	6.7	---
	1	5.6	16.4179
	2	5	25.3731
	3	3	55.2239
	4	4.2	37.3134

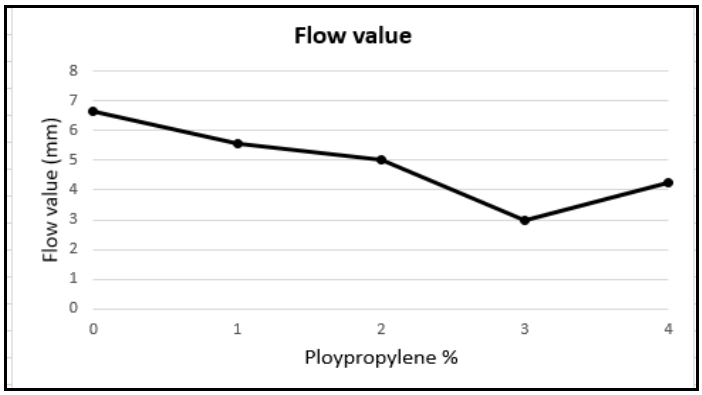

Chart 2: Marshall Flow Value Vs Polypropylene content.

It is observed that Marshall Stability value increases with polypropylene content up to 3% and there after it decreases. We observe that the Marshall Flow value decreases upon addition of polypropylene fiber content. Therefore the optimum percentage of polypropylene fiber is taken as 3%.

O. Density and Void analysis:

After completion of stability and flow test, a density and void analysis is done for each set of specimens. Air voids (VA), Voids in mineral aggregate (VMA), Voids filled with bitumen (VFB) are computed using the standard equation and tabulated in Table 9.

Table 9: Density and Air voids analysis for polypropylene fiber modified bituminous mix

%Bitumen	%polypropylene	VA	VMA	VFB
5	0	7.1112	18.1125	60.8421
	1	5.0895	14.9606	68.8380
	2	2.3914	12.2228	80.4146
	3	1.8398	9.0275	81.3125
	4	1.3049	5.9191	82.5143

The obtained value of Air voids analysis shows the voids present in the specimen when polypropylene is added to the bituminous concrete mix is plotted in chart with respect to the percentage of polypropylene fiber content. The chart 3, 4 & 5 shows the Air voids(VA), Voids in mineral aggregate (VMA), Voids filled with bitumen (VFB) Vs % of polypropylene content respectively.

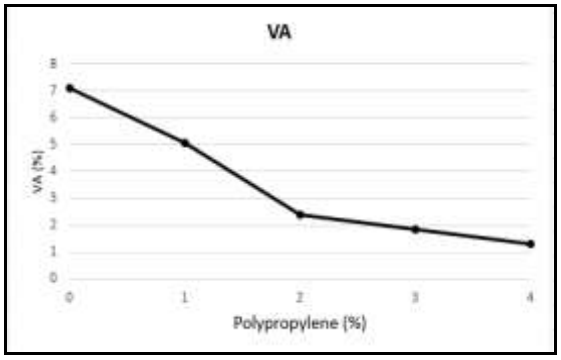

Chart 3: VA Vs Polypropylene fiber %

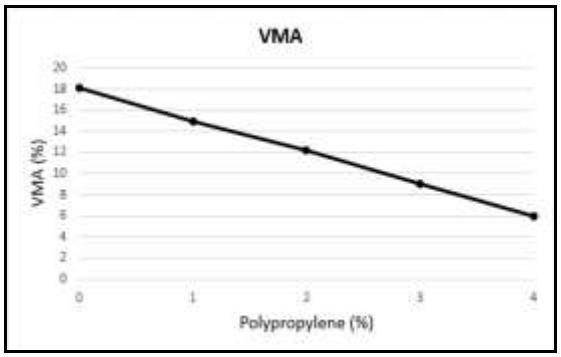

Chart 4: VMA Vs Polypropylene fiber %

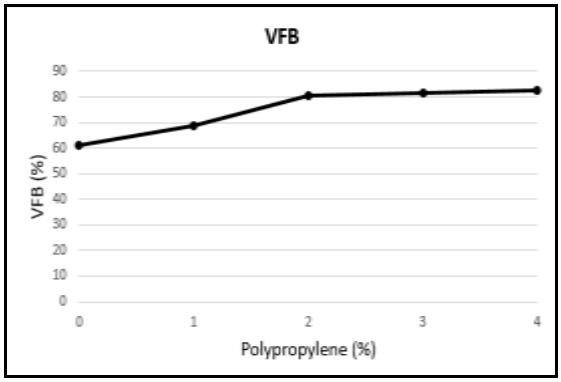

Chart 5: VFB Vs Polypropylene fiber %

From the above experimental work we obtain the optimum percentage of polypropylene content is 3%. Now, the crumb rubber of various percentages is added to the obtained optimum percentage of polypropylene

fiber and the above procedure is repeated again to obtain the optimum percentage of crumb rubber Table 10 & 11 shows the Marshall stability and flow value of crumb rubber and polypropylene fiber added specimens.

Table 10: Marshall Stability value for crumb rubber & polypropylene (PP) fiber added samples

%Bitumen	% of PP fiber	% of crumb rubber	Stability value (kN)	% decrease in stability value
5	3	1	19.6387	16.2725
		2	22.750	27.7231
		3	13.771	16.2501

The obtained Marshall Stability value is plotted in chart 6.

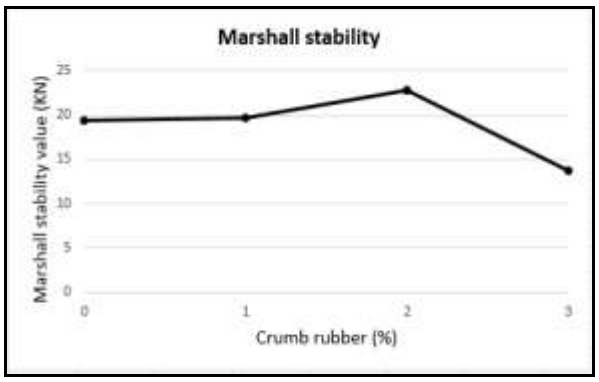

Chart 6: Marshall Stability value Vs crumb rubber content

Table 11: Marshall Flow value for crumb rubber & polypropylene (pp) fiber added specimen

%Bitumen	% of PP fiber	% of crumb rubber	Flow value(mm)	% Decrease in flow value
5	3	1	3.3	9.091
		2	2.6	13.333
		3	3.26	7.9754

The obtained Marshall Flow value is plotted in chart 7 and the optimum crumb rubber content is determined

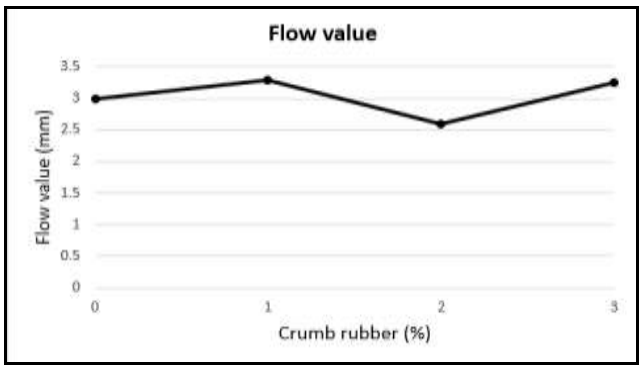

Chart 7: Flow value Vs crumb rubber content

The void analysis is made for these specimens also and the value of VA, VMA and VFB are calculated & tabulated in table 12, and plotted in Chart 8, 9 & 10 respectively.

Table 12: Density & void analysis of crumb rubber and polypropylene fiber added samples

%Bitumen	% of PP fiber	% of crumb rubber	VA	VMA	VFB
5	3	1	1.8092	7.7911	83.0123
		2	1.7973	6.3091	85.8064
		3	1.8422	1.8422	76.4856

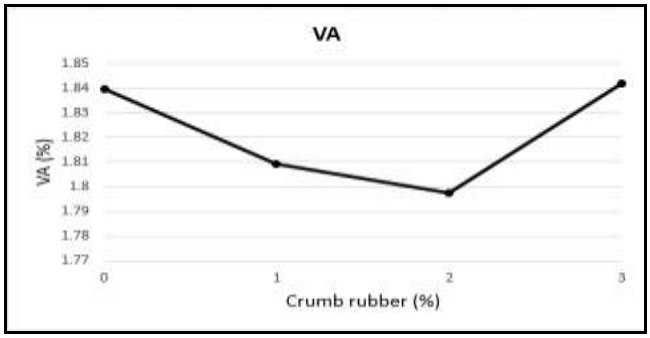

Chart 8: VA Vs crumb rubber content

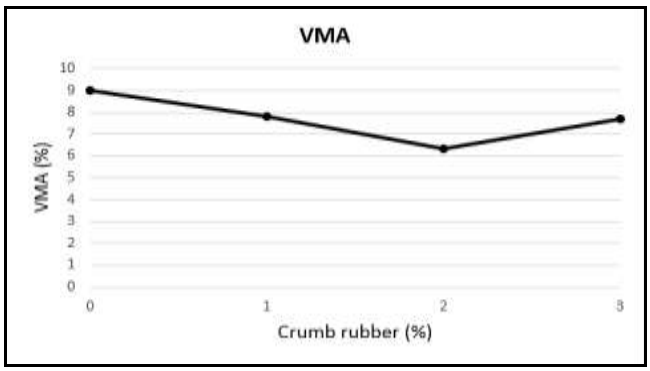

Chart 9: VMA Vs crumb rubber content

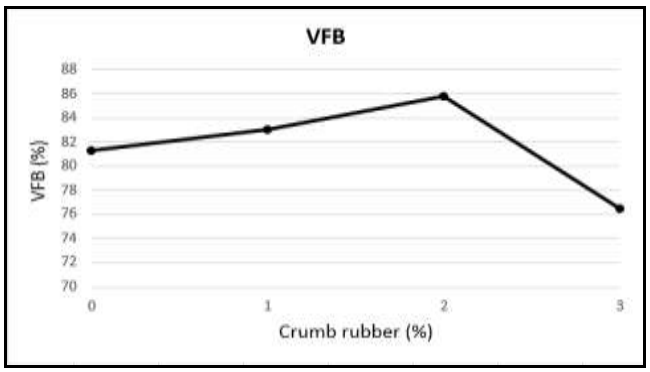

Chart 10: VFB Vs Crumb rubber content

From the above experimental work we obtain 2% of crumb rubber content as optimum value because for 2% of crumb rubber content the stability value is high with low flow value.

4.0 Discussions

From the chart (1 & 6), it is observed that with the addition of modifiers, stability value also increases up to certain limits and further addition decreases the stability. This may be due to excess amount of modifier which is not able to mix in bitumen properly. Thus at optimum bitumen content, varying contents of modifiers it was found in both cases maximum stability was obtained at 3% for polypropylene fiber content & 2% crumb rubber content for sample made with both polypropylene and crumb rubber. Thus the optimum modifier content was obtained as 3% & 2% for samples made with polypropylene fiber alone and crumb rubber with polypropylene fiber respectively. It is observed from Chart (2&7) addition of modifier flow value decreases than that of conventional mixes, again further addition of modifier after optimum percentage the flow value starts to increase.

5.0 Conclusion

The result indicated that the behavior of modified bitumen mix possesses improved various characteristic of pavement . Considering these factor we can obtain more stable and durable mix for the pavement by modification of Bituminous mix. By using the modifiers like polypropylene fiber & crumb rubber the frequency of void is reduced due to increased bonding. Hence, the roads can withstand heavy traffic, thereby making them more durable but when more crumb rubber is added to the polypropylene modified bituminous concrete mix the bonding becomes week therefore the voids increases. The modified bitumen pavement has better age resistance properties, delay of cracking and reflective cracking, resistance to deformation at high pavement temperature, better rutting resistance. So the modification of bituminous concrete mix with Fibers, Crumb rubber is the best way to improve pavement performance.

6.0 References:

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