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Experimental Investigation on Modified Bituminous Mix Using Wood-waste, HDPE and Crumb rubber

Bhanu Sri Routhu[1], M. Aravind Reddy[2]

[1]*Assistant Professor, Department of Civil Engineering, Aurora's Engineering College, Telangana, India*
[2]*Graduate Student, Department of Civil Engineering, Aurora's Engineering College, Telangana, India*

Abstract - *Construction of highways involves huge investment. Improper maintenance and the vast increase in traffic lead to road deterioration. The bitumen produced in India, is not reaching the requirements of the varied weather conditions. An accurate engineering design and right mix of ingredients for bituminous mix would result in an adequately durable, fatigue-resistant highway and may also save considerable investment as well as amplify the performance of the highway. In order to achieve this, an attempt was made to use various waste materials like Crumb Rubber, High Density Polyethylene (HDPE) and Waste Wooden Sticks. For any given aggregate gradation, the optimum bitumen content is estimated by satisfying a number of mix design parameters. Conventionally, cement and lime are used as fillers. In this investigation, an attempt has been made to evaluate the non-conventional and cheaper filler like stone dust and wood dust. These waste materials are reusable. It has been observed that, the bituminous mixes with these different proportional combinations result in satisfactory Marshall Properties, thus supporting the need for its use. The waste materials used in this investigation are likely to partly solve the solid waste disposal of the environment and a part of Sustainable Construction.*

Keywords: Bitumen, Crumb rubber, High density Polyethylene (HDPE), Wooden Sticks, Bituminous Mix, Marshall Properties, Sustainable Construction.

1. INTRODUCTION

The main objective of the mix design is to determine the right blend of aggregates, fillers and bitumen which gives adequate strength and is economical. This mix should satisfy strength requirements for the present traffic and should be durable. Indian highways are usually flexible pavements. Due to improper maintenance and shortage of funds, deterioration of roads are taking place. But, in general flexible pavements has lesser flexure strength when compared to rigid pavements. An attempt was made in order to overcome such strength characteristics in this Investigation.

Addition of Polyethylene increases stiffness and improves temperature capability of bitumen. As the stiffness increases, resistance increases. Crumb rubber is a recycled form of rubber obtained from automobile tire scraps. The ones with good durability are considered for the investigation. Voids in total compaction mix is also an important factor in bituminous mix as it allows additional compaction and traffic load without flushing, bleeding and loss of stability yet good enough to keep out moisture and harmful air. Here, small wooden strips are also used as part of the investigation. This study aimed at preparation of modified graded bitumen mix to find out variation of conventional properties, mechanical properties and optimum percentage of modified bituminous mix using a combination of these materials.

2. LITERATURE REVIEW

The properties of various such materials has a noticeable effect on the durability of bituminous mix, it was also confirmed by **Craus et al.** (1981) study on mixes consisting of one type of aggregate, one gradation and six types of fillers. Lime and stone dust/quarry dust are predominantly used as fillers in the mix. Their influence and fatigue performance was studied by **Chari and Jacob** (1984) and they have found lime to have some effect on fatigue properties. **Wahhab and Baig** (1998) compared rock wool natural fibres i.e., Hematite, as a filler material and compared it with conventional crushed stone filler. **Mohammad T** (2007) made a detailed investigation on the optimum amount of HDPE and found it to be 6-18% by weight of the optimum asphalt percent (5.4%) and also showed using HDPE in the bituminous mix reduces pavement deformation and increases resistance. **Sharma et al.**(2010) showed that use of fly-ash in bituminous mix would increase its strength as it contains high calcium oxide. **Rokade** (2012) showed that there was an increase in Marshall Stability value and bulk density when crumb rubber was used with 8-10% of the weight of bitumen.

3. EXPERIMENTAL INVESTIGATION

3.1 Material Characteristics

Aggregates

The Coarse aggregate uses was a normal weight aggregate of size 10mm to 2.36mm. Stone dust and wood dust from the wooden strips are used as fillers.

Table -1: Characteristics of Aggregate

S. No	Test	MORTH Specifications	Test Values		Standard
1.	Impact Value (%)	<30	27.46		IS 2386 Part IV
2.	Crushing Value (%)	<30	25.52		IS 2386 Part IV
3.	Specific Gravity Test	2.5-3	10mm Aggregate	2.71	IS 2386 Part III
			2.36mm Aggregate	2.68	
			Stone Dust	2.62	
4.	Water Absorption	<2	1.21		IS 2386 Part III

Bitumen

Bitumen of grade 60/70 is used as the binder and its properties are determined by standard test procedures as show below.

Table- 2: Characteristics of Bitumen

S.No.	Test	Permissible Values	Test Values	Standard
1.	Penetration value 25^{0}c	50-70	66	IS 1203-1978
2.	Softening point, ^{0}c	>50	59	IS 1205-1978
3.	Ductility value at 27^{0}c, cm	>75	92	IS 1208-1978
4.	Specific gravity	>0.99	0.98	IS 1202-1978

Crumb Rubber

Crumb rubber from locally available used tyres is considered which passed through a 2.36mm sieve, to reduce the voids and increase the durability of the pavement. The specific gravity of the crumb rubber obtained by the test is 0.38.

High Density Polyethylene

HDPE is used in the investigation work as plastic improves the ductile nature in bitumen which helps in increasing the stability. In this modified bituminous mix, 0.5% of HDPE to the aggregates is added in replacement with bitumen for better performance of the pavement.

Wooden Strips/Waste wood

Untreated small wooden sticks/strips of 20mm each are used in this investigation.

3.2 Proportioning of Aggregates

Semi Dense Bituminous Concrete

The properties of this modified bituminous mix are considered as a grade 1 semi dense bituminous concrete mix as per MORTH specifications.

Table- 3: Requirements for Coarse Aggregate in SDBC Grade 1

Property	Test	Value (%)
Cleanliness	Grain size Analysis	5 Max. Passing 0.075mm sieve
Strength	Aggregate Impact Value	Max. 27
Water absorption	Water absorption	Max. 2
Stripping	Static Immersion Test	95 min. Retained coating

Table- 4: MORTH Specific Gradation for Aggregates in SDBC

IS Sieve in mm	Required %Passing	Upper Limit	Lower Limit	Average Value
13.2	90-100	100	90	95
9.5	70-90	90	70	80
4.75	35-51	51	35	43
2.36	24-39	39	24	31.5
1.18	15-30	30	15	22.5
0.3	9-19	19	9	14
0.075	3-8	8	3	5.5

The above table describes the properties of aggregates used in grade 1 semi dense bituminous concrete mix as per MORTH specification.

Grade 1 Semi Dense Bituminous Concrete Mix Proportions

The following are the SDBC mix as per MORTH specifications.

Considering, 13.2 mm Aggregate: 60%

4.75 mm Aggregate: 20%

Stone Dust: 20%

Table- 5: Gradation of the Mix Proportion

IS Sieve in mm	10 mm	2.36 mm	Dust	Proportioned Value	Required Value	Acceptable Range
13.2	100	100	100	100	95	90-100
9.5	72.5	100	100	90.83	80	70-90
4.75	1.5	80	100	60.5	43	35-51
2.36	0.5	16	100	36.8	31.5	24-39
1.18	1.5	1.8	75.3	26.2	22.5	15-30
0.3	0.5	1.4	48.8	16.9	14	9-19
0.075	0.5	0.8	15.9	5.73	5.5	3-8
Proportion(%)	60	20	20			

3.3 Preparation of Bituminous Mix

In the present investigation bituminous concrete gradation was used following MORTH specifications. Three specimens of Marshall Moulds and one un-compacted mix are prepared for each proportions of crumb rubber. Aggregates are oven dried and sieved according to the gradation and separated.

Bitumen is heated to a temperature of 121^{0}C to 125^{0}C with the first trial of nominal mix of 5% bitumen by weight of the aggregates to the heated aggregates and mixed at temperature around 150^{0}C to 160^{0}C. This mix is placed in mould and compacted by rammer with 75 blows on each side. All mixed aggregates are weighed for the preparation of the specimen and compacted thoroughly to obtain the required thickness. The experiment is repeated by varying the proportions of crumb rubber, HDPE and wooden strips.

Initially, bitumen is partially replaced by various proportions of crumb rubber i.e. 0.5%, 1% & 1.5%. Highest was obtained for 1.5% of crumb rubber replaced mix. So, 0.5% HDPE was replaced for that mix and further replacement was not possible as bitumen content was decreasing. Hence the replacement was stopped and 0.5% wooden strips were added.

4. EXPERIMENTAL RESULTS

The Marshall Stability test is used for the bituminous mix design as per MORTH recommendation

Principle of Marshall Method

It is similar to unconfined compression test where the load is applied to the specimen gradually. It provides the performance measure for the mix design. This method measures the maximum support load by the test specimen at a loading rate of 50.88mm/min in terms of stability.

In this method we also determine the density, void percentages filled with bitumen and aggregates for various modified bituminous mixes.

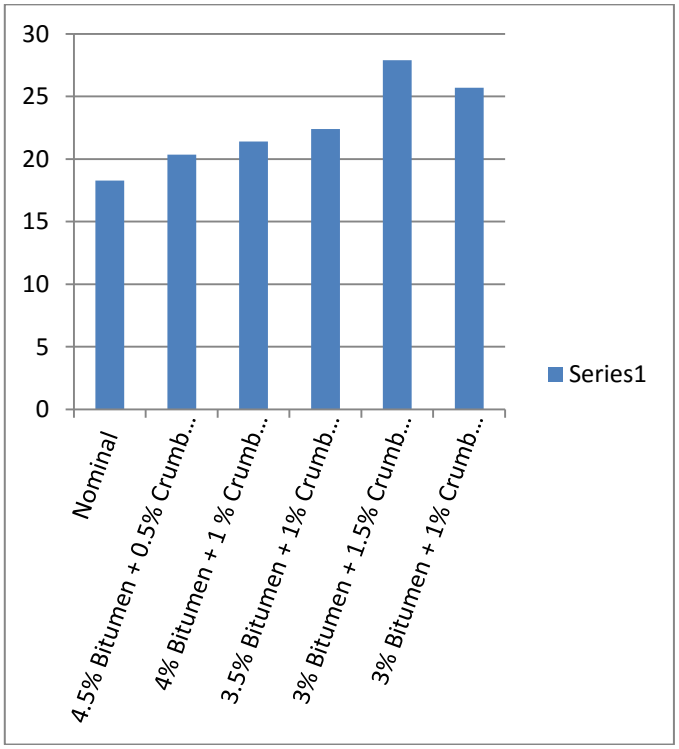

Chart -1: Stability of Various Bituminous Mixes

Table- 6: Marshall Stability Test Results

S.No	Proportions	Moulds	Stability	Average Stability
1	Nominal	1	18.5	18.27
		2	18.4	
		3	17.9	
2	4.5% Bitumen + 0.5% Crumb Rubber	1	21.8	20.36
		2	20.1	
		3	19.2	
3	4% Bitumen + 1% Crumb Rubber	1	21.9	21.4
		2	21.6	
		3	20.7	
4	3.5% Bitumen + 1% Crumb Rubber + 0.5% HDPE	1	21.6	22.4
		2	22.4	
		3	23.2	
5	3% Bitumen + 1.5% Crumb Rubber + 0.5% HDPE	1	26.7	27.9
		2	30.8	
		3	26.4	
6	3% Bitumen + 1% Crumb Rubber + 0.5% HDPE + 0.5% Wooden Strips	1	26.5	25.7
		2	24.9	
		3	25.7	

From the above table and figure it is observed that the fifth and sixth proportions i.e., 3% bitumen + 1.5%crumb rubber + 0.5% HDPE and 3% Bitumen + 1% Crumb Rubber + 0.5% HDPE + 0.5% Wooden Strips has showed an increase in the stability than the conventional mix, which indicates better resistance of pavements.

The results of this study also indicate that waste wood and wooden strips has a positive influence on the stability and the voids are better filled with this (i.e., 6th proportion) modified bituminous mix.

Table- 7: Marshall Stability Test Results

S.No	Proportions	Air Voids (%) V_A	Voids In Aggregate (%) V_{AGG}	Voids Filled with Bitumen (%) V_B
1	Nominal	6.40	18.14	63.8
2	4.5% Bitumen + 0.5% Crumb Rubber	4.63	16.6	71.8
3	4% Bitumen + 1% Crumb Rubber	3.68	15.2	75.6
4	3.5% Bitumen + 1% Crumb Rubber + 0.5% HDPE	4.8	16.2	73.7
5	3% Bitumen + 1.5% Crumb Rubber + 0.5% HDPE	3.6	16.3	76.8
6	3% Bitumen + 1% Crumb Rubber + 0.5% HDPE + 0.5% Wooden Strips	3.14	17.1	78.45

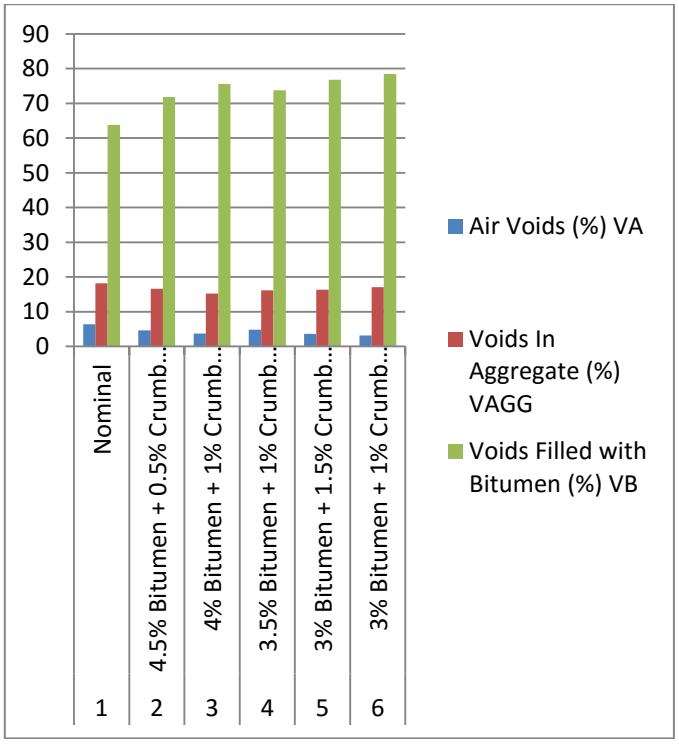

Chart -2: Void Percentages VS Various Bituminous Mix Proportions

4. CONCLUSIONS

- Addition of HDPE, Crumb rubber and Wood waste to the bituminous mix increased the stability and performance when compared to the nominal bituminous mix.
- From the investigation it can be concluded that penetration values and softening points of bitumen can be improved significantly by the addition of crumb rubber which is a major environmental pollutant.
- Waste dust and small sticks generated from carpentry and any wooden related works, can be effectively used in the bituminous mix as a filler and partial substitute without reducing its strength characteristics.
- Keeping in view the extinction of natural resources and environmental pollution, an attempt has been made as part of sustainable development which is economical and durable.
- Further tests have to be carried out in order to understand the characteristics of fillers, reusable materials and their influence on fatigue and rutting.
- The cost effectiveness of these unconventional materials can be realized after performing a cost analysis.

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