EFFECT OF USING FILLERS ON LABORATORY PERFORMANCE STUDIES ON BITUMINOUS CONCRETE MIX PREPARED USING BITUMEN AND MODIFIED BITUMEN

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***Abstract:** A bituminous mix has complex temperature sensitivity behaviour. Its response to a given loading is strongly dependent on temperature and loading. At high temperatures, binders have a purely ductile behaviour, whereas at very low temperature their behaviour is purely breakable. In the present study, an attempt is made to design the bituminous concrete mixes by Marshall method using both Viscosity grade Bitumen (VG 30) and polymer modified bitumen (PMB 40) with two different fillers i.e., stone dust and Tiles powder and also laboratory performance studies like Indirect tensile strength, moisture susceptibility. From the present study, it is concluded that polymer modified bituminous concrete (PMBC) mix with stone dust and tiles powder as fillers showed higher Marshall Stability when compared to bituminous concrete (VG-30) mix. It is observed that the polymer modified bituminous concrete (PMBC) mixes showed higher indirect tensile strength compared to bituminous concrete mixes.*

Keywords: VG-30(Viscosity Grade-30), PMB-40(Polymer modified bitumen), VMA (Volume in mineral aggregates), VFB (Volume filled with bitumen), ITS (Indirect tensile strength), TSR (Tensile strength ratio)

1. INTRODUCTION

Bitumen has been widely used in India for the construction of flexible pavements for more than a century. Flexible pavements with bituminous surfacing are widely used in India. Exponential increase in traffic, overloading of commercial vehicles and significant variations in daily and seasonal temperatures have shown some limitations in bitumen binder performance and this has led to early developments of distress symptoms like cracking, rutting, ravelling, undulations, shoving and potholing of bituminous surfacing. The transportation industry is the largest industry in the world. It includes the manufacture and distribution of vehicles, the production and distribution of fuel, and the provision of transportation services. Rapid industrialization and large scale infrastructural development in India, has resulted in huge scarcity of construction materials and tremendous increase in the environmental pollution. Disposal issue of the waste product is a challenge .Indian ceramic production is 100 Million ton per year. In the ceramic industry, about 15%-30% waste material generated from the total production.Generally stone dust, cement are used as a filler in bituminous mix, but the cost of cement is much high, hence here project cost is increase. Concerned about this, the scientists are looking for alternative filler for bituminous mix that may reduce the pollution and disposal problem. In the current study, the feasibility of improving the properties of Bituminous Concrete (BC) mix with Tiles powder as filler in place of conventional costly fillers like lime and cement was studied. In the present study Paving Bitumen (VG-30) and Modified bitumen (PMB-40) is used for the preparation of Bituminous concrete mix.Tiles powder and stone dust are used as mineral fillers for preparation of Bituminous concrete mix.

1.1 Characteristics of Filler

Filler imparts a considerable importance on the properties of bituminous mixtures .The amount of filler influence the optimum bitumen content the addition of mineral filler increases the resilient modulus of a bituminous mixtures. Different types and quantity of filler have different effect on the performance of bituminous mixture. Filler provides better resistance to micro cracking increasing the fatigue lie of bituminous mixture. The workability during the operation of mixing and compaction of bituminous mixture Filler play important role.

2. Objective of the present study

1. To conduct tests on aggregate and assess the physical properties of aggregate as per MoRT&H (V revision) requirements.
2. To conduct tests on paving bitumen (VG-30) and assess the physical properties of bitumen as per IS 73 2013 requirements.
3. To conduct tests on modified bitumen and assess the physical properties of polymer Modified bitumen (PMB-40) as per IRC SP: 53-2010 requirements.
4. To design bituminous concrete mix prepared using VG-30 and PMB 40 as binders with grade II aggregate gradation by Marshall Mix design method using stone dust and tiles powder as fillers.

5. To compare the Marshall Properties bituminous concrete mix prepared using bitumen (VG-30) and PMB-40 as binder using stone dust and tiles powder as filler.
6. To determine the Indirect tensile strength (ITS) and Moisture susceptibility of bituminous concrete mix prepared using VG-30 and PMB 40 as binder using stone dust and tiles powder as filler at 25°C temperature.

3. LITERATURE REVIEW

Afifa Rahman et al (2012) studied the effects of different types of fillers (e.g. non-conventional and conventional) on the Marshall properties of bituminous paving mix. For this purpose, non-conventional filler such as brick dust and conventional fillers such as cement and stone dust were used. The Marshall properties obtained for both types of fillers reveal that, brick dust filler specimens have been found to exhibit higher stability value compared to cement and stone dust filler specimens. In addition, mixers containing brick dust filler showed maximum stability at 6.2% bitumen content and the percentage of air voids were found to be decreased with the increase of bitumen content. This study concludes that brick dust can be successfully utilized in the production of Polymer modified bituminous concrete mix for the highway construction. It is expected to provide an economical, environment friendly and long lasting solution for construction of asphalt pavement.

Chethan M K et al (2015) made an attempt to utilize copper slag, stone dust and fly ash in Polymer modified bituminous concrete. Copper slag as fine aggregate in varying percentage with stone dust and fly ash as filler. Marshall Test has been considered for the purpose of mix design as well as evaluation of paving mix. Marshall Stability is higher for stone dust as filler when compared to fly ash. Marshall Stability is higher for 20% of copper slag replacement when compared to 10% and 30% replacement. Bulk density has increased with addition of copper slag. Volume of void is less when fly ash is used as filler. VMA and VFB have increased with increase in bitumen content.

Hassan Y. Ahmed et al (2006) studied the effect of using waste cement dust as mineral filler on the mechanical properties of hot mix asphalt. The optimum cement dust was determined and effect of cement dust on indirect tensile strength (ITS) was determined. Five asphalt concrete mixtures with various cement dust contents, namely; 0%, 25%, 50%, 75% and 100% by weight of the limestone mineral filler was studied. Laboratory testing indicated that the indirect tensile strength increased as the ratio of cement dust increased. Optimum cement dust content found to be 100%.

Debashish Kar et al (2015) carried out studies to explore the use of fly ash, a by-product of a coal based thermal power plant in bituminous paving mix. For comparison, control mix with cement and stone dust have also been considered. Indirect tensile test has been carried out to know the tensile strength of mix. It was observed that the mix with fly ash as filler exhibit marginally inferior properties compared to control mix and satisfy desired criteria specified by a much higher margin. It was observed that at a particular temperature, the indirect tensile strength of BC mix with cement as filler has the highest value followed by stone dust and fly-ash. As temperature increases, ITS value in general decreases. However, the temperature susceptibility improves for mix with fly ash, which was an added advantage.

4. MATERIALS USED

4.1 Coarse aggregate

Aggregates form the major portion of pavement structure and they form the prime materials used in pavement construction. One of the most important aspects of an aggregate affecting the stability and working properties of a mix is the gradation. Aggregates smaller than 25 mm in size and larger than 2.36 mm in size are regarded as coarse aggregates. And aggregates smaller than 2.36 mm in size and larger than 75 µ in size are taken as fine aggregates.
Aggregates are collected from M/s Rite Way M-Sand stone crusher Ramanagar, Karnataka
The results are as shown table 1.

Table –1: Properties of Aggregate

Aggregate Test	Test result	Requirements as per Table 500-18 of MORT&H (V revision) Specifications
Aggregate impact value (%)	23.86	Max 24%
Los Angeles abrasion value (%)	20.10	Max 30%
Combined Index (%)	23.31	Max 30%
Water absorption (%)	0.25	Max 2%
Aggregate specific Gravity		
• Coarse aggregates	2.67	----
• Fine aggregates	2.60	----

4.2 Binder

Bitumen acts as a binding agent to the aggregates, fines and stabilizers in bituminous mixtures. Binder provides durability to the mix in this study, VG-30 and PMB 40 grades are used as binders. And the test results are shown in the table 2 and table 3

Table -2: VG-30 Binder test results

Tests on Bitumen	Test Results VG 30	Requirements as per IS 73-2013
Penetration at 25°C	69	Min 45
Softening point (Ring & Ball), °C	59	Min 47
Flash point, °C	225	Min 220
Ductility @27 °C, cm	95.75	Min 40
Specific gravity	1.02	Min 0.99

Table -3: PMB-40 Binder test results

Particulars	Test Results	Requirements as per Table-2 of IRC SP-53-2010
Penetration at 25°C, 100gm, 5 Seconds, 0.1mm	46.5	30-50
Softening point (Ring & Ball), °C	57	Min 60
Flash point, °C	270	Min 220
Specific gravity	1.03	Min 0.99
Elastic recovery @ 150C, %	62	Min 60

4.3 Filler

Filler fills the voids between aggregate grains and improves the wearing capabilities of mix. It is stored and fed dry into the mix, during or after addition of binder. Fine aggregate below 75micron can be used as filler.

Stone dust: The specific gravity of stone dust is 2.72

Tiles powder: Broken tiles are collected from highway engineering laboratory, UVCE. They were crushed manually whose size varies from 300 microns to 75 microns passing. In the study material passing 75 microns is considered as filler. Specific gravity of tiles is 2.65 and gradation value are shown in table 4

Table -4: Mineral filler gradation

IS Sieve (mm)	Cumulative %passing by weight of total	Stone dust	Tiles powder
0.6	100	100	100
0.3	95-100	100	100
0.075	85-100	97.48	99.5

4.4 Gradation

The aggregate gradation (grading-2) was adopted for both bituminous concrete and polymer modified bituminous concrete mix as per MORT&H (V Revision) specifications. The gradation values are presented in Table 5

Table -5: Aggregate gradation

Sieve Size in mm	Specified gradation, % Passing	Gradation obtained, % passing (Mid-limit)
19	100	100
13.2	90-100	95
9.5	70-88	79
4.75	53-71	62
2.36	42-58	50
1.18	34-48	41
0.6	26-38	32
0.3	18-28	23
0.15	12-20	16
0.075	4-10	7

5. Marshall Method of Mix Design

The proportion of aggregates done as per gradation table.

Aggregates were heated to temperature of 170°C Required amount of Bitumen heated to temperature of 140-150°C.The heated Bitumen was added to the aggregate mix and thoroughly mixed to have a uniform bituminous mix at a desirable temperature 135°-140°C.The mould of 101.6mm diameter and 63.5mm height was heated and bituminous mix was placed providing with base plate and collar. After leveling the top surface the mix was compacted by means of rammer weight of 4.54 kg and with a height of fall 457 mm with 75 blows on either side at a temperature of 130°C.Three specimens were prepared using each trial bitumen content .The compacted specimens were cooled to room temperature and removed from mould after 24 hours The diameter, mean height, weight in air and weight in water were determined.

FIGURE: 1 preparation of sample

5.1 Determination of Optimum Binder Content

In order to determine the optimum binder content for this type of mixture four different percentages of bitumen content are used (4.5, 5.0, 5.5, 6.0) % respectively by weight of aggregate. The optimum binder content is determined by the ability of a mix to satisfy the Mechanical properties and volumetric properties. The data obtained from Marshall stability-flow test are used to plot the Marshall properties versus bitumen content, from these plots optimum bitumen contents are determined corresponding to maximum stability, maximum bulk density and 4% air voids in total mix. The optimum bitumen content of the mix is the numerical average of the three values for bitumen contents determined as above. Marshall Properties are shown in table 6 and table 7 and the relationship between Marshall Properties and bitumen content are shown in Figure 1 and 2.

Table -6: Marshall Properties of Bituminous concrete mix (VG-30) at Optimum binder content using Stone Dust and Tiles powder as fillers

SL No	Marshall properties	Test result		Requirements as per Table 500-11 of MORT&H (V revision) Specifications
		Stone dust	Tiles powder	
1	Optimum Bitumen Content (%)	5.42	5.44	Min 5.4
2	Marshall Stability, kN	12.07	12.01	Min 9.0
3	Flow, mm	3.2	3.4	2.0 - 4.0
4	Air voids, (V_v) %	3.74	3.23	3.0 - 5.0
5	VMA, %	16.27	15.82	Min 14
6	VFB, %	74.18	74.60	65-75

Table -6: Marshall Properties of Polymer Modified Bituminous concrete mix (PMBC- 40) at Optimum binder content using Stone Dust and Tiles powder as fillers

SL No	Marshall properties	Test result		Requirements as per Table 500-11 of MORT&H (V revision) Specifications
		Stone dust	Tiles powder	
1	Optimum Bitumen Content	5.43	5.52	Min 5.4
2	Marshall Stability, kN	14.80	14.31	Min 12.0
3	Flow, mm	3.06	2.76	2.0 - 4.0
4	Air voids, (V_v) %	4.28	3.23	3.0 - 5.0
5	VMA, %	16.88	15.86	Min 14
6	VFB, %	74.63	75.58	65-75

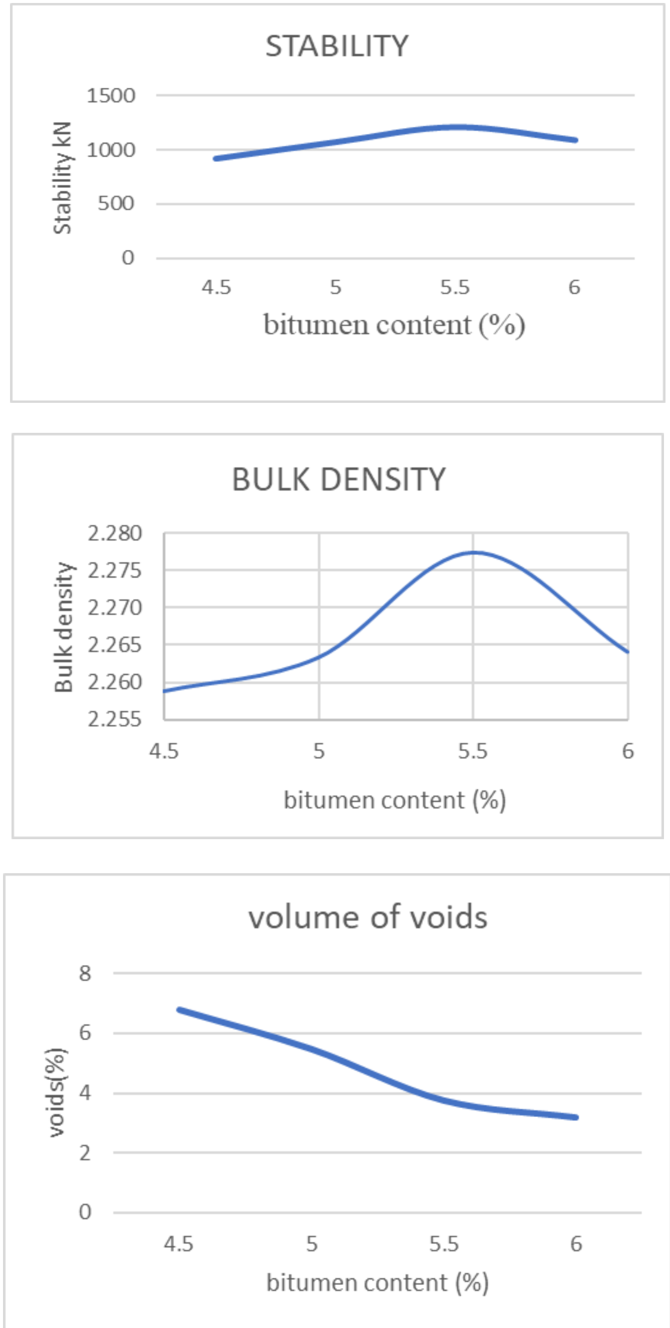

FIGURE: 2 Relationship of Marshall Properties v/s bitumen content of BC mix with Tiles powder as filler

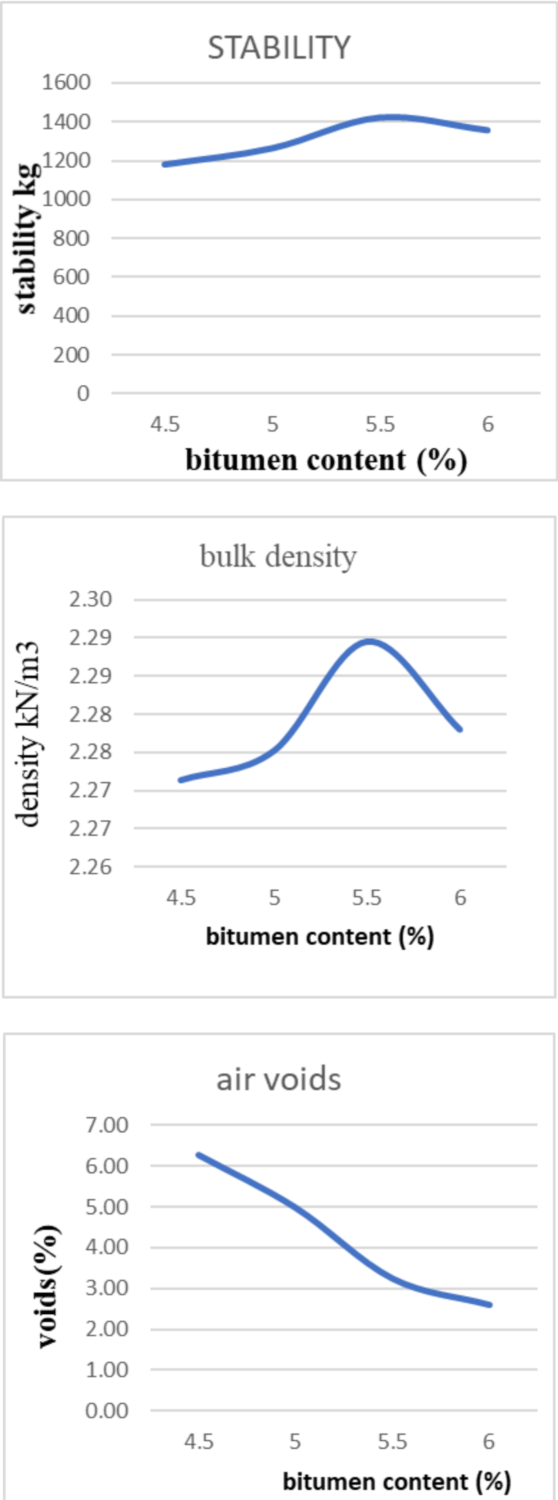

FIGURE: 3 Relationship of Marshall Properties v/s bitumen content of PMBC mix with Tiles powder as filler.

5.2. Indirect Tensile Strength and Moisture Susceptibility Test Laboratory performance evaluation of BC and PMBC mix using two fillers was carried out by conducting Indirect Tensile Strength (ITS) and Tensile Strength Ratio tests at 25°C temperature. The test specimens are prepared at optimum binder content using Marshall Method of mix design for bituminous concrete mix (Grade II) as per MORT&H specifications. The height of the specimens, the weight of the specimens in both air and water are noted down and Specimens are tested at 25 °C to determine their indirect tensile strength. This was achieved by using breaking head under a load applied at a rate of 50 mm/min. The load at failure is recorded and indirect tensile strength was computed using the relation is given in equation below.

$$s_x = (2xP) / (\pi xDxT)$$

Where, s_x = Horizontal tensile strength or tensile stress, N/mm^2

P = Failure Load, N
D= Diameter of the specimen, mm
T = Height of the specimen, mm

5.2.1 Moisture Susceptibility Test

Samples were divided into two sets. The first set of specimens was then tested in a dry condition (unconditioned state), while the second set was then tested in a soaking condition (conditioned).For the dry test, set the specimens were brought to a test temperature of 25±1°C, by storing them in a water bath maintained at the test temperature for not less than 2 hour and then tested to obtain their indirect tensile strength. This was achieved by using breaking head under a load applied at a rate of 51 mm per minute. The load at failure was recorded and the indirect tensile strength was computed. The average value for the indirect tensile strength for the dry set was calculated. For the second set of specimens were placed in water bath maintained at 600 C for24 hours. The specimens were transferred to the second water bath maintained at250 C stored for 2 hours. The indirect tensile strength was then run, as described for the dry set and indirect tensile strength for the saturated conditioned samples was computed.

TSR = ITS of Conditioned Sample/ Unconditioned Sample

Where TSR: Indirect Tensile Strength Ratio

The test results of ITS and TSR for the bituminous concrete mix (VG-30) and (PMB-40) specimens prepared using Stone dust, Tiles powder as mineral filler is presented in Table,7 and 8.

6. CONCLUSIONS

- The optimum bitumen content for Polymer Modified Bituminous concrete mix (PMBC) with stone dust and Tiles powder as filler is higher when compared to Bituminous concrete mix (VG-30) with Stone dust and Tiles powder as fillers.
- The Marshall properties of Polymer Modified Bituminous concrete mix (PMBC) is superior to bituminous concrete mix (VG-30) with Stone dust and Tiles powder as filler.
- The ITS values of Polymer Modified Bituminous concrete mix (PMBC) is higher than that of Bituminous concrete mix (VG-30)with Stone dust and Tiles powder as fillers, thus from ITS results it can be stated that Polymer Modified Bituminous concrete mix (PMBC) performs better than Bituminous concrete mix (VG-30).
- Polymer Modified Bituminous concrete mix (PMBC) is less temperature susceptible than Bituminous concrete mix (VG-30) with Stone dust and Tiles powder as fillers.

Table 9: Results of ITS test at 250 C test Temperature

Test Temperature, ^{0}C	Tensile Strength Ratio(TSR), %		As per IRC Specifications, %
25	Stone dust	Tiles powder	
	93.50	93.42	Min 80

Table 8: Results of TSR at 250 C test temperature

Test Temperature, 0C	**Tensile Strength Ratio(TSR), %**		**As per IRC Specifications, %**
	Stone dust	**Tiles powder**	
25	82.07	81.42	Min 80

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