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LABORATORY STUDIES ON BITUMINOUS CONCRETE MIX WITH DIFFERENT MINERAL FILLERS

Prithviraj SV*1, Dr. G. Suresh*2

*1M.Tech (Highway Engineering), UVCE, Karnataka, India.

*2Professor, Civil Engineering Department, UVCE, Karnataka, India.

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ABSTRACT

Flexible pavements with bituminous surfacing are the most common Pavement Structure in India due to its fast and relatively simple construction. Stone aggregates are the most extensively used natural resource in Infrastructure development. The Present Flexible pavement design guidelines in India largely rely on use of stone aggregate for various courses. In view of the extensive and enormous road construction activities taking place in the country, which consume substantial natural resources and also availability of aggregates in high use urban areas is very less because of restrictions on mining, hence there is a strong need to incorporate alternate or waste materials in the construction. In the present study, an attempt is made to utilise Industrial wastes such as Phosphogypsum and GGBS as mineral filler by replacing conventionally used Stone dust in the Bituminous Concrete mix prepared using VG-30 and PMB-40 as Binders by adopting Marshall method of Bituminous mix design. Indirect Tensile Strength Test and Moisture Susceptibility Test are conducted on bituminous concrete mixes and it is observed that Bituminous Concrete mix with PMB-40 as binder and GGBS as mineral filler is superior in terms of Marshall Properties, ITS and TSR when compared to other Bituminous Concrete mixes.

Keywords: Viscosity Grade Bitumen (VG-30), Polyer Modified Bitumen (PMB-40), Marshall Properties, Indirect Tensile Strength (ITS) And Tensile Strength Ratio (TSR).

I. INTRODUCTION

A Bituminous concrete as well as Dense Bituminous Macadam are commonly used asphalt courses. Mix design for Bituminous Concrete are based on guidelines given by MORT&H (V^{th} revision). Normally Marshall Mix design method is adopted for mix design of Bituminous Concrete (BC) in India. Mix design objectives are to provide sufficient workability to permit easy placement without segregation, sufficient flexibility to avoid premature cracking due to repeated bending by traffic, sufficient air voids in the compacted mixes to allow for additional compaction by traffic, sufficient strength to resist shear deformation under traffic at higher temperature, sufficient bitumen to ensure a durable pavement and sufficient flexibility at low temperature to prevent shrinkage cracks. Bituminous concrete is mainly used as wearing course for roads having much higher number of heavy commercial vehicles. Bituminous concrete mix consists of a mixture of aggregates continuously graded from maximum size, typically less than 25 mm, through the fine filler that is smaller than 0.075mm. Sufficient bitumen is added to the mix so that the compacted mix is effectively impervious and will have acceptable elastic properties. The bituminous mix design aims to determine the proportion of bitumen, filler, fine aggregates, and coarse aggregates to produce a mix which is workable, strong, durable and economical.

II. LITERATURE REVIEW

Satish Chandra and Rajan Choudhary (2013) 1 summaries that The large quantities of Granite and marble dust from the stone industry and fly ash from thermal power plants are waste products that are produced in India and physical properties of these materials meet the requirements laid for fillers in Indian specifications. The Study was made to use these three industrial wastes, along with hydrated lime and conventional stone dust from quartzite, as filler in bituminous mix. Bituminous concrete (BC) mixes were designed according to the Marshall method at four different percentages (4.0%, 5.5%, 7% and 8.5%) of the five types of fillers. The performance studies on bituminous concrete mixes such as moisture susceptibility, static creep, flexural fatigue, and wheel-tracking tests were conducted. From the results of moisture susceptibility tests suggest that three industrial wastes (fly ash, marble dust, and granite dust) selected in the study can be optimally used up to

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7.0% as filler in a bituminous mix. Static creep tests and wheel-tracking tests conducted on various mixes indicate better performance of a mix when these wastes are used as filler in bituminous mixes. Mixes with fly ash, granite dust, and marble dust have almost 40% more life in rutting when compared with conventional stone dust filler. The fatigue life of a mix with marble dust is 50–70% higher than that of a mix with conventional stone dust. Among the three industrial wastes, marble dust is the most promising filler and will prove to be very economical also, as mixes with marble dust have the lowest optimum binder content (OBC).

Savitha T Sudhakaran et al (2012) 2 in their study, Experimental investigation were carried out to develop a mix design for Bituminous mix with added hydrated lime and phosphogypsum then to evaluate structural characteristics of the bituminous mixes such as Marshall stability value, Creep characteristics and Indirect tensile stiffness modulus value, a simplified mix design procedure was used for producing the bituminous mixes. OBC obtained for three mixes is 5.4% and Optimum Lime and Phosphogypsum contents was found 3%. The Marshall stability value and stiffness modulus value of sample with phosphogypsum is more than control mix with stone dust but less than sample with lime. The use of phosphogypsum in pavement construction reduces enivronmental problems related with the large stockpiles of phosphogysum and their negative impact on surrounding land,water and air.

Suvarna. P et al (2018) 3 in their investigation, The objective of the study was to investigate and evaluate effects of mineral fillers on fatigue properties of hot mix asphalt (HMA) mixtures. Several tests such as: Marshal Stability, Indirect tensile strength and fatigue test were conducted. The fatigue life of mixtures has been evaluated based on the initial stiffness modulus at 20%, 30% and 40% stress levels. Using of waste from special industries is current scenario, that's why industrial wastes like fly ash, pond ash, GGBS, copper slag, marble dust etc. are being used in bituminous mixes. In the study, an attempt was made to use stone dust, ceramic dust and brick dust as filler in bituminous concrete mix. BC mix with ceramic dust has higher Marshall Stability value of 1310 kg, which is higher than BC mix with Stone dust and brick dust with stability 1220 and 1297 kg respectively. Tensile stresses get induced at the bottom of bituminous concrete layer due to wheel load movements over the surface of the flexible pavement. To examine the tensile strength of the bituminous concrete, Indirect Tensile Strength (ITS) check was carried out at 25 °C. Since the pavement temperature isn't always regular, it is necessary to assess the strength attributes of bituminous blends at various temperatures. The stiffness of the mixture may be advanced by using use of suitable fillers. In the study, an attempt was made to evaluate the temperature effects on ITS of bituminous mixes when stone dust, ceramic dust and brick dust are used as fillers at 20°, 30°, 40° and 50°C. The results show that fatigue life of asphalt mixtures prepared with ceramic dust as filler is longer than HMA blends with stone dust and brick dust as fillers. Also, it was seen that industrial waste addition leads to relative increase in indirect tensile strength and resilient modulus of asphalt mixtures. Finally, based on experimental results, a model is proposed to describe the fatigue behaviour of asphalt mixtures containing various fillers.

OBJECTIVE OF THE PRESENT STUDY

1. Design of Bituminous Concrete mixes prepared using Viscosity Grade Bitumen (VG-30) and Polymer Modified Bitumen (PMB-40) as binders by adopting Marshall method of Bituminous mix design.
2. To determine the Marshall Properties of Bituminous Concrete mix prepared using VG-30 as binder at optimum bitumen content (OBC) by varying different mineral fillers.
3. To determine the Marshall Properties of Bituminous Concrete mix prepared using PMB-40 as binder at optimum bitumen content (OBC) by varying different mineral fillers.
4. To compare the Marshall Properties of Bituminous Concrete mix prepared using VG-30 and PMB-40 as binders at optimum bitumen content.
5. To conduct Indirect Tensile Strength Test and to determine Tensile Strength Ratio of Bituminous Concrete mix prepared with VG-30 at optimum bitumen content by using Phosphogypsum, GGBS and Stone Dust as mineral fillers.
6. To conduct Indirect Tensile Strength Test and to determine Tensile Strength Ratio of Bituminous Concrete mix prepared with PMB-40 at optimum bitumen content by using Phosphogypsum, GGBS and Stone Dust as mineral fillers.

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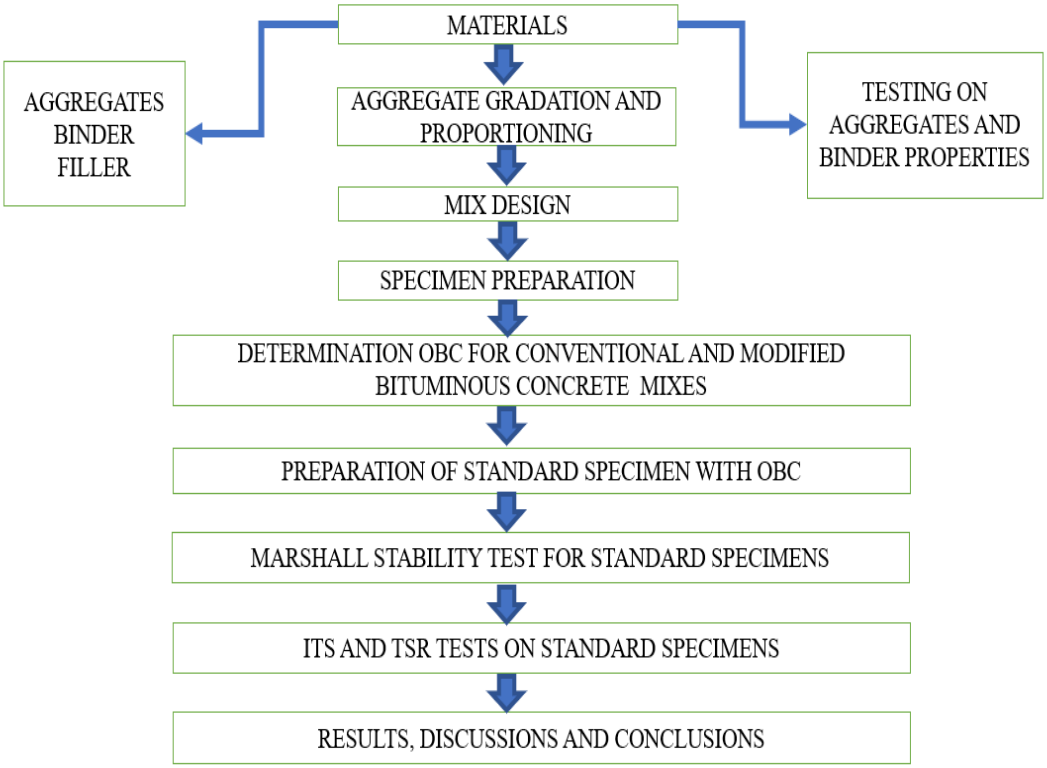
III. METHODOLOGY



EXPERIMENTAL INVESTIGATION AND ANALYSIS

3.1 MATERIALS

3.1.1 Aggregates

The coarse aggregates consists of crushed rock and shall be clean, hard, durable, free from dust or friable matter, organic or other deleterious substances. Aggregates offer good compressive and shear strength along with they provide good interlocking facility with sufficient permeability. Coarse aggregate passing 19.0 mm and retained on 2.36 mm sieve and Fine aggregates passing 2.36 mm and retained on 75 micron sieve are used. For the present study aggregates are collected from Nearby Quarry Site, Bengaluru, Karnataka. The test results are presented in Table 3.1.

Table 3.1 Test Results of Aggregates

Tests	**Result**	**Requirements as per MORT&H (Vth revision) Specifications, Table:500-16**
Aggregate impact value, %	22	Max 24%
Los Angeles abrasion value, %	26	Max 35%
Aggregate crushing value, %	27	-
Flakiness and Elongation Index (Combined), %	19.64	Max 35%
Water absorption, %	0.5	Max 2%
Aggregate specific Gravity		
Coarse aggregate	2.67	-
Fine aggregates	2.62	-

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3.1.2 Binder

In the present study, Viscosity Grade Bitumen (VG-30) and Polymer Modified Bitumen (PMB-40) are used as binders. Tests are conducted on the VG-30 and PMB-40 binders and the test results are presented in Table 3.2 and Table 3.3.

Table 3.2 Test Results of Viscosity Grade (VG-30) Bitumen

Tests	Results	Requirements as per IS: 73-2013
Penetration at 25°C, 100gm, 5 Seconds, 0.1mm	52	Min 45
Softening point (Ring & Ball), °C	53	Min 47
Flash point, °C	230	Min 220
Fire point, °C	240	Min 220
Ductility @27 °C, cm	85	Min 40
Viscosity*(Poise)	--	Min 2400

Table 3.3 Test Results of Polymer Modified (PMB-40) Bitumen

Test	Test Result	Requirement as per IRC SP: 53-2010
Penetration at 25^0C, 100gm, 5 Seconds, 0.1 mm	46	30-50
Softening Point (Ring & Ball), ^{0}C	67	Min. 60
Flash point, ^{0}C	240	Min. 220
Elastic Recovery of Half Thread in Ductilometer at 15^0C, %	75	Min. 60
Separation, difference in softening point (Ring & Ball), ^{0}C	2	Max. 3
Viscosity*@150^0C, Poise	-	5-9
Specific gravity, 27^0C	1.01	-
RTFOT; Loss in mass, %	1	Max. 1
Increase in Softening point (Ring and Ball), ^{0}C	3	Max. 5
Reduction in penetration of residue at 25^0C, %	16	Max. 35
Elastic Recovery of Half Thread in Ductilometer at 25^0C, %	62	Min. 50

3.1.3 Mineral Filler

Mineral filler consists of very fine, inert mineral matter that is added to the Bituminous Concrete mix, to increase the density and enhance strength of the mixture. The Mineral filler shall be free from organic impurities. stone dust/slag dust/ hydrated lime/fly ash/ cement can be used as mineral filler. Also, fine aggregate below 75micron can be used as filler. For this observation stone dust, phosphogypsum and ggbs has been used as filler for both bituminous concrete mixes prepared using VG-30 and PMB-40 as binders. The filler also improves the binding property between the aggregate. Filler content of 2% by weight of total aggregates is added in the preparation of bituminous concrete mix. The specific gravity and Gradation details of Stone dust, Phosphogypsum and GGBS are shown in Table 3.4 and Table 3.5.

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Table 3.4 Specific Gravity of Mineral Filler

Mineral Filler	Specific gravity
Stone dust	2.47
Phosphogypsum	2.05
GGBS	2.65

Table 3.5 Gradation details of Phosphogypsum, GGBS and Stone dust as filler materials

Sieve size (mm)	Cumulative (%) passing by weight of total aggregate			
	Obtained results, %passing			Requirements as per MORT&H (Vth revision), Table 500-9
	Phosphogypsum	GGBS	Stone dust	
0.6	100	100	100	100
0.3	100	100	100	95-100
0.075	91	93	100	85-100

3.2 GRADATION OF AGGREGATE

The Aggregate gradation (Grading-II) is adopted for preparation of Bituminous Concrete mix as per MORT&H (Vth revision) Specifications presented in Table 3.6 and Fig 3.1.

Table 3.6 Aggregate Gradation of BC- II mix

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

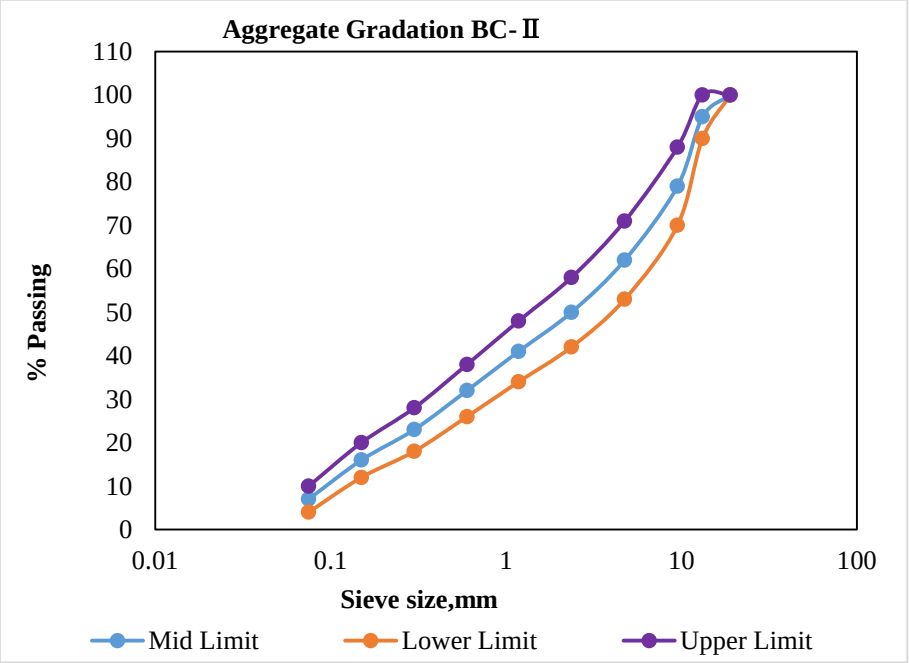

Fig 1: Aggregate Gradation of BC- II mix

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3.3 ANALYSIS OF DATA

The Optimum bitumen content for the mix design is found by taking the average value of the following three bitumen content found from the graphs of the test results.

- Bitumen content corresponding to maximum Stability Value.
- Bitumen content corresponding to maximum Unit weight/ Bulk density.
- Bitumen content corresponding to the median of designed limits of % voids in total mix (4%).

3.3.1 Marshall properties

Marshall properties of bituminous concrete mix with Stone dust, Phosphogypsum and GGBS as mineral fillers. The relationship between Marshall properties and bitumen content is shown and the test results are in Table 3.7 and Table 3.8.

Table 3.7 Marshall Properties of BC mix prepared using VG-30 with 2% (Stone Dust-SD, Phosphogypsum-PG and GGBS-GG) as mineral filler at Optimum Bitumen Content

Sl No.	Marshall Properties	Test Results of VG-30 with SD	Test Results of VG-30 with PG	Test Results of VG-30 with GG	Requirements as per Table-500-10 of MORT&H (Vth Revision)
1	Optimum Bitumen Content, %	5.45	5.44	5.46	**5.40 (Min.)**
2	Marshall Stability, kN	12.56	12.71	13.28	**9.0 (Min.)**
3	Flow, mm	3.10	2.90	3.30	**2.0 - 4.0**
4	Air voids(Vv), %	4.23	4.33	4.34	**3.0 - 5.0**
5	Voids filled with Bitumen (VFB), %	74.93	74.35	74.48	**65-75**

Table 3.8 Marshall Properties of BC mix prepared using PMB-40 with 2% (Stone Dust-SD, Phosphogypsum-PG and GGBS-GG) as mineral filler at Optimum Bitumen Content

Sl No.	Marshall Properties	Test Results of PMB-40 with SD	Test Results of PMB-40 with PG	Test Results of PMB-40 with GG	Requirements as per IRC SP 53 -2010, Table-3
1	Optimum Bitumen Content, %	5.69	5.64	5.65	**5.60 (Min.)**
2	Marshall Stability, kN	14.01	14.45	14.60	**12.0 (Min.)**
3	Flow, mm	3.60	3.40	3.35	**2.5 – 4.0**
4	Air voids(Vv), %	4.43	4.38	4.41	**3.0 - 5.0**
5	Voids filled with Bitumen (VFB), %	74.72	74.73	74.71	**65-75**

The comparative graphs are plotted for Marshall Properties of Bituminous Concrete (Grading II)Mix prepared using VG-30 & PMB- 40 with 2% Baghouse & 2% Stone Dust as mineral fillers are shown below in the Figures 2, 3, 4 & 5.

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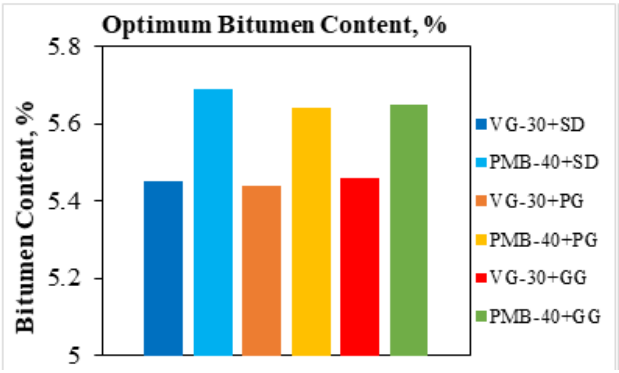

Fig 2: OBC for VG-30 & PMB-40 with Mineral Fillers

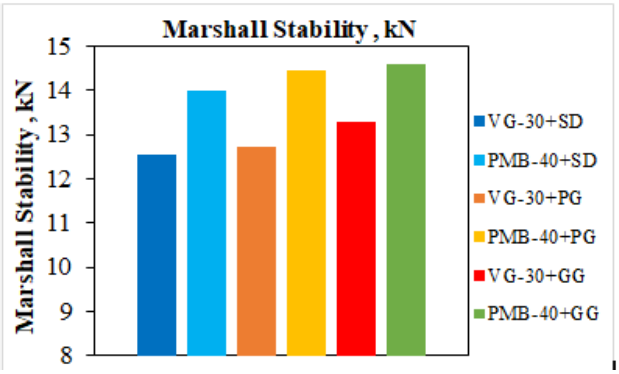

Fig 3: Marshall Stability for VG-30 & PMB-40 with Mineral Fillers

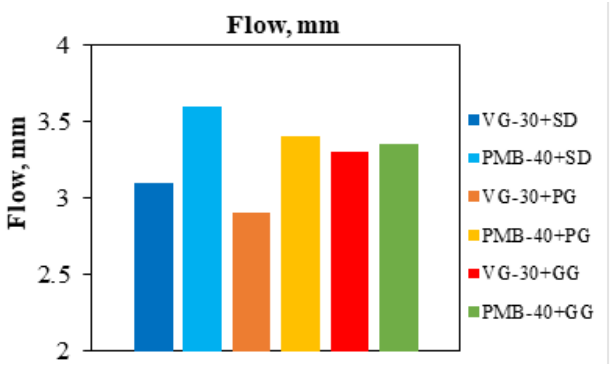

Fig 4: Flow for VG-30 & PMB-40 with Mineral Fillers

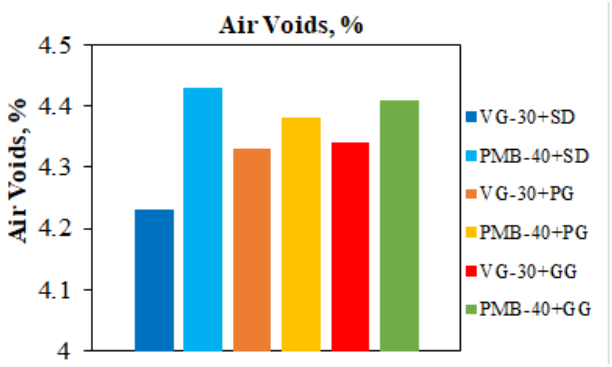

Fig 5: Air Voids for VG-30 & PMB-40 with Mineral Fillers

3.3.2 Indirect Tensile Strength

Indirect Tensile Strength test is conducted on Bituminous Concrete mix (Grading-II) prepared using Stone dust (2%), Phosphogypsum (2%) and GGBS(2%) as mineral filler at optimum bitumen content of binders VG- 30 and PMB- 40. Specimens are conditioned at 25˚C in water bath for duration of 2 hours.

3.3.3 Moisture susceptibility test: tensile strength ratio

Moisture damage in bituminous mixes refers to the loss of serviceability due to the percent of moisture. The extent of moisture damage is called the moisture susceptibility. The Indirect Tensile Strength test is a performance test which is often used to evaluate the moisture susceptibility of a bituminous mixes. Tensile Strength Ratio (TSR) is a measure of water sensitivity or to say moisture susceptibility. Tensile Strength Ratio is expressed as the percentage of ratio of average indirect tensile strength of the conditioned specimen to the average indirect tensile strength of the unconditioned specimens and the results are shown in table 3.9 & table 3.10 with graph of Figure 6, 7, 8 & 9.

Table 3.9 TSR for BC mix prepared using VG-30 as binder with Stone Dust, Phosphogypsum and GGBS as mineral fillers

Mineral Filler	**Indirect tensile Strength, N/mm²**		**TSR, %**	**Requirements as per Table 500-38 MORT&H (VthRevision)Specifications**
	Unconditioned	Conditioned at 60° C		
Stone Dust	1.05	0.93	88.90	Min 80%
Phosphogypsum	1.02	0.90	88.24	
GGBS	1.09	0.96	88.20	

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Table 3.10 TSR for BC mix prepared using PMB-40 as binder with Stone Dust, Phosphogypsum and GGBS as mineral fillers

Mineral Filler	Indirect tensile Strength, N/mm²		TSR, %	Requirements as per Table-3 of IRC SP:53-2010 Specifications
	Unconditioned	Conditioned at 60° C		
Stone Dust	1.232	1.111	90.19	Min 90%
Phosphogypsum	1.214	1.098	90.41	
GGBS	1.257	1.147	91.24	

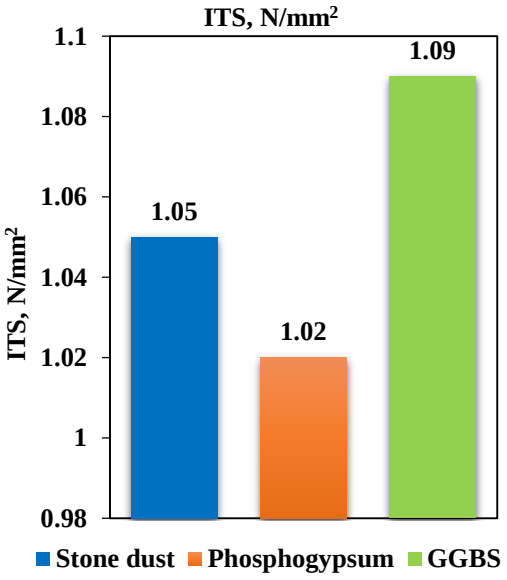

Fig 6: ITS and Mineral Filler Comparison for BC mix with VG-30 Bitumen

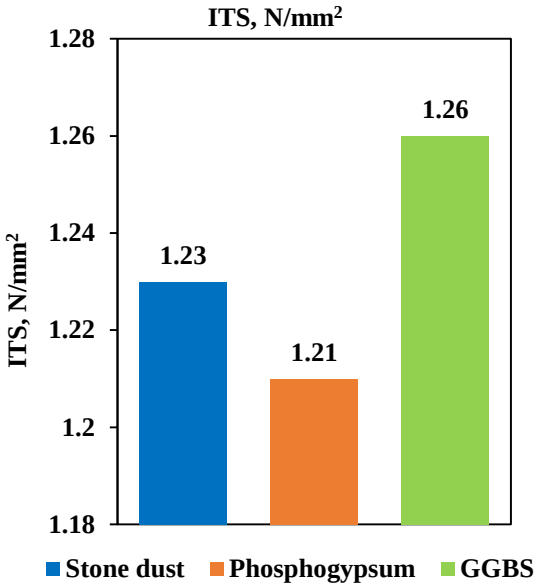

Fig 7: ITS and Mineral Filler Comparison for BC mix with PMB-40 Bitumen

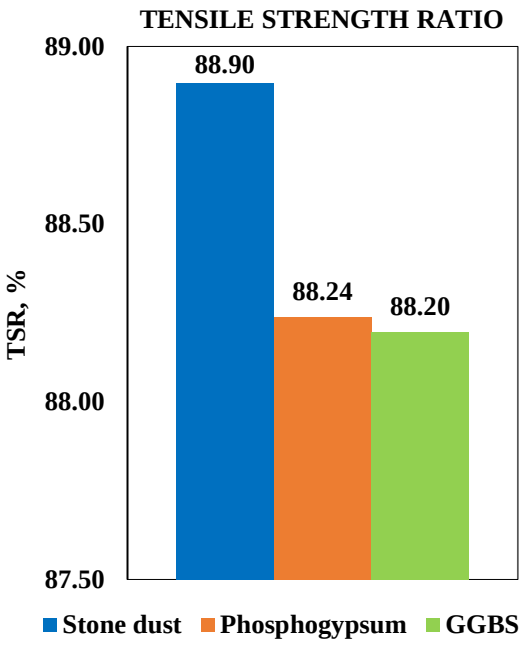

Fig 8: TSR and Mineral Filler Comparison for BC mix with VG-30 Bitumen

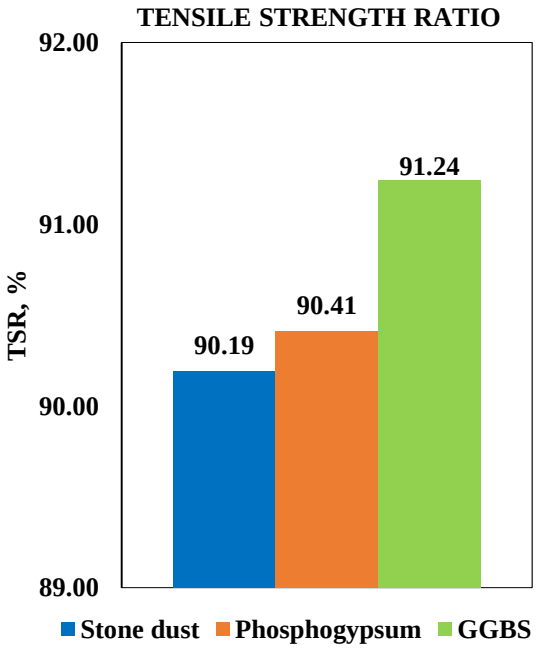

Fig 9: TSR and Mineral Filler Comparison for BC mix with PMB-40 Bitumen

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IV. RESULTS AND DISCUSSION

4.1 MARSHALL PROPERTIES

4.1.1 Optimum Bitumen Content

Optimum bitumen content for BC mix prepared using VG-30 with Stone dust, Phosphogypsum and GGBS as mineral fillers is 4.41%, 3.68%, 3.48% is lower than that of BC mix prepared using PMB-40 with Stone dust, Phosphogypsum and GGBS as mineral fillers.

4.1.2 Marshall Stability

Marshall Stability for BC mix prepared using VG-30 with Stone dust, Phosphogypsum and GGBS as mineral fillers is 11.54%, 13.69%, 9.94% is lower than that of BC mix prepared using PMB-40 with Stone dust, Phosphogypsum and GGBS as mineral fillers.

4.1.3 Marshall Flow

Marshall Flow for BC mix prepared using VG-30 with Stone dust, Phosphogypsum and GGBS as mineral fillers is 16.13%, 17.24%, 1.52% is lower than that of BC mix prepared using PMB-40 with Stone dust, Phosphogypsum and GGBS as mineral fillers.

4.1.4 Total Air voids

Total Air voids for BC mix prepared using VG-30 with Stone dust, Phosphogypsum and GGBS as mineral fillers is 4.73%, 1.39%, 1.61% is lower than that of BC mix prepared using PMB-40 with Stone dust, Phosphogypsum and GGBS as mineral fillers.

4.1.5 Voids Filled with Bitumen

Voids Filled with Bitumen for BC mix prepared using VG-30 with Stone dust as mineral filler is 0.28% is higher than that of BC mix prepared using PMB-40 with Stone dust as mineral filler.

Voids Filled with Bitumen for BC mix prepared using VG-30 with Phosphogypsum and GGBS as mineral fillers is 0.51%, 0.31% is lower than that of BC mix prepared using PMB-40 with Phosphogypsum and GGBS as mineral fillers.

4.2 INDIRECT TENSILE STRENGTH TEST

Indirect Tensile Strength for Bituminous Concrete mix prepared using VG-30 with Stone dust, Phosphogypsum and GGBS as mineral fillers as mineral fillers is 17.14%, 18.63%, 15.60% is lower than that of Bituminous Concrete mix prepared using PMB-40 with Stone dust, Phosphogypsum and GGBS as mineral fillers.

4.3 TENSILE STRENGTH RATIO TEST

Tensile Strength Ratio for Bituminous Concrete mix prepared using VG-30 with Stone dust, Phosphogypsum and GGBS as mineral fillers as mineral fillers is 1.45%, 2.46%, 3.45% is lower than that of Bituminous Concrete mix prepared using PMB-40 with Stone dust, Phosphogypsum and GGBS as mineral fillers.

V. CONCLUSION

1. Bituminous Concrete mix prepared using VG-30 as binder with Stone dust, Phosphogypsum and GGBS as mineral fillers is satisfying the requirements as per MORTH (V^{th} Revision).
2. Bituminous Concrete mix prepared using PMB-40 as binder with Stone dust, Phosphogypsum and GGBS as mineral fillers is satisfying the requirements as per IRC SP 53-2010 specifications.
3. Marshall properties of Bituminous Concrete mix prepared using VG-30 at optimum bitumen content (OBC) and GGBS as mineral filler is superior in terms of Marshall properties when compared to mix prepared using Stone dust and Phosphogypsum as mineral fillers.
4. Marshall properties of Bituminous Concrete mix prepared using PMB-40 at optimum bitumen content and GGBS as mineral filler is superior in terms of Marshall properties when compared to mix prepared using Stone dust and Phosphogypsum as mineral fillers.
5. The Indirect Tensile Strength and Tensile Strength Ratio for Bituminous Concrete mix prepared using VG-30 at OBC with Stone dust as mineral filler is performing better when compared to the mix, prepared using Phosphogypsum and GGBS as mineral fillers.

6. The Indirect Tensile Strength and Tensile Strength Ratio for Bituminous Concrete mix prepared using PMB-40 at OBC with GGBS as mineral filler is performing better when compared to the mix, prepared Stone dust and Phosphogypsum as mineral fillers.

VI. REFERENCES

[1] ASTM D 1074-02 (2002). "Standard Test Method for Compressive Strength of Bituminous Mixtures".

[2] ASTM D 1075 – 07 (2007). "Standard Test Method for Effect of Water on Compressive Strength of Compacted Bituminous Mixtures".

[3] D. Lekhaz et al (2016). "The Study of Bituminous concrete mix by Using Different Type of Fillers like Cement, GGBS and Brick Dust". International Journal of Engineering Science and Computing (IJESC), Vol-6, Issue-8, 2415-2419.

[4] Hassan Y. Ahmed et al (2006). "Effect of using waste cement dust as a mineral filler on the mechanical properties of hot mix asphalt". Ass. Univ. Bull. Environ. Res. Vol. 9, No. 1, 51-60.

[5] IS 73-2013. Indian standard paving bitumen - specification, fourth Revision. Bureau of Indian Standard, New Delhi, India; 2013.

[6] IRC SP-53:2010. "Guidelines on Use of Modified Bitumen in Road Construction".

[7] IS 15462-2004. "Polymer and Rubber modified Bitumen Specifications‖ Indian Road Congress", New Delhi, India.

[8] Khanna S. K., Justo C. E. G., Veeraragavan A. (2014), Text Book of Highway Engineering (revised 10th edition), Nem Chand & Bros, Roorkee, India.

[9] Lokesh Gupta and G. Suresh (2018). "Determination of indirect tensile strength of bituminous concrete mix prepared using stone dust and cement as filler materials." Springer International Publications, 249-261.

[10] Ministry of Road Transport, and Highways (MORT&H). "Specifications for road and bridge works, fifth revision". Indian Roads Congress,New Delhi, India; 2013.

[11] MS-2 Manual (2014). "Asphalt Mix Design Methods (7th Edition)", Asphalt Institute, USA 38.

[12] Satish Chandra and Rajan Choudhary (2013). "Performance Characteristics of Bituminous Concrete with Industrial Wastes as Filler". American Society of Civil Engineers (ASCE), 25(11): 1666-1673.

[13] Savitha T Sudhakaran et al (2012). "Study on Structural Characteristics of Bituminous mix with added Hydrated lime and Phosphogypsum". International Journal of Emerging trends in Engineering and Development, Vol-04, Issue-02, 73-83.

[14] Suvarna P et al (2018). "Study on the effect of stone, dust, ceramic dust and brick dust as fillers on the strength, physical and durability properties of bituminous concrete (BC –II) mix". International Journal of Applied Engineering Research Vol-13, No-7, 203-208.

[15] Tarekegn Kumala Sherre and Min-Chih Liao (2022). "Characteristics of Recycled Mineral Fillers and Their Effects on the Mechanical Properties of Hot-Mix Asphalt When Used as Limestone Filler Replacements". Journal of Materials in Civil Engineering, ASCE, 34(1): 04021395, 1-13.