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LABORATORY STUDIES ON WARM BITUMINOUS CONCRETE MIX PREPARED USING GGBS AS FILLER MATERIAL AND ZYCOTHERM AS ADDITIVE

Ashik Bellary[1], Lokesh Gupta[2]

[1.] *Student, M.E (Highway Engineering),*
UVCE, Bangalore University, Bangalore.(India)
[2.] *Assistant Professor, Dept. of Civil Engineering,*
Sir Padampat Singhania Univerisity, Udaipur.(India)

ABSTRACT

Over the past twenty years, road traffic has grown significantly and loading is progressively getting worse due to the introduction of newer and supplementary influential trucks with heavier and wider bodies in India. Present study emphasizes on the mix design considerations. In this regard, an attempt has been made to assess the influence GGBS as filler material and Zycotherm additive on the Warm Mix Asphalt paving mix to achieve sufficient stability, durability and to satisfy requirements. The present work is about the effect of additive Zycotherm(0.1% by weight of binder) on the Marshall Properties, Indirect tensile strength and Tensile strength ratio of Warm mix asphalt. The parameters such as Bulk density (Gb), Volume of Air Voids (Vv), Voids in Mineral Aggregates (VMA), Voids Filled with Bitumen (VFB), Stability (S) and Flow (F), ITS, TSR were determined. The test results were satisfying the requirements as per MORT&H specifications. From the test results obtained, it is observed that Warm mix asphalt mix prepared using GGBS (2%) is exhibiting higher Marshall stability, OBC, bulk density, indirect tensile strength, tensile strength ratio and lesser total air voids and VFB values than the mix prepared using GGBS (1%). Based on the limited laboratory studies carried out, it can be conclude that warm mix asphalt prepared using GGBS (2%) is superior than mix prepared using GGBS (1%) by adding Zycotherm (a chemical additive).

Keywords: GGBS, ITS, Marshall Stability, WMA and Zycotherm

I. INTRODUCTION

The rapid growth of cities in recent years resulted in a lot of transportation. Road surface have experienced a significant increase of traffic flows and carrying loads. In tropical countries, the normal temperature in summer will make the asphalt material become softer. This will also reduce the service life of the road. The two main damages are permanent deformation and fatigue cracking. Therefore, the issue of improving qualities and properties of asphalt materials was made by using domestic additives. With the development of the global economy, how to address sharply increasing demand for fossil fuels and to reduce gas emissions has become a

critical issue for society. The asphalt industry all the time looks for an well-organized way to save energy and reducing the emissions. Rising energy cost and increased environmental awareness due to HMA (Hot Mix Asphalt) Asphalt industry have brought attention to the potential benefits of Warm Mix Asphalt (WMA) binders. Warm Mix Asphalt (WMA) is a fast emerging new technology with potential of revolutionizing the production of asphalt mixt. WMA technology may permit the mixing, and compaction of asphalt at 30°C to 40°C lower temperatures compared to Hot Mix Asphalt (HMA). WMA is produced by incorporating additives into asphalt mixtures to let the production and placement of the mix at temperatures well below the temperatures of conventional hot mix asphalt (HMA). Warm Mix Asphalt (WMA) is the process of using additives to reduce the mixing temperatures of HMA by 10ºC to 35ºC. Zycotherm, Aspha-min, Sasobit, Warm asphalt-mix foam, Revix and Rediset-WMX.For thepresent study Zycotherm additive has been used. Zycotherm is WMA additive developed by Zydex Industries, Gujarat, India. This is an odour-free, chemical warm mix additive which has been developed to provide significantly enhanced benefits over the existing. WMA technologies by offering lower compaction temperatures and at the same time improving the moisture resistance of pavements by serving as an antistrip. Zycotherm modified mix can be produced at 120°C - 135°C for and compacted at 90°C - 120°C. Zycotherm offers temperature reductions depending on the properties of the mix. The superiority and stability of bituminous mixtures are affected by various aspects together with amount and type of filler materials as well as gradation of aggregates. Filler acts as one of the major constituents in Asphalt concrete mix design. Fillers is preferred primarily to fill voids in the coarse and fine aggregates and secondly to affect the ageing characteristics of the mix. Suitable material combinations can serve for extended life for surface courses depending upon the percentage of filler and type of fillers used.

1.1 Objectives of Present Study

- To determine the Marshall properties of Warm Mix Asphalt at optimum binder content.
- To compare Marshall Properties of Warm Mix Asphalt prepared using GGBS (1% and 2%) as filler and Zycotherm as an additive.
- To determine the Indirect tensile strength and Tensile strength ratio of Warm Mix Asphalt.
- To study the influence of warm mix additive (Zycotherm) on the behavior of Warm Mix Asphalt prepared using GGBS as filler material.

II. MATERIAL CHARACTERISATION

Aggregates play a major role in the performance of a bituminous mix and final characteristics of bituminous mixes is of great concern. One of the most important aspects of an aggregate affecting the stability and working properties of a mix is the gradation. The test results obtained are presented in Table-1. Filler fills the voids in the bituminous mix and makes it dense graded. It results in enhancement of wearing capabilities of bituminous mix. In the present study Ground Granulated Blast Furnace slag is used as mineral filler. The specific gravity of GGBS is found to be 2.82. Viscosity grade (VG-30) bitumen modified by Zycotherm additive is used as binder. The test results are satisfy the requirements as per IS 73-2006 and presented in Table-2.

2.1 Zycotherm Additive

Zycotherm is an advance generation Silane additive with multiple benefits. Zycotherm gives chemical bonding for extended moisture resistance, enables 100% Coating of Bitumen on aggregates and allows wider temperature zone for compaction, resulting in a pavement with extended life cycle. Zycotherm chemically modifies the aggregate surface from water loving to bitumen loving, gives strong permanent bonding of bitumen on the aggregates. Zycotherm modified bitumen achieves complete coating faster due to improved wetting. It also helps to saturate the finest pore and crevices of aggregate surface. Fines are completely coated in the mixing time of 45-60 seconds and ensure pinhole surface. Reduces stripping potential and oxidative effect at the aggregates-bitumen interface due to elimination of air interface at the aggregate surface. It enhance the no of load repetition of pavement due to chemical bonding and complete mechanical impregnation of bitumen into the finest pore of aggregate surface. The specific gravity of Zycotherm is found to be 1.00.

III. GRADATION OF AGGREGATES

The aggregate gradation (grading-2) was adopted for Asphalt concrete mixes as per MORT&H (V revision) specifications. The gradation values are presented in Table-3.

Indirect tensile strength test (ITS)

Test Procedure for Conducting Indirect Tensile Strength Test

- The test specimens are prepared at the optimum bitumen content using Marshall Method mix design for Warm Mix Asphalt (Grade-2) as per MoRT&H (V revision) specifications.
- The height of the specimens is recorded. Each set of specimens was tested at test temperature of 25^0C for two different fillers specimens to determine their indirect tensile strength. This was achieved by using breaking head under a load applied at a rate of 50 mm per minute.

Load at failure is recorded and the indirect tensile strength is computed using the relation given below.

$$\sigma_x = \left(2 \times P\right) \Big/ \left(\pi \times D \times t\right) \qquad \text{---------- Eq.1}$$

Where: σ x= Horizontal tensile stress/tensile strength, kg/cm^2

P= Failure load, kg

D= Diameter of the specimen, cm

t = Height of the specimen, cm.

Test Procedure for conducting Tensile Strength Ratio test (TSR)

Similar to Indirect Tensile Strength test procedure, Marshall Specimens are prepared at optimum bitumen content for all the three gradations as per ASTM D-1075

- Samples were divided into two group i.e. Group-1 and group-2.
- The Group-1 of specimens are tested in a dry condition (unconditioned state), while the Group-2 specimen are tested in soaked condition.

- For the Group-1, specimens are treated as control without any conditioning and then all specimens are tested for ITS at test temperature of 25±1°C (by storing them in a water bath maintained at the test temperature for not less than 2 hour) under the loading rate of 50 mm per minute. The load at failure is recorded and the indirect tensile strength is computed using the equation 1.
- The average value for the indirect tensile strength of Group-1 set is calculated.
- For the Group-2, specimens are placed in water bath maintained at 60°C for 24 hours. The specimens were transferred to the second water bath maintained at 25°C stored for 2 hours.
- All the specimens are tested for ITS at test temperature of 25±1°C and indirect tensile strength for the saturated conditioned specimens is computed.
- The indirect tensile strength ratio (TSR) can be determined using the following relation-

$$TSR = Sn / St \quad \text{---------- Eq. 2}$$

Where TSR: Indirect Tensile Strength Ratio

St: Average Indirect tensile strength of Group-1 specimens

Sn: Average Indirect tensile strength of Group-2 specimens

V. TABLES AND FIGURES

Table-1 Aggregates test results

Aggregate Test	Test result	Requirements as per MORT&H (V revision) Specifications
Aggregate impact value (%)	21.82%	Max 24%
Los Angeles abrasion value (%)	22.92%	Max 30%
Flakiness and Elongation Index (Combined) (%)	28.65%	Max 35%
Water absorption (%)	0.92%	Max 2%

Table-2 Bitumen test results

Bitumen Test	Test Results		Requirements as per IS 73-2006
	VG-30	VG-30+Zycotherm Mix	
Penetration at 25°C	65	65	50-70
Softening point (Ring & Ball), °C	52	49	47-57
Flash point, °C	270	270	Min 220
Absolute viscosity@60°C, Poises	2540.68	2520.32	2400(Min)
Kinematic viscocity@135 °C, cSt	461.54	458.62	350 (Min)
Ductility @27 °C ,cm	88	98	Min 75
Specific gravity	1.02	1.00	Min 0.99

Table-3 Aggregate gradation for Asphalt concrete mix (grading-2) as per MoRT&H (V revision) specification

Sieve Size in mm	% Passing (Specified)	Obtained Gradation
19	100	100
13.2	79-100	89.5
9.5	70-88	79
4.75	53-71	62
2.36	42-58	50
1.18	34-48	41
0.60	26-38	32
0.30	18-28	23
0.15	12-20	16
0.075	4-10	7

Table-4 Marshall Properties of Warm Mix Asphalt Prepared Using Zycotherm and GGBS (1%) as Filler Material

Bitumen content, %	Marshall stability, kg	Flow, mm	Bulk density, gm/cc	Total air voids, %	Voids Filled with bitumen, %	Voids in Mineral Aggregate, %
4.5	1087	2.15	2.328	7.771	56.932	18.041
5	1294	2.55	2.357	5.962	65.973	17.517
5.5	1238	2.95	2.364	4.568	71.68	17.785
6	1184	3.85	2.400	2.936	82.80	17.053

Table-5 Marshall Properties of Warm Mix Asphalt Prepared Using Zycotherm and GGBS (2%) as Filler Material

Bitumen content, %	Marshall stability, kg	Flow, mm	Bulk density, gm/cc	Total air voids, %	Voids Filled with bitumen, %	Voids in Mineral Aggregate, %
4.5	1116	2.60	2.361	6.598	61.227	17.016
5	1233	2.95	2.371	5.539	67.735	17.164
5.5	1374	3.30	2.392	4.059	76.064	16.957
6	1317	3.95	2.383	3.750	78.898	17.771

Table-6 Marshall Properties Warm Mix Asphalt Prepared Using GGBSas Filler Materials at Optimum Bitumen Content

S. N.	Marshall properties	Test Results		Requirements as per MoRT&H specifications
		GGBS 1%	GGBS 2%	
1	Optimum bitumen content, (%)	5.4	5.56	5.4 (Min)
2	Marshall stability, kg	1300	1390	900 (Min)
3	Flow, mm	2.08	3.30	2.0 - 4.0
4	Air voids(Vv), %	4.5	4.20	3.0 - 6.0
5	VMA, %	17.90	17.50	17.0 (Min)
6	VFB, %	72.3	73.90	65-75

Table-7 ITS and TSR Warm Mix AsphaltPrepared Using Zycotherm and GGBS as Filler Materials

Type of mix	Filler	Indirect Tensile Strength, N/mm^2		TSR %
		Unconditioned	Conditioned at 60°C	
Warm Mix Asphalt Grade-II	GGBS (1%)	0.862	0.761	88.28
	GGBS (2%)	0.934	0.870	93.14

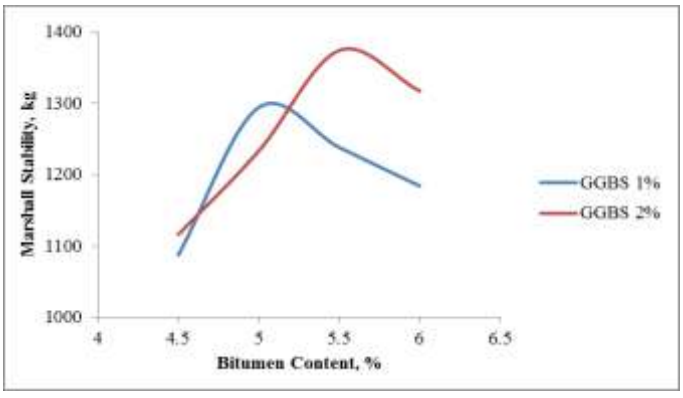

Fig 1 Marshall Stability Vs Bitumen Content

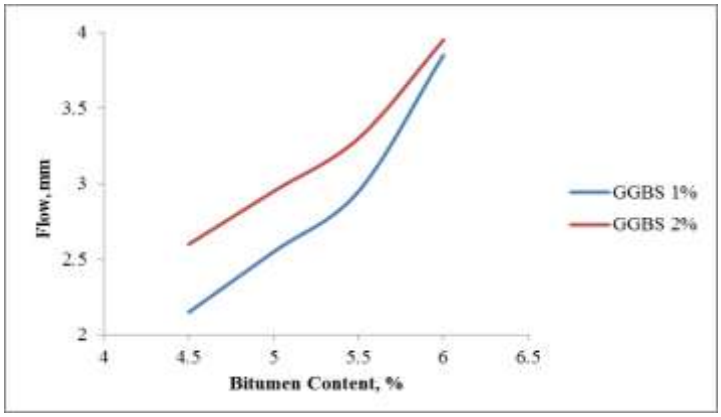

Fig 2 Flow Vs Bitumen Content

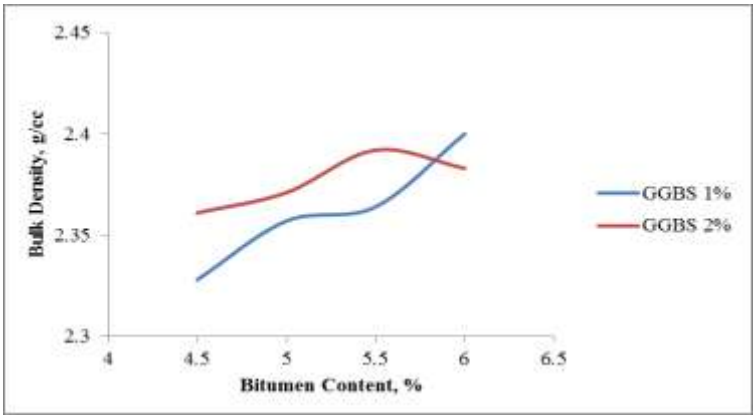

Fig 3 Bulk Density Vs Bitumen Content

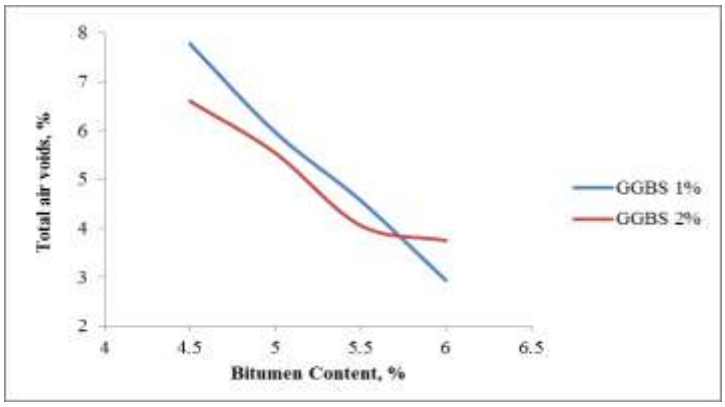

Fig 4 Total air voids Vs Bitumen Content

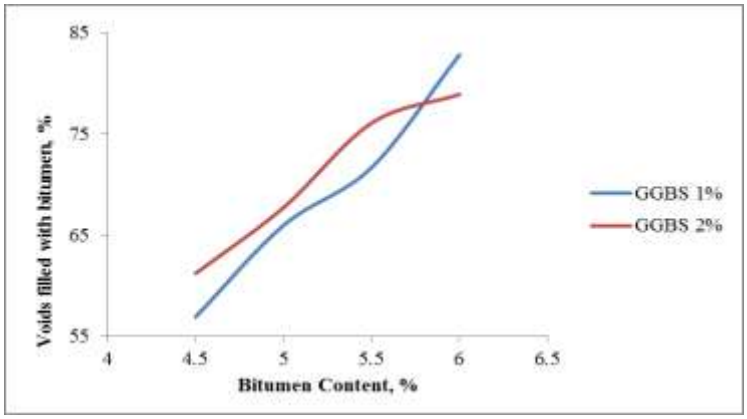

Fig 5 Voids filled with bitumen Vs Bitumen Content

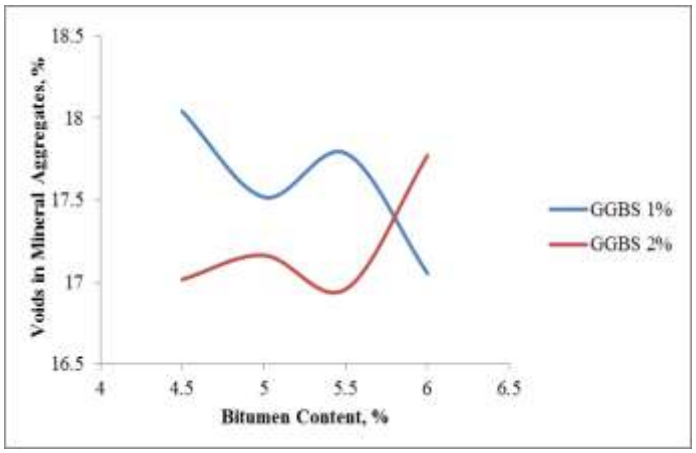

Fig 6 Voids in Mineral aggregates Vs Bitumen Content

VI. CONCLUSIONS

- As per the present study, the conclusions are summarized-
- There is a marginal increase in optimum binder content for Warm mix asphalt specimens prepared using GGBS 2% when compared to GGBS 1% and Zycotherm as chemical additive.
- There is a marginal increase in Marshall Stability for Warm mix asphalt specimens prepared using GGBS 2% when compared to GGBS 1% and Zycotherm as chemical additive.
- There is a substantial increase in flow value for Warm mix asphalt specimens prepared using GGBS 2% when compared to GGBS 1% and Zycotherm as chemical additive.
- There is a substantial decrease in air voids for Warm mix asphalt specimens prepared using GGBS 2% when compared to GGBS 1% and Zycotherm as chemical additive.
- There is a marginal decrease in Voids in Mineral Aggregates for Warm mix asphalt specimens prepared using GGBS 2% when compared to GGBS 1% and Zycotherm as chemical additive.
- There is a substantial increase in Indirect tensile strength value for Warm mix asphalt specimens prepared using GGBS 2% when compared to GGBS 1% and Zycotherm as chemical additive.

- There is a substantial increase in Tensile strength ratio for Warm mix asphalt specimens prepared using GGBS 2% when compared to GGBS 1% and Zycotherm as chemical additive
- Thus it can be concluded that GGBS 2% filler can be used effectively in the preparation of Warm Mix Asphalt by using Zycotherm as chemical additive. And GGBS 2% is superior filler material.

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