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Performance of Modified Bituminous Mix with GGBS as Filler Material

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Abstract:

India has one of the largest road networks over the world, fording over a total of 5.5 million kilometres, and virtually all of them are designed using natural materials. The usage of conventional materials has a compelling impact on the depletion of natural resources and effects the environment. The focus of this project is to combine GGBS (Ground Granulated Blast Furnace Slag) in Flexible Pavement as filler material. GGBS is an industrial by-product that is obtained from molten iron slag from blast furnaces. GGBS accounts for about 40 million tons as a waste product from iron industries alone in India. Due to an escalation in demand for iron, the iron ores are being extracted at vast quantities, and the by-product obtained from the iron industries is increasing swiftly and is creating disposal problems. This fine dust causes air pollution and further leads to health problems in living things, such as respiratory illnesses, cancer, cardiac issues, and eye conditions if these heaps of powdery dust are left exposed in the atmosphere. Stone dust, cement, and sand are mostly used in pavement construction as filling materials. GGBS has cementitious properties that confer us that it can be used as filler material as well. The efficient use of this material as filler in pavement design resulted in data compliance of Marshall mix design requirements, solve dumping problems, and reduce construction costs.

Keywords: *Marshall Stability, GGBS, Flexible Pavement, Bituminous Macadam, Filler Material.*

I. INTRODUCTION

In India, the transport sector is growing at a brisk rate, even to the contemporary day. Roads are generally the primary mode of transportation in rural and urban areas. Standard materials used in road construction are obtained through mining and other processes that result in environmental degradation. Extensive use of such conventional materials is depriving them and causing an increase in price. Largescale road infrastructure projects in India are the sources for the consumption of good quality mineral aggregate, and it is, hence, necessary to investigate the use of contrasting types of fillers, such as GGBS, Fly Ash [2]. The performance of an asphalt concrete mixture is impacted by various types and quantities of filler used. The filler provides improved microcracking resistance, allowing asphalt concrete mixture to have increased fatigue life. The pavement can achieve a significant improvement in fatigue life through the use of GGBS, Fly ash, Cement. Standard flexible pavements are designed with substandard materials at the bottom where the stress magnitude is low, and with more robust elements on above where the concentration of stress is extreme [5].

Moreover, to this method, the use of local materials is feasible and usually leads to the most economical

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design. In substitution to these traditional materials, it is possible to build the roads with vast quantities of waste, which harm the environment. Iron is the second most common metal on earth and is one of the extensively used metal. Cast iron is commonly used as the architectural metal in construction and various other industries. These factors are responsible for the immense extraction of iron from its ores, and iron is responsible for 11.6% CO_2 emissions in India [3]. During the process of mining iron from its ore, blast furnace slag is obtained. It is the byproduct formed as an impurity during the extraction process and floats on the surface of molten metal as fluid and hardens on cooling. Blast furnace slag can be cooled in several ways to produce different types of slag products. Granulated slag is obtained by quenching the molten slag in water to produce sand-like granules which are then grounded [4].

Furthermore, the resulting byproducts obtained are considerably high due to this massive demand for iron. Several millionsof tons of slag are produced from iron industries, and the residue obtained is dumped irregularly [4]. Air pollution, soil quality degradation, sickness in living things, hazards to the environment are the reasons due to inappropriate dumping. GGBS has cementitious properties that act as an excellent binder. This study investigates the use of GGBS in the construction of asphalt as a filler material and contrasts the result with stone dust as traditionally used filler material [2].

Figure – 1 GGBS

II. Materials and Methods

A. Bitumen

Bitumen comprising of Viscous Grade (VG-40) is utilized as a binder. The necessary tests of bitumen are assessed according to IS 73:2013 and the outcomes attained are

Table – 1 Bitumen Test Results

S.No	Test	Result	Requirements as per IS 73:2013
1	Penetration at 25° C, mm	52	50-75
2	Softening Point, °C	58.4	47-57
3	Ductility, cm	95.5	Min 7.5
4	Flash Point, °C	266.3	Min 220
5	Fire Point, °C	298	Min 220

B. Aggregates

Aggregates comprising of coarser and finer sizes are used. Aggregates are sieved according to Bituminous Macadam of Grade 2 and proportioned as required.

Table – 2 Aggregate Test Results

S. No	Test		Result	Test conducted as per	Requirements as per MORTH, V Revision
1	Aggregate Impact Test, %		16.6	IS 2386: Part (IV)	Max 35
2	Los Angeles Abrasion Test, %		24.92	IS 2386: Part (IV)	Max 40
3	Flakiness Index, %		12.3	IS 2386: Part (I)	Max 15
4	Elongation Index, %		18.9		Max 20
5	Aggregate Water Absorption, %		0.8	IS 2386: Part (IV)	Max 2%
6	Aggregate Specific Gravity	Coarse	2.67	IS 2386: Part (III)	Min 2.5
		Fine	2.56		

C. GGBS

GGBS is a byproduct of iron industries, and the material was collected from Vizag Steel Plant, Visakhapatnam, India. The attributes of GGBS are tabulated below.

Table – 3 Properties of GGBS

S. No	Property	Value
1	Specific Gravity	2.2
2	Density, kg/m^3	1200
3	Color	Off White
4	Particle Size	75 – 150 µ

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The composition of GGBS is as follows

Table – 4 Composition of GGBS

Chemical Compound	Mass Percentage (%)
SiO_2	30 – 35
Al_2O_3	18 – 20
Fe_2O_3	0.5 – 0.8
CaO	30 – 35
MgO	8 – 10

The GGBS used in the bituminous mix must follow conventional aggregates requirements as specified in the code of practice.

D. Stone Dust

Stone Dust acquired is from the university laboratory, and the attributes of the material are listed beneath.

Table – 5 Stone Dust Properties

S. No	Property	Value
1	Specific Gravity	2.54
2	Density, kg/m^3	1520
3	Color	Ashen White
4	Particle Size	150 µ

E. Aggregate Gradation

Gradation of aggregates is essential to obtain stability because it is dependant on it. Bituminous mix Stability is increased with a decrease in air voids. Gradation for Bituminous Macadam (Grade – 2) is chosen as per IRC 27:2009 (Table – 4) and is posted below.

Table – 6 Aggregate Gradation

S.No	IS Sieve Size, mm	% Passing
1	45.0	-
2	37.5	-
3	26.5	100
4	19	90 - 100
5	13.2	56 - 88
6	4.75	16 - 36
7	2.36	4 - 19
8	0.3	2 - 10
9	0.075	0 - 8

F. Marshall Stability

To determine the Stability, Flow of the bituminous concrete mix using GGBS and Stone Dust, the Marshall test is carried out. These tests were carried out by replacing GGBS as Filler material in replacement of stone dust for bitumen percentages of 4%, 4.5%, and 5%.

The required specifications of Marshall as per MORTH (V Revision) of Table 500-10 are

Table – 7 Marshall Specifications

Property	Value
Stability, kg	Min 900
Flow, mm	2 - 4
Air Voids in Total Mix, %	3 – 6
Voids Filled with Bitumen, %	65 – 75
Voids in Mineral Aggregates, %	13 – 15

The mean Binder Content at 4% Air Voids, Maximum Stability and Density are termed as Optimum Binder Content (OBC) [6].

It is acquired by taking the average of the obtained values from the graphs plotted from test results.

III. Results

Bituminous Mix Marshall properties are identified and the Outcome with 4%, 4.5% and 5% binder content with Stone Dust and GGBS as filler materials are presented in the figures below.

Table – 8 Marshall Properties of Specimen with Stone Dust as Filler Material

Bitumen %	Stability kg	Flow mm	V_v %	VFB %	VMA%	Density g/cc
4	1501.01	3.1	4.95	65.08	14.10	2.52
4.5	1590.13	3.47	4.28	69.9	14.81	2.57
5	1447.21	3.63	3.77	73.71	15.20	2.54

Table – 9 Marshall Properties of Specimen with GGBS as Filler Material

Bitumen %	Stability kg	Flow mm	V_v %	VFB %	VMA%	Density g/cc
4	1462.52	3.27	5.12	64.88	14.13	2.5
4.5	1551.05	3.67	4.48	69.7	14.71	2.55
5	1520.46	3.95	3.94	73.65	15.13	2.52

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The following graphs are plotted

1. Bitumen Content (%) against-
   i) Stability (kg)
   ii) Density (g/cc)
   iii) Flow (mm)
   iv) Voids Filled with Bitumen (%)
   v) Air Voids (%)

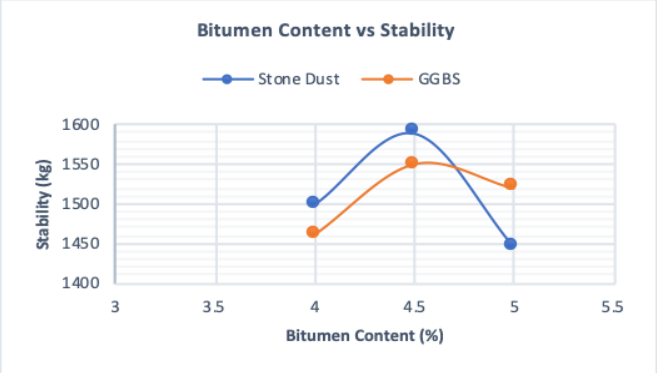

Figure – 2 Bitumen Content (%) vs Stability (kg)

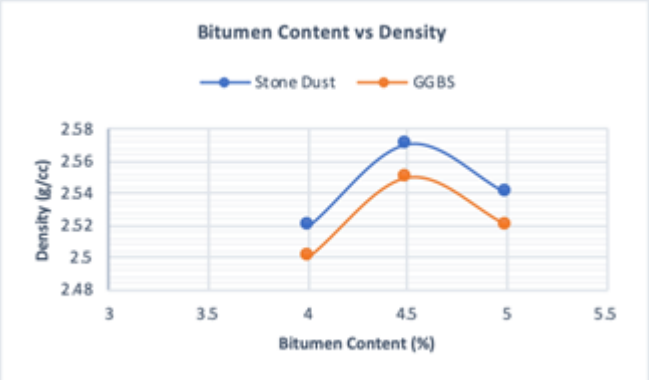

Figure – 5 Bitumen Content (%) vs Density (g/cc)

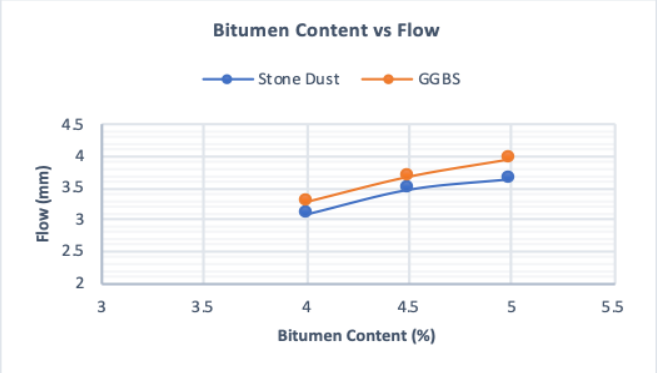

Figure – 3 Bitumen Content (%) vs Flow (mm)

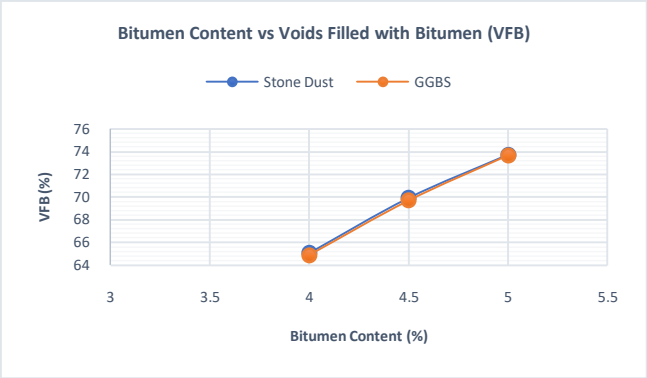

Figure – 6 Bitumen Content (%) vs VFB (%)

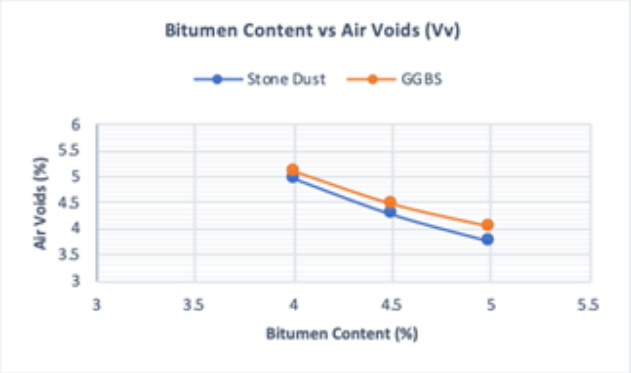

Figure – 4 Bitumen Content (%) vs Air Voids (%)

Table – 10 Comparison of results obtained using Stone Dust and GGBS at OBC:

Properties	Stone Dust	GGBS
OBC, %	4.54	4.62
Stability, kg	1578.69	1543.7
Flow, mm	3.48	3.73
V_v, %	4.23	4.35
VFB, %	70.2	70.64
VMA, %	14.84	14.81

IV. Conclusion

1. The results indicate that bituminous mixes contain GGBS as filler material in replacement to stone dust has similar properties.
2. The results are compliance with the Marshall properties as per MORTH (V Revision).
3. The utilization of GGBS as filler materials can solve disposal problems and can reduce air pollution.
4. Practicing these materials in mix design may reduce the cost of pavement construction.

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