Strength Rate Analysis Of Hot Asphalt Mixes Of Bituminous Class -II By Part Of Substituent By Conventional Concrete With Copper Slag

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Abstract: Aggregates are significant constituent of any infrastructure building including roads. Use of natural aggregates like sand, broken up stone and rocks are increasingly restricted by the zoning regulations, urbanization, environmental concerns and increased costs. Though the utilization of slag has begun in India, technologies and studies should be advanced to make full utilization of slag. But use of slag aggregates in road construction is least practiced in India. Limited utilization of slag is made in preparation of hot asphalt mixes. Hence there is a need to study the properties of hot asphalt mixes prepared using slag aggregates. In the present investigation an attempt made to examine the properties of hot asphalt mixes prepared by adding copper slag as major admixture by conducting laboratory studies on strength and performance of the mix. Copper slag used as partial replacement of conventional coarse and fine aggregates respectively. Bituminous concrete grade-II as per Ministry of Road Transport and Highways (MORT&H) specification is selected for the present study. The conventional aggregates were replaced with copper slag in the hot asphalt mixes of bituminous concrete grade-II. Marshall Stability Test (MST) and Indirect Tensile Strength (ITS) were conducted on bituminous concrete grade-II asphalt. From the MST it is noticed that the highest stability for mix containing copper slag and the increase in Marshall Stability is about 7% respectively compared to conventional mix. The tensile strength ratio of mixes containing copper slag for varying temperature of 25oC, 35oC, 45oC, 55oC and 65˚Cwas found to be 1.94, 2.01, 2.16, 2.76, and 4 times higher respectively as compared to conventional mixes.

Index Terms: Copper slag, Marshall Stability Test (MST) and Indirect Tensile Strength (ITS).

1.INTRODUCTION

Transportation sector is an essential part of the national infrastructure which satisfies economic and human need in terms of passenger carriage and cargo transportation. Transportation field is the foundation element of all supply door to door facility. Transportation, without any exception are used by non-production and all economic activity sectors. Updating of the transport system is an optimistic factor for economic and social growth of a country, without an efficient transport system development of economy is hardly possible. The key components for sustainable functionality of transport system are traffic, vehicles and transport infrastructure. [1,3] Construction and maintenance of highway call for the growth of stone material production industry. The extensive utilization of industrialized waste and secondary resources can reduce the increasing need for stone materials. The ferrous and non-ferrous metallurgy is the most accepted wastes used in road construction which are more and more widespread with each year.

1.1 Necessity of slag

Slag's are smelted by product of very high temperature processes, during metal extraction and are mainly used to break up the nonmetal and metal constituent enclosed in the ore. [2] Due to certain properties of slag it is an important basic material for construction of macadam and mineral binder, serving as a foundation for asphalt concrete mixture and production of cement emulsion, which are used in road paving. For crushed stone material power requires substantial energy and material resources at manufacture, utilization of slag as alternate material will effect in substantial decrease in electric power, fuel and manpower cost, which generally reduce the cost price of road construction materials manufactured from slag compared to the products manufactured from rock materials. [5]The discarding of marginal materials directly to the environment can cause ecological problem. This marginal material could be used to manufacture new goods at the same time as admixtures for effective utilization of natural resource and by this environment is protected from waste deposit. [4] Therefore the industrial and scientific community must put forward towards more sustainable practice. There are not many recycling answers for industrial by-product, both in reasonable applications and at an exploratory stage. [18,19]

1.2 Copper Slag

At 1000oC the slag is discharged from the furnace which form hard crystalline dense product when it is cooled slowly and when poured in water it solidifies quickly forming amorphous slag. Air cooled slag has glassy and dark black color appearance. [7] Copper slag has materials such as silica, calcium oxide, aluminum, iron and others. Depending upon the content of iron the specific gravity varies from 2.8 to 3.8. The conventional aggregate unit weight to some extent is lesser than copper slag. About 2.2 to 3 tons Copper slag is formed for every ton of copper production. Copper slag is used in the building industries as fractional or full replacement of either aggregates or cement. Copper slag has many favorable engineering properties for aggregate use, including good abrasion resistance, good stability and good soundness characteristics.

2. OBJECTIVES OF THE PRESENT INVESTIGATION

I. To understand the variability in the strength of the Bituminous Concrete grade-II mix after adding copper slag as a aggregates.

II. To examine the performance of both conventional and modified mixes from the Indirect Tensile Strength Test (ITST).

3. METHODOLOGY OF PRESENT STUDY

The assessment study was done to understand the possibility of use of slag aggregates in bituminous road construction. Accordingly to laboratory studies and comparative studies on hot bituminous mixes with and without slag aggregate were performed. [6] The intention of present study is to study the likelihood of using slag aggregates in Bituminous Concrete grade-II mix. [9,10] The comparative study on the strength and performance of hot bituminous mix containing slag and conventional aggregate were carried out.[12] The bituminous mix properties were studied by carrying out MST, ITS test and RLF test in the laboratory. The step by step methodology adopted in the present investigation has been presented in the figure 1.

3.1 Data collection

The slag aggregate gradation and conventional gradation was compatible with bituminous concrete grade-II as per MoRT&H. The natural aggregates from Ramnagar quarry, Bangalore, copper slag has been collected from Chitradurga, Karnataka state. The basic tests on conventional and slag aggregate were performed to know their basic mechanical properties so that the slag aggregate may be employed to replace conventional aggregate in bituminous concrete grade-II mix. The basic test gave the acceptable result with respect to all the basic properties of slag aggregates; hence they were selected as partial replacement material to conventional aggregates in the above prescribed mix.

3.2 Laboratory testing

3.2.1. Marshall Stability Test (MST)

The MST was performed according to ASTM D 6926-10. Around 1200g of aggregate and filler were taken for the preparation of the specimen. At first the mould was heated for compaction temperature of 138oC to 149oC and the aggregates were heated to a temperature of 175oC-190oC and trial percent of bitumen was heated to flowing temperature of 121oC-125oC and they were mixed properly and transferred to the mould and then the mix was compacted at temperature of 138oC to 149oC with 75 blow on both the sides. [8,11] This procedure was repeated for different binder content. The prepared specimen was then tested on Marshall testing setup. Prior to testing the specimens were kept in water bath for 60 min at 60oC and then the specimens was kept on a Marshall Test head. Stability is found by applying the load at the rate of 50.8mm/min till the specimen fails and simultaneously the specimen deformation in mm was noted which gives the flow value of the mix specimen.

3.2.2. Indirect Tensile Strength Test (ITST)

The ITST was performed using the same Marshall Test apparatus with a deformation rate of 50.8 mm per minute. A vertical compressive load was applied along the vertical diametrical plane and the load was measured with the help of proving ring. [13] Two loading strips made of stainless steel with dimensions of 13mm wide, 13mm deep and 75mm long were used to transfer the applied load on to the specimen. The internal diameter of the strip was same as that of a Marshall Specimen. The ITST was conducted as per ASTM D6931-12 for both conventional and modified mixes with varying replacement of coarse and fine slag aggregates. The following formula was used to calculate indirect tensile strength.

$$\mathrm{ST} = \frac{2\mathrm{F}}{\pi \times \mathrm{h} \times \mathrm{d}}$$

4. Results and Discussions

The basic tests performed on conventional aggregates, slag aggregates, bitumen and filler material for their basic properties exhibited satisfactory results and hence were used in the present study. The effect of slag aggregates as a partial replacement to conventional aggregates on different properties like, Marshall properties, temperature and moisture sensitivity and fatigue properties for hot bituminous mixes have been studied.

4.1 Marshall Test

Hot bituminous mixes prepared with conventional aggregates and modified slag aggregates mix was subjected to Marshall Test. Slag aggregates were used to replace conventional coarse and fine aggregates partially in each case. [14,15] VG-30, bitumen was used as binding material for all the mixes. The present study focused to understand the effects of using copper slag aggregates as replacement to fine aggregates on the performance of hot bituminous mix. The Marshall stability of mixes containing blast furnace slag and copper slag was found to be 9.0% and 7.0% respectively higher as compared to conventional mix. The Marshall Tests were carried out on bituminous mixes for bituminous concrete grade-II with completely replacing 4.75 mm down size with blast furnace slag and 300 mm down size with copper slag. The test results obtained are presented in Table 2 and 3.

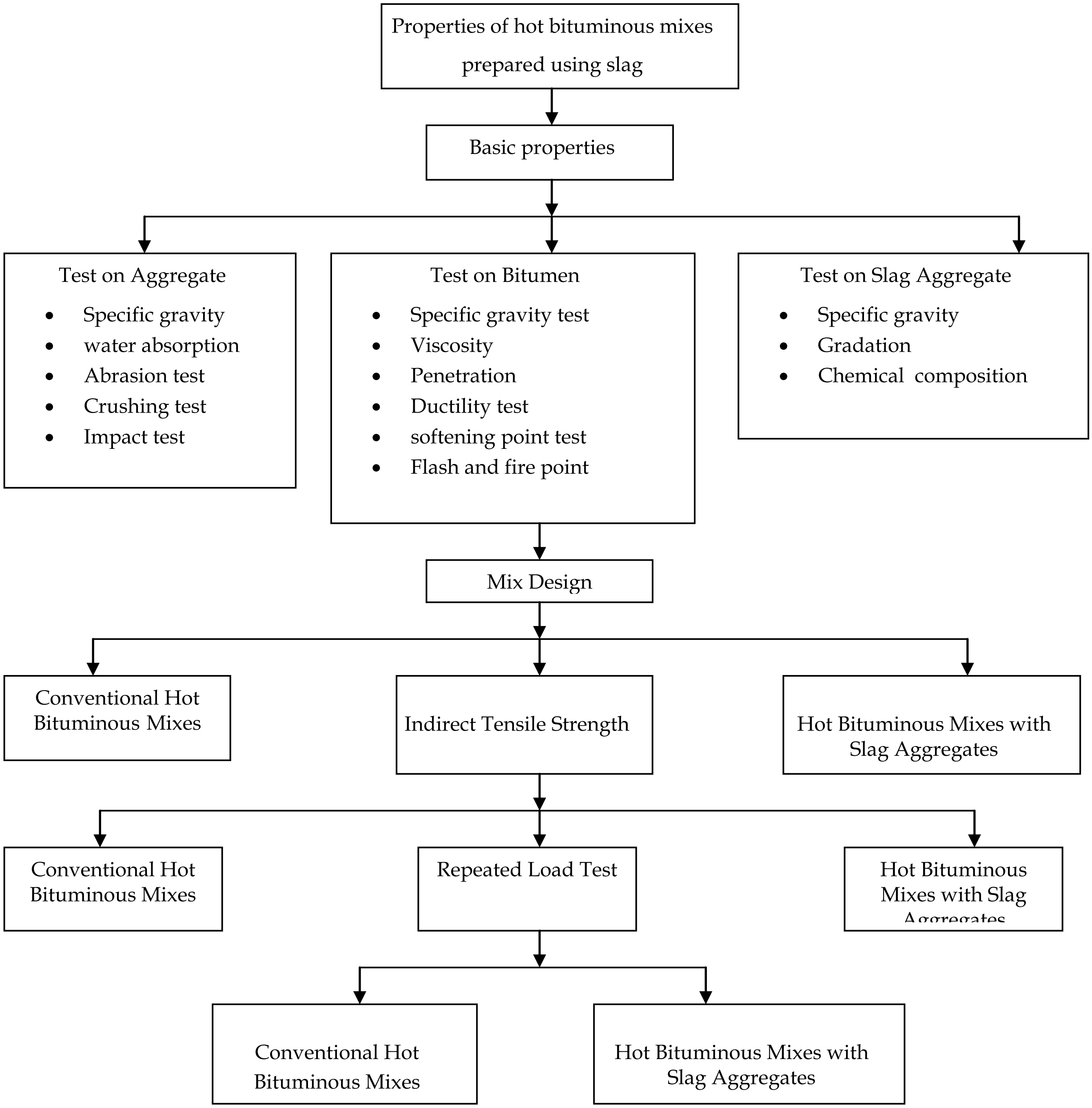

Figure 1: *Step by step methodology used in the present investigation.*

Table 2: *Marshall Properties of Bituminous Mix with Conventional Aggregate*

S. No	Bitumen content (%)	Bulk Density KN/m3	Air Voids (%)	Voids in Bitumen (%)	Voids in mineral aggregate (%)	Voids filled with bitumen (%)	Flow (mm)	Stability (Kg)
1	4.5	2.47	5.7	11.1	16.9	65.8	2.8	3203
2	5	2.50	4.0	12.6	16.5	75.7	3.1	3504
3	5.5	2.48	3.96	13.7	17.6	77.5	3.1	3108
4	6	2.47	3.83	14.8	18.7	79.4	3.9	2160
5	6.5	2.46	3.41	16.0	19.4	82.4	5.2	2025

Table 3: *Marshall Properties of Bituminous Mix with Copper Slag*

S. No	Bitumen content (%)	Bulk Density KN/m3	Air Voids (%)	Voids in Bitumen (%)	Voids in mineral aggregate (%)	Voids filled with bitumen (%)	Flow (mm)	Stability (Kg)
1	4.5	2.38	6.1	10.7	16.8	63.7	1.9	2340
2	5	2.39	5.0	11.9	16.9	70.5	2.7	2884
3	5.5	2.40	3.9	13.2	17.2	76.8	2.9	3309
4	6	2.49	3.7	14.3	18.0	79.4	3.4	2602
5	6.5	2.38	3.5	15.4	19.0	81.2	4.6	1947

4.2 Indirect Tensile Strength Test

ITST were conducted on the hot bituminous mixes casted with and without slag aggregates replacement, at varying temperatures of 25oC, 35oC, 45oC, 55oC and 65oC and Tensile strength ratio was also calculated according to ASTM D 6931. Test results obtained and Tensile Strength for conventional mix and bituminous mix containing copper slag is presented in Table 4. The indirect tensile strength of bituminous mix containing slag aggregates was found to be more than conventional mix at different test temperatures. [16,17] The test results also showed that bituminous mix containing slag aggregates exhibited better tensile strength as compared to conventional mix. The tensile strength value of bituminous mix at varying temperature of 25oC, 35oC, 45oC, 55oC and 65˚C containing copper slag are 1.94, 2.01, 2.16, 2.76, 4

Table 4: *Indirect Tensile Strength Test Result*

S. no	Temperature °C	Indirect tensile strength, (Mpa)	
		Conventional mix	Copper slag
1	25	0.72	1.40
2	35	0.53	1.07
3	45	0.25	0.64
4	55	0.17	0.47
5	65	0.09	0.36

Table 5: *Fatigue Test Result for Conventional Mix at 20% Stress Level for Varying Temperature*

Stress level (%)	Temperature oC	Applied load (N)	Height of the Specimen (mm)	Stress Mpa	Resilient Horizontal Deformation mm	Resilient Modulus Mpa	Initial Tensile Strain, Micro Strain	Fatigue Life No of Cycles
20	25	1540	65	0.15081	0.0055	2670.77	115.7573766	3822
	35	1130	64.5	0.11152	0.0061	1780.66	128.3854541	2789
	45	540	64.5	0.05329	0.0076	682.987	159.9556477	1506
	55	360	64.5	0.03553	0.0089	388.816	187.3164822	780
	65	200	65	0.01959	0.0148	128.898	311.4925772	568

Table 6: *Fatigue Test Result for Copper Slag Mix at 20% Stress Level for Varying Temperature*

Stress level (%)	Temperature oC	Applied load (N)	Height of the Specimen (mm)	Stress Mpa	Resilient Horizontal Deformation mm	Resilient Modulus Mpa	Initial Tensile Strain, Micro Strain	Fatigue Life No of Cycles
20	25	3000	64.5	0.29606	0.00372	7751.94	78.2940802	4523
	35	2260	64.5	0.22303	0.00398	5458.3	83.7662471	2021
	45	1380	64.5	0.13619	0.0053	2502.85	111.5480175	1564
	55	1010	64.5	0.09967	0.00596	1628.95	125.4389027	1116
	65	780	64.5	0.07698	0.00935	801.89	196.7875403	246

5. CONCLUSIONS

The laboratory investigation was carried out on conventional mixes, bituminous mixes with copper slag. Various tests like Marshall stability test, fatigue test and indirect tensile strength tests are conducted and the following conclusion were made from the test results.

1. The MST conducted on mix containing copper slag were found have 7% greater stability respectively than the conventional mixes. This may be happened by the high value of specific gravity of slag.
2. Optimum binding mix content for mixes containing copper slag was 0.5% less respectively compared to the conventional mix. This is due to less voids in the mix containing slag.
3. The indirect tensile strength of copper slag mix for all temparature 25oC, 35oC, 45oC, 55oC and 60oC are more compared to conventional mixes. This indicates that the mix containing slags as aggregates will have high fatigue and rutting resistance. But indirect tensile strength of slag mixes and conventional mix decreased with increase in temparature.
4. The repeted load fatigue test results showed that the resilient modulus of copper slag is better than the conventional mixs.

The tests showed satisfactory results thus employment of slag aggregate mixes in bituminous concrete grade II is encouraging.

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