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A Study of Alternative Materials for Flexible Pavement using Copper Slag, Fly Ash and Waste Plastics in Bituminous Concrete

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***Abstract*: - In this paper an attempt has been made to utilize the copper slag, fly ash and waste plastics in bituminous concrete. The copper slag is produced as waste from roasting of copper, in which sulphur is eliminated. Copper slag is used as a fine aggregate by varying the percentage from 20%, 30% and 40% with stone dust and fly ash as a filler material and also with waste plastic, provides good interlocking and eventually improves volumetric and mechanical properties of bituminous mixes. Marshall test has been considered for the purpose of mix design as well as evaluation of paving mixes. The Marshall property such as stability, flow value, % of air voids, void filled in mineral aggregate (VMA), void filled in bitumen (VFB) and optimum bitumen content was found**

Key words: Copper Slag, Stone Dust, Fly Ash, Plastic Waste, Marshall Test.

INTRODUCTION

In India, there is great demand of aggregates mainly from Civil Engineering industry for road and concrete constructions. The construction of highways and development of several expressways for high-speed corridors exert tremendous pressure on natural resources. Many highway agencies, private organizations, and individuals are in the process of completing a wide variety of studies and research projects concerning the feasibility, environmental suitability, and performance of using waste industrial products in highway construction.

These studies try to match society's need for safe and economic disposal of waste materials with the highway industry's need for better and more cost-effective construction materials. This study aims to explore the potential use of copper slag (CS) as fine aggregate. When CS is used as an aggregate replacement in an asphalt mixture, the leaching that copper slag could generate is controlled, as each of the slag particles is coated by asphalt binder and sealed of all voids. Fly ash is a mineral by-product of coal combustion in Thermal power projects, used as a filler in bituminous concrete and Plastic is versatile material which is used as binder with metal aggregate in the design of bituminous mixes for Bituminous Concrete (BC).

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In India, about 60000 MT of copper slag is produced per month at the rate of 1.8-2.2 tonnes of slag per tonne of metal produced. The slag is highly stable and non-leachable in nature. With increasing scarcity of river sand and natural aggregates across the country, construction sector is under tremendous pressure to explore alternative to these basic construction material to meet the growing demand of infrastructure demands. In India, three copper producers namely Sterlite, Birla Copper and Hindustan Copper Produce around 6-6.5 tones of slag at different sites. The companies take initiatives to utilize CS on road and abrasives. Therefore, Copper Slag is a suitable alternative material to these resources.

MATERIAL AND METHODS

Materials Used

Bitumen: The bitumen used in this study was tested in the laboratory. The physical properties such as Softening Point, Ductility, Water Content, Viscosity, Flash Point and Specific Gravity were evaluated and the results are tabulated in Table 1.

Table 1 – Properties of VG 30 grade bitumen

Properties	Unit	Method of test	Test value
Softening Point, R & B	°C	IS 1205:1978	67
Ductility at 25 °C	Cm	IS 1208:1978	75+
Water content	% wt	IS 1211:1978	0.2
Viscosity at 60 °C	Poise	IS 1206:1978	2600
Viscosity at 135 °C	Cst	IS 1206:1978	410
Flash point, COC	°C	IS 1448	230
Specific gravity at 27 °C	--	IS 1201:1978	0.99

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Aggregates: The aggregates present in BC should be highly durable, strong and tough to resist heavy loads. They undergo internal friction and high rubbing; hence the physical properties of these aggregates should be given high importance. Aggregates having sufficient strength, hardness, toughness, specific gravity and shape are chosen. The properties of aggregates used in the present study are tabulated in Table 2.

Table 1 – Properties of Coarse and Fine aggregates

Properties	Unit	Method of test	Test value
Properties of coarse aggregates			
Bulk specific gravity	–	IS 2386(I)	2.68
Apparent specific gravity	–	IS 2386(I)	2.72
Impact Value	%	IS 2386(IV)	18
Flakiness and Elongation (Combined) Index	%	IS 2386(I)	40
Water absorption	%	IS 2386(Part -3)	0.5
Properties of fine aggregates			
Bulk specific gravity	–	IS 2386(I)	2.68
Apparent specific gravity	–	IS 2386(I)	2.72
Copper slag			
Unit weight	kg/m^3	IS 2386(I)	2800 - 3800
Absorption	%	IS 2386(Part -3)	0.13

Aggregate Gradation Adopted

Aggregate grading that satisfied the requirement of the Ministry of Road Transport and Highways (MoRT&H, 2001) specification for midpoint gradation for Grading- II of Bituminous Concrete were selected. The aggregate gradation for BC is shown in Table -3.

TABLE-3 AGGREGATE GRADATION FOR BITUMEN CONTENT

Combination	Volume dosage (%)			
	AG	CS	FLY	Pla (% in binder)
I	100			
II	80	20		
III	70	30		
IV	60	40		
V	73	20	7	
VI	63	30	7	
VII	53	40	7	
VIII	73	20	7	8
IX	63	30	7	8
X	53	40	7	8

Aggregates (AG), Copper slag (CS), Fly ash (FLY) and Plastic (Pla)

Design of Bituminous Concrete Mix

Marshall's Method of mix design as per ASTM D-1559 was adopted for this study. The aggregates of various grades were sieved through various IS Sieves and they were kept in various containers with proper marking. The mixing of materials required for mould formation was done as needful quantities of coarse aggregate, fine aggregate & fillers were taken in an iron container. The Marshall Test specimens were prepared by adding 4.5, 5.0, 5.5, and 6.0 per cent of bitumen by weight of aggregates. Please See figure-1. Following procedure was adopted to prepare the samples:

The aggregates were proportioned and mixed (aggregate and filler contribute to 1200gm). The aggregates were heated to temperature of 140^0C-165^0C. The bitumen heated to140^0C to 160^0C was added in required quantity i.e., 4.5, 5.0, 5.5, and 6.0 per cent by weight of aggregates and was thoroughly mixed at a desired temperature of 155^0C. The mix was placed in preheated mould of 10.16 cm diameter and 6.35 cm height with a base plate. After leveling the top surface, the mix was compacted by a rammer of 4.54 kg weight and 45.7 cm height of fall with 75 blows on either side at temperature of 100^0C-115^0C.

Three specimens were prepared for different bitumen content (4.5, 5.0, 5.5, and 6.0 per cent) by weight of aggregates. Compacted specimens were removed after 24 hours using specimen extractor. The diameter, mean height, weight in air and weight in water of the specimens were noted.

Fig. 1 Marshall Apparatus

RESULTS AND DISCUSSSION

The Following Graphs shows the result of Marshall properties such as Marshall stability, Flow, Bulk Density, volume of voids, voids in mineral aggregate, voids filled with bitumen. The Marshall stability for the 20% the addition of the copper slag to the bitumen mix as a replacement of fine aggregate is higher than 30%and 40%. Please See Figure-2. As the bitumen content increases the flow value increases. The bulk density increases with the addition of copper slag to the mix due to the fact that the specific gravity of copper slag is high compared to the specific gravity of natural aggregate.

The volume of voids is lower when fly ash is used as the filler material. This is due to the fact that fly ash being too fine having highest surface area fills the voids more effectively. The voids in the mineral aggregate and void filled with bitumen increases with the increase in the bitumen content. Due to the use of fly ash and copper slag in the bituminous mix, the disposal problem and the environmental problem can be reduced to certain extent. Please See Figure-2 to 4.

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Once the physical characterization of the materials is obtained, the optimum binder content was determined for the ten combinations. The bulk density curve shows that an increase in incorporation of CS produces an increase in bulk density, achieving denser mixes with the conventional aggregates. Due to the angularity of the CS the interlocking of aggregates increases thereby reduces the binder content. While adding fly ash as filler material the bitumen requirement gets reduced.

Stability value decreases when compared with the conventional one. The increase in addition of CS from 20% to 40% reduces the stability value considerably. Reduction of stability was observed while adding Fly ash. The fines of Fly ash increases the flow value thereby considerably reducing the stability of the mix and it is shown in Table -4. Copper slag helps to reduce the quantity of asphalt binder to be used in the mix thereby optimizing the air void content.

Table 4 – Properties of bituminous mixes for the combination

Combination	Binder content (By weight of mix)	Bulk density, g/cc	Air voids, % (3-5 %)	VMA, % 14	VFB, % (65-75)	Stability , kg	Flow, mm
I	5.38	2.385	4.188	16.789	75	1863	2.68
II	5.48	2.429	4.169	17.237	75	1832	2.91
III	5.39	2.517	4.247	17.568	75	1646	2.98
IV	5.37	2.611	5.936	19.708	70	1204	3.43
V	5.35	2.405	4.134	16.758	75	1723	2.92
VI	5.32	2.496	4.150	17.162	75	1442	3.20
VII	5.88	2.610	4.023	19.088	79	1018	3.49
VIII	5.29	2.409	4.083	16.597	75	1767	2.84
IX	5.26	2.498	4.161	17.050	76	1518	3.06
X	5.94	2.606	4.078	19.278	79	1128	3.48

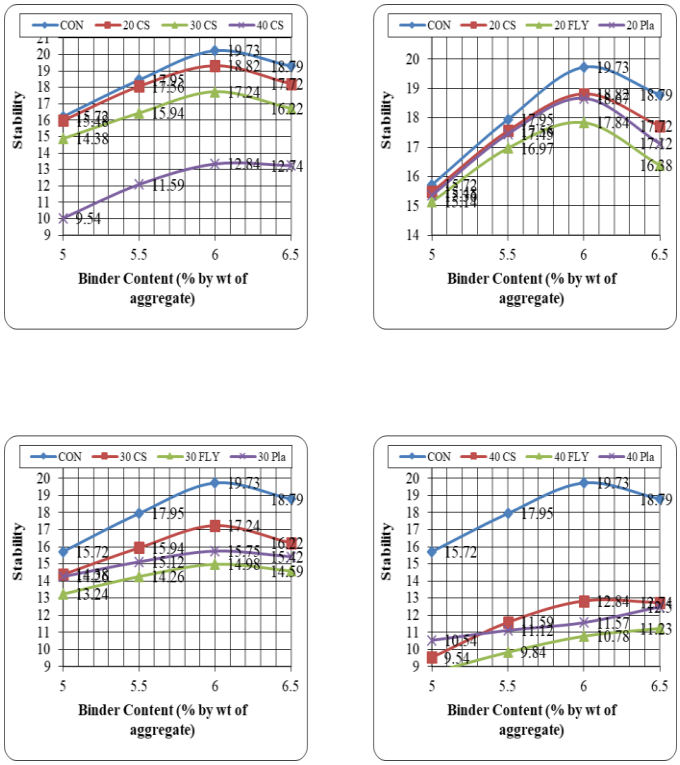

Figure-2 Binder Content Vs Stability

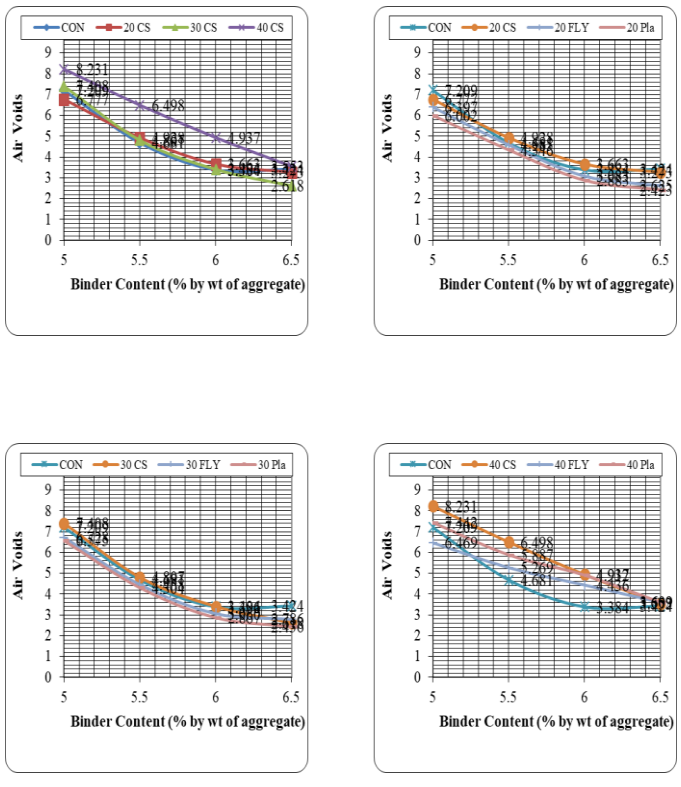

Figure-3 Binder Content Vs Air voids

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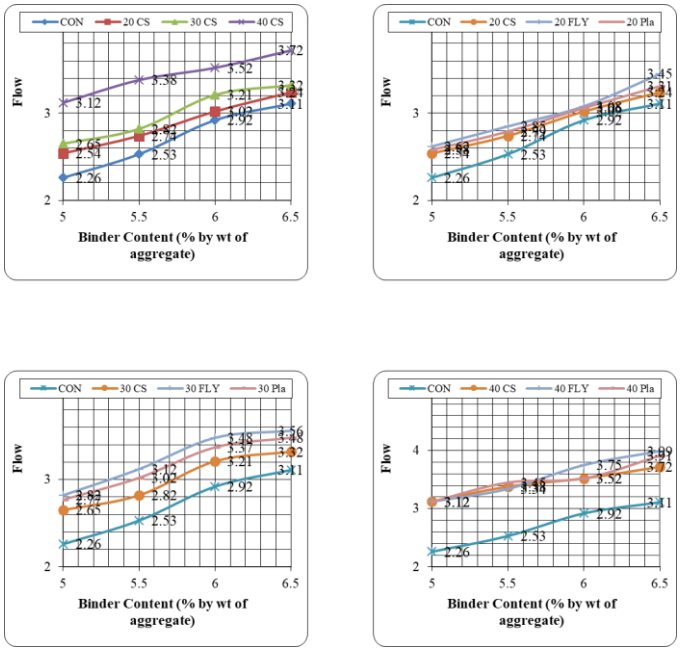

Figure 4 Binder Content Vs Flow

CONCLUSIONS

Addition of copper slag as fine aggregates in bituminous mix (BC) improves good interlocking and improves the volumetric and mechanical properties of the mix. Because of its improved property it can be used as a substitute for the crusher dust which is used in the conventional bituminous mix. Addition of Fly ash and Plastics in the bituminous mix finds an alternate way of its disposal. A field study using all the alternate materials may enhance the application of the materials in the current scenario of scarcity of conventional materials.

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