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Performance Evaluation of Hot Mix Asphalt and Warm Mix Asphalt With Incorporation of Copper Slag

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Abstract*— Construction of roads requires huge quantity of aggregates not only for the paving surface but also for the base course and sub base course. And there is depletion of natural resources where we are using m-sand instead of natural sand and on the other hand there is lots of waste material been dumped on the land. And these kinds of materials can utilized for the construction purposes, out of which copper slag is one such material. Copper Slag (CS) is a by- product obtained during the matte smelting and refining of copper. It is classified as waste materials and, therefore, is taken into account as an environmental issue to deal with. It can be effectively used for construction of pavement layers. On the other hand, in order to save energy and reduce the amount of pollutants that are being released in the process of asphalt production, Warm Mix Asphalt (WMA) technology can also be employed. So this paper presents the influence of replacing fine aggregates by copper slag on the performance of warm mix asphalt and hot mix asphalt. We are incorporating copper slag in the asphalt mixes with varying percentages like 0%, 10%, 20%, and 30% by total weight of aggregate. And mix design for Bituminous concrete grade-2 is been performed for bitumen percentages of 5%, 5.25%, 5.5% and 5.75%. The specimen prepared with this mix design was evaluated for the stability properties. And it was observed that the maximum stability of 9.23KN and 9.1KN was achieved for OBC of 5.5% and copper slag content of 20% for HMA and WMA respectively.

Keywords*— Copper Slag (CS), Warm Mix Asphalt (WMA), Hot Mix Asphalt (HMA) & Bituminous Concrete (BC).

I. INTRODUCTION

In India, there's great demand of aggregates mainly from engineering industry for road and concrete constructions. But now a days it is very difficult problem for available of fine aggregates. So researchers developed waste management strategies to use for replacement of fine aggregates for specific need. Natural resources are depleting worldwide while at the same time the generated wastes from the industry are increasing substantially. The sustainable development for construction involves the use of nonconventional and innovative materials, and recycling of waste materials so on compensate the shortage of natural resources and to find alternative ways conserving the environment.

Copper slag is one among the materials that's considered as a waste which could have a promising future in housing industry as partial or full substitute of either cement or aggregates. It is a by-product obtained during the matte smelting and refining of copper. To produce every ton of copper, approximately 2.2–3.0 tons copper slag is generated as a by-product material. Copper slag may be a by-product material produced from the method of producing copper. As the copper settles down in the smelter, it has a higher density, impurities stay in the top layer and then are transported to a water basin with a low temperature for solidification. The end product may be a solid, hard material that goes to the crusher for further processing. Copper slag may be a by-product obtained during the matte smelting and refining of copper. Copper slag utilized in this work was brought from Sterlite Industries Ltd (SIL), Tuticorin, Tamil Nadu, India. SIL is producing Copper slag during the manufacture of copper metal. Currently, about 2600 plenty of Copper slag is produced per day and a complete accumulation of around 1.5 million tons.

To produce every ton of copper, approximately 2.2–3.0 tons copper slag is generated as a by- product material. Utilization of copper slag in applications like Portland cement substitution and/or as aggregates has threefold advantages of eliminating the costs of dumping, reducing the worth of concrete, and minimizing air pollution problems.

In developing countries like India the dramatic growth in vehicular traffic have augmented axle loads and increased tire pressure on the pavements. Compaction and type of binder and aggregates used in flexible pavements plays a major role in the performance of these pavements. Mix properties, like stability and air voids are highly hooked in to the degree and therefore the method of compaction. In this paper attempt was done to use CS as additive in bituminous mix to evaluate physical and mechanical properties of ASPHALT, CS and to develop volumetric based mix design for ASPHALT and WMA with incorporation of copper slag.

II. MATERIALS

a. Copper Slag (CS) collected from Sterlite Industries Ltd (SIL), Tuticorin, and Tamil Nadu.

b. Aggregate nearby site.

c. Asphalt

III. METHODOLOGY

Basic property of material collected are tested as per IS standard.

a. Testing of Aggregate as per IS: 2386 specification

b. Testing of Copper Slag as per IS: 2386 specification

c. Testing of Asphalt as per IS: 73 – 2013 specification

d. WMA mix proportion for varying aggregate precent by 0, 10, 20 and 30% of copper slag by Marshall Method.

IV. RESULT AND DISCUSSION

Tests on aggregate were conducted and physical properties are show in Table below. Tests were conducted as per IS 2386 part 1 to part 4.

A. Test on Aggregate

TABLE I
TEST PROPERTY OF COURSE AGGREGATE

Sl. No,	Property of Course Aggregate		
	Test	**Result**	**Limit**
1	Specific Gravity	2.62	-
2	Impact Value	18.34%	Max 24%
3	Abrasion Value	19.5%	Max 30%
4	Crushing Value	22.13%	-
5	Flakiness index	23.84%	Max 15%
6	Elongation	20.22%	Max 20%

B. Test on Copper Slag

Copper slag collected in field are tested in laboratory for its properties and found specific gravity of 3.67.

C. Test on Asphalt

Asphalt (VG – 30) collected are tested in laboratory for its properties and found following reading

TABLE III
TEST PROPERTY OF VG – 30 GRADE

Sl. No,	Property of Asphalt		
	Test	**Result**	**Standard value as per IS: 73 -2013**
1	Penetration test	60/70	45mm(min)
2	Softening point	53.5*C	47*C (min)
3	Ductility	68cm	40cm (min)
4	Flash point	183.3*C	220*C (min)
5	Fire point	198.3*C	-
6	Specific gravity	0.98	0.97 to 1.02

D. Test result on Marshall Sample

Approximately 1200gm of aggregates and filler is heated to a temperature of 175-190°C for ASPHALT and 140-150°C for WMA. Then heated aggregates and bitumen are thoroughly mixed. The mix is placed in a preheated mould and compacted by a rammer with 50 blows on either side. The weight of mixed aggregates taken for the preparation of the specimen may be suitably altered to obtain a compacted thickness of 63.5+/-3 mm. prepare the specimens as said above by varying the bitumen content by +0.5% and copper slag content by 10%, 20% and 30%.

The quantity of material required for preparing Bituminous Concrete mix are calculated by mix design. Detail are tabulated in following table 3.

TABLE IIIII
QUANTITY OF MATERIAL FOR BITUMINOUS CONCRETE MIX

Copper Slag (%)	**Aggregate Size (g)**			**Copper Slag (g)**	**Bitumen (%)**	**Bitumen (g)**
	20 mm	13 mm	Dust (4.75mm)			
0	57.00	342	741.00	0.00	5	60.00
	56.85	341.1	739.05	0.00	5.25	63.00
	56.70	340.2	737.10	0.00	5.5	66.00
	56.55	339.3	735.15	0.00	5.75	69.00
10	57.00	342	666.90	74.10	5	60.00
	56.85	341.1	665.15	73.91	5.25	63.00
	56.70	340.2	663.39	73.71	5.5	66.00
	56.55	339.3	661.64	73.52	5.75	69.00
20	57.00	342	592.80	148.20	5	60.00
	56.85	341.1	591.24	147.81	5.25	63.00
	56.70	340.2	589.68	147.42	5.5	66.00
	56.55	339.3	588.12	147.03	5.75	69.00
30	57.00	342	518.70	222.30	5	60.00
	56.85	341.1	517.34	221.72	5.25	63.00
	56.70	340.2	515.97	221.13	5.5	66.00
	56.55	339.3	514.61	220.55	5.75	69.00

E. Result of HMA and WMA shows variation in strength property of mix.

Table 4 shows result of HMA for optimum binder content

TABLE IVV
RESULT OF HMA FOR OPTIMUM BINDER CONTENT

Properties	**0% CS**	**10% CS**	**20% CS**	**30% CS**
OBC%	5.5	5.5	5.5	5.5
Stability (KN)	6.91	8.5	9.23	8.1
Flow (mm)	3.05	3.5	3.24	3.2
Air Voids (%)	3.22	3.35	3.86	3.91
VMA%	13.4	13.67	14.1	15.34
Bulk Specific Gravity	2.33	2.43	2.45	2.49

Table 5 shows result of HMA for optimum binder content

TABLE V
RESULT OF WMA FOR OPTIMUM BINDER CONTENT

Properties	0% CS	10% CS	20% CS	30% CS
OBC%	5.5	5.5	5.5	5.5
Stability (KN)	6.52	7.4	9.1	6.93
Flow (mm)	3.5	3.45	3.5	3.1
Air Voids (%)	3.4	4.2	4	4.05
VMA%	13.8	14.4	15.1	15.56
Bulk Specific Gravity	2.4	2.42	2.47	2.53

V. CONCLUSIONS

This study was investigated to know the performance evaluation of HMA and WMA which contained copper slag. Copper slag content of 10%, 20% and 30% by weight of the aggregate was incorporated in the mix having different binder content. From the result it was concluded that the stability increases with increase in copper slag content for up to 20%. It showed significant results at optimum binder content of 5.5%. The maximum stability was achieved in both HMA and WMA with OBC of 5.5% and copper slag content of 20%. The stability value at 20% copper slag was increased by almost 40% for HMA. The stability value at 20% copper slag was increase by about 33% for WMA. It proves to be environment friendly if WMA with 20% copper slag is used instead of conventional HMA. Huge area of land will be saved from depositing of copper slag, if it is utilized properly.

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