USE OF ALTERNATIVE NON CONVENTIONAL AGGREGATES FOR RIGID PAVEMENTS

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Abstract— *The need to preserve diminishing natural resources and increase the usage, recycling or reprocessing, with disposal being the last resort has become an issue of great importance in the modern society . Many researches and policies have been driven in this support to ensure that these sustainable goals are met. Use of iron and steel making slags represent success story consistent with these goals. Generated as by-products in the manufacture of iron and steel, these reprocessed materials provide opportunities in road construction and maintenance to recycle on a large scale. Typically, for ore feed containing 60 to 65% iron, blast furnace (BF) slag production ranges from about 300 to 540 kg per tonne of pig or crude iron produced. Lower grade ores yield much higher slag fractions, sometimes as high as one tonne of slag per tonne of pig iron produced. Steel slag output is approximately 20% by mass of the crude steel output. Hence, an effort is made in this study to use slag as aggregates that aims in reducing the carbon footprint of steel sector in line with the INDC targets. This study is based on experimental analysis of designing a concrete mix with M50 grade using Slag Aggregates i.e, Steel Slag, Air-Cooled Blast Furnace Slag and Granulated Blast Furnace Slag as a partial replacement by weight for fine and coarse aggregate. The mixes are designed as per IS: 10262-2009. 16 mix proportions were made with combinations of natural aggregates and non traditional aggregates. Slump value, compressive strength and flexural strength of various mixes were determined. Concrete mixes with coarse slag aggregates show better performance than natural aggregates. Further, cost comparison is made for a cement concrete pavement with and without the use of slag aggregates. The results show a significant increase in compressive strength and flexural strength by 24.33 % and 45 % respectively and an average cost saving of 22% in rigid pavement or road construction.*

Keywords— carbon footprint, non conventional aggregates, steel slag, sustainable goals

I. INTRODUCTION

Due to demand for reducing overexploitation of the natural quarries, the use of the waste materials has become an increasing practice in the sustainable construction industry. Waste materials whose application is possible in road construction are divided into three basic groups: re- usable construction materials, industry by-products and natural construction materials of a lower usability value.

An attempt is made in this study to use an industry by- product from steel production. Primarily, two slag types are formed in the steel industry- Blast furnace slag and steel slag. Steel slag is generated as a melt at about 1600°C during steelmaking from hot metal in the amount of 15%– 20% per equivalent unit of steel. Indian National steel policy 2017 considers all waste materials as an economic asset, and promotes use of iron and steel slag in alternate uses like road making, rail ballast, construction material, soil conditioner etc

II. LITERATURE REVIEW

Steel slags have been successfully utilized for the construction of roads in wearing course, base and sub base as well. Especially Europe, Canada, Australia and USA have not treated it as an industrial waste but a useful construction material, and successfully using steel slag as aggregate in surfacing and base of flexible pavements. Stock and Ibberson, reported the use of steel slag in bituminous road construction in South Yorkshire and its environs for the past 60 years. Above 300,000 tons of steel slag per year was utilized for road construction. As an assessment of skid resistance of asphalt surfaces incorporating steel slag, side force coefficient Routine Investigation Machine (SCRIM) was measured on various categories of roads (100 mm and 14 mm surface dressings). The surveys show that steel slag road surfaces have at least as good long-term skid resistance properties as those of comparable natural aggregate road surfaces under similar traffic conditions . SSA has also been successfully utilized countries with high ambient temperatures that cause major problems in asphalt surfaces. Amongst the various countries around the world with hot climates, such as Singapore, Malaysia, Australia, South Africa, Saudi Arabia and Italy, have already realized the superior properties of steel slag asphalt. Pazhani and Jeyaraj studied feasibility of Granulated Blast Furnace slag (GBFS) for production of high performance concrete. Use of steel slag in asphaltic concrete minimizes potential expansion and takes advantage of the positive features in giving high stability, stripping resistant asphalt mixes with excellent skid resistance.

Kundan Pawar, have studied the feasibility of Blast furnace slag produced from steel plant by understanding the effect of replacing conventional materials by alternate raw materials like blast furnace slag. A study on durability of the concrete made with Electric Arc Furnace slag as an aggregate was done by Manso and Gonzalez, and the results showed that it was acceptable. The concrete mixes using conditioned EAF slag showed good fresh and hardened properties and acceptable behavior against aggressive environmental conditions. Comparison of steel slag and crushed limestone aggregate was done by Maslehuddin. They studied the mechanical properties and durability characteristics of steel slag aggregate concrete in comparison with limestone aggregates. Their results showed that the durability and physical properties of concrete with steel slag aggregates was better than limestone aggregates

III. INVESTIGATION

A. *Material properties*

The physical properties of steel slag were examined and are stated in Table 1. The specific gravity of SSA was found to be 2.58.

**TABLE I
PHYSICAL PROPERTIES FOR STEEL SLAG AGGREGATES**

Properties	Percentage
Water absorption	2.1
Crushing strength	25.3
Impact value	19
Los Angeles Abrasion	22

The various slags used in the investigation are shown in figures from 1 to 5.

FIG 1. AIR-COOLED BLAST FURNACE SLAG IN FINE AGGREGATE FORM

FIG 2. GRANULATED BLAST FURNACE SLAG

FIG 3. STEEL SLAG IN COARSE AGGREGATE FORM

FIG 4. AIR COOLED BLAST FURNACE SLAG IN COARSE AGGREGATE FORM

B. Mix Proportioning

A single batch of Portland Pozzolona cement (PPC) was used in this study. Steel slag was collected from the Harsco Metals and Minerals, India. It was crushed down to 20 mm size for use as a coarse aggregate in concrete. The sand used in concrete was local river sand and the natural coarse aggregate was 20 mm crushed granite. The study is for replacing natural coarse aggregate (NCA) with steel slag aggregate (SSA) for pavement concrete. The concrete mix selected is M45 and is proportioned as per Indian Roads Congress. The quantity of materials per m^3 of concrete is shown in Table 2. The obtained Mix proportion is 1:1.35:1.52:0.37 (Cement : FA: CA : Water-cement ratio).

TABLE II.
QUANTITIES OF MATERIALS REQUIRED FOR 1M3 OF CONCRETE

C. Details of test Specimen

Concrete cubes of size 150 x150 x 150 mm, were cast for compressive strength tests and Cylinders, 100 x 300 mm, were cast for splitting tensile strength test and to determine the flexural strength, 100 x 100 x 500 mm prisms were cast. All specimens were demoulded 24 hrs after casting, and then cured for 28 days

TABLE III.
NOTATION OF DIFFERENT PROPORTIONS

S.No	Mix type	Coarse aggregates			Fine aggregates			
		N.A %	A.BS %	S.S %	N.A %	A.BS %	S.S %	G.B.S %
1	PROP0	100	-	-	100	-	-	-
2	PROP1	80	20	-	75	25	-	-
3	PROP2	80	20	-	25	50	25	-
4	PROP3	65	-	35	50			50
5	PROP4	60	-	40	-	-	-	100
6	PROP5	60	20	20	25	75	-	-
7	PROP6	50	50	-	75	-	25	-
8	PROP7	50	50	-	50	-	-	50
9	PROP8	50	-	50	-	-	-	100
10	PROP9	50	-	50	50		50	-
11	PROP10	50	-	50	25	25	25	25

12	PRO P11	25	50	25	25	50	25	-
13	PRO P12	25	25	50	25	25	50	-
14	PRO P13	25	25	50	-	50	50	-
15	PRO P14	25	50	25	-	25	25	50
16	PRO P15	25	25	50	-	-	50	50

Where,
N.A =Natural Aggregates (Traditional Aggregates)
S.S=Steel Slag
A.B.S=Air Cooled Blast Furnace Slag
G.B.S=Granulated Blast Furnace Slag

RESULTS

A. *Slump Test*

From the slump test it is found that the value increases with percentage increase of S.S and A.B.S. The mixture ID is given as per table 3. Fig. 5 represents the slump values.

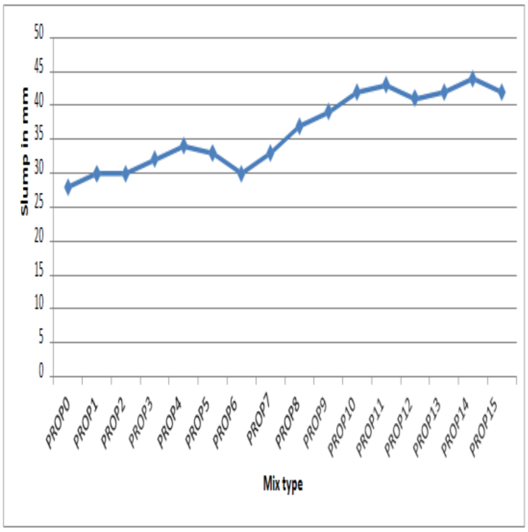

FIG 5. SLUMP VALUES FOR VARIOUS MIX TYPES

A. *Compressive Strength*

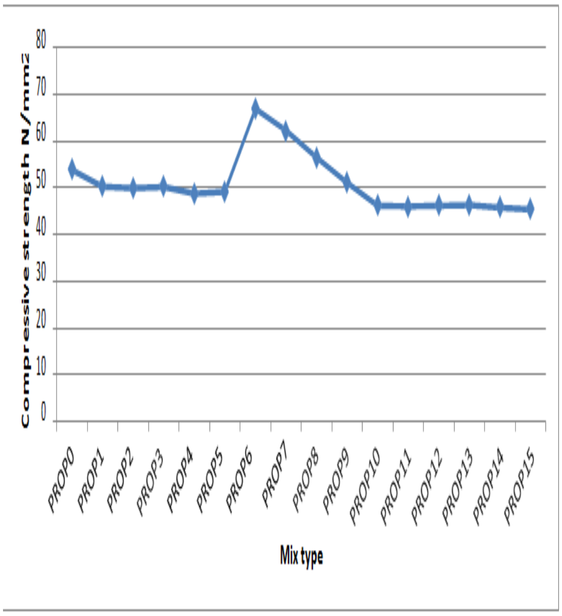

Fig. 6 represents the 28 day compressive strength of

The compressive strength of concrete cubes for above mix proportions were determined.
different percentage of SS and ABS replaced M50 concrete. It shows that the compressive strength decreases with increase in percentage of steel slag.

Flexural Strength

In this test, three specimens from each group were subjected to flexure using symmetrical two point loading until failure occurs.

Flexural strength of the conventional and slag replaced concrete is given in Fig. 7. Flexural strength decreases with increase in percentage of steel slag. But all the batches of SS and ABS replaced concrete have sufficiently good flexural strength.

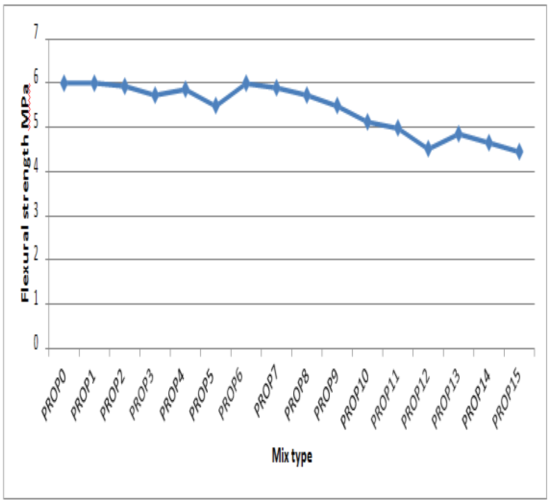

FIG 7. FLEXURAL STRENGTH TEST RESULTS FOR VARIOUS PROPORTIONS

It has been observed that Proportion 6 with 50% natural aggregates and 50% slag aggregates have performed well with respect to slump, compressive strength and flexural strength .

IV. PAVEMENT DESIGN

A cement concrete pavement was designed for a four- lane divided National highway with two lanes in each direction in the state of Telangana. Design the pavement a period of 30 years. Lane width=3.5m; transverse joint spacing =4.5m. It is expected that the road will carry about 3000 commercial vehicles per day in each direction. Axle load survey of commercial vehicles indicated that the percentages of front singe (steering) axle, roar single axle, rear tandem axle and rear tandem axle are 45%. 15%. 25% and 15% respectively. The percentage of commercial vehicles with spacing between the front axle and the first roar axle less than 4.5 m is 55%. Traffic count indicates that 60% of the commercial vehicles travel during night- hours (6 PM to 6 AM).

Details of axle bad spectrum of rear single, tandem and tridem axles are given below. Front (steering) axles are not included. The average number of axles per commercial vehicle is 2.35 (due to the presence of multi-axle vehicles).

TABLE IV. ASSUMED AXLE LOAD SPECTRUM

Single Axle		Tandem Axle		Tridem Axle	
Axle Load class (kN)	Frequency (% of Single Axles)	Axle Load class (kN)	Frequency(% of Tandem Axles)	Axle Load Class (KN)	Frequency (% of Tridem Axles)
185-195	18.15	380-400	14.5	530-560	5.23
175-185	17.43	360-380	10.5	500-530	4.85
165-175	18.27	340-360	3.63	470-500	3.44
155-165	12.98	320-340	2.5	440-470	7.12
145-155	2.98	300-320	2.69	410-440	10.11
135-145	1.62	280-300	1.26	380-410	12.01
125-135	2.62	260-280	3.9	350-380	15.57
115-125	2.65	240-260	5.19	320-350	13.28
105-115	2.65	220-240	6.3	290-320	4.55
95-105	3.25	200-220	6.4	260-290	3.16
85-95	3.25	180-200	8.9	230-260	3.1
<85	14.15	<180	34.23	<230	17.58
	100		100		100

PQC
DLC/CEMENT TRATED AGGREGATES SUBBASE
DRAINAGE LAYER As per Deign
SEPARATION LAYER Grading I/II/V/VI OF MORTH 401.2.2
SUBGRADE

FIG 8. TYPICAL CROSS SECTION OF CONCRETE PAVEMENT

TABLE V.
DESIGN OF RIGID PAVEMENT THICKNESS FOR TRADITIONAL AGGREGATES CONCRETE (PROP0): CUMULATIVE FATIGUE DAMAGE VALUES FOR DIFFERENT TRAIL THICKNESSES

Slab thick	CFD for BUC case	CFD for TDC case	CFD of	Remarks

ness h (m)	Due to rear single axles	Due to tandem axles	Total CFD	Due to rear single axles	Due to tandem Axles	Due to tridem axles	Total CFD	BUC+ CFD OF TDC	
0.20	57.214	7.173	64.386	4.802	6.264	0.872	11.939	76.325	Unsafe
0.21	18.385	1.940	20.326	1.715	2.442	0.266	4.424	24.750	Unsafe
0.22	6.5210	0.339	6.860	0.502	0.820	0.065	1.387	8.247	Unsafe
0.23	2.164	0.020	2.184	0.101	2.212	0.010	0.323	2.508	Unsafe
0.24	0.557	0.000	0.557	0.010	0.029	0.000	0.039	0.596	Safe

Hence, design thickness for rigid pavement for traditional aggregates concrete is found to be 0.24 m i.e. 240mm.

TABLE VI.
DESIGN OF RIGID PAVEMENT THICKNESS FOR NON-TRADITIONAL AGGREGATES CONCRETE (PROP6):
CUMULATIVE FATIGUE DAMAGE VALUES FOR DIFFERENT TRAIL THICKNESSES

Slab thickness h (m)	CFD for BUC case			CFD for TDC case				CFD of BUC+ CFD OF TDC	Re-Marks
	Due to rear single axles	Due to tandem axles	Total CFD	Due to rear single axles	Due to tandem axles	Due to tridem axles	Total CFD		
0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Safe
0.24	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Safe
0.23	0.046	0.000	0.046	0.000	0.000	0.000	0.000	0.046	Safe
0.22	0.057	0.000	0.000	0.000	0.000	0.000	0.000	0.057	Safe
0.21	3.036	0.000	0.000	0.000	0.000	0.000	0.000	3.036	Unsafe

Hence, design thickness for rigid pavement for non-traditional aggregates concrete is found to be 0.29 m i.e. 290mm.

TABLE VII.
DIFFERENCE IN COSTS OF PROP0 CONCRETE AND PROP6 CONCRETE

Pavement condition	Cost of PROP0 concrete (in lakhs)	Cost of PROP5 concrete (in lakhs)	Difference in cost (in lakhs)
Concrete pavement with tied concrete shoulder with dowel bars across transverse joints	168	133	35
Concrete pavement with no concrete shoulder and without dowel bars across transverse joints	203	154	49
Concrete pavement with widened outer lanes	168	133	35

V. CONCLUSION

Based on experimental investigation conducted for compressive strength and flexural strength characteristics of concrete, where the fine and coarse aggregates partially replaced with non-traditional aggregates i.e. steel slag, air-cooled blast furnace slag and granulated blast furnace slag. The following conclusions are drawn.

1. The maximum compressive strength and flexural strength of concrete is obtained when the fine aggregates and coarse aggregates replaced with steel slag and air-cooled blast furnace slag by weight of 25% and 50% respectively .
2. When characteristic compressive strength of non- traditional aggregates concrete (i.e., fine aggregates and coarse aggregates replaced with steel slag and air- cooled blast furnace slag by weight of 25% and 50% respectively) is compared with characteristic compressive strength of traditional aggregates concrete, there is an increase in strength of about 24.33% .
3. When flexural strength of non-traditional aggregates concrete (i.e., fine aggregates and coarse aggregates replaced with steel slag and air-cooled blast furnace slag by weight of 25% and 50% respectively) at 28 days is compared with flexural strength of traditional aggregates concrete at 28 days, there is an increase in strength of about 45.50%.
4. Workability of concrete is not affected much when the fine and coarse aggregates replaced with non-traditional aggregates.
5. The fine aggregates can be replaced with Granulated blast furnace slag by weight of 100%.
6.

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