Use of Steel Slag in Concrete in place of Fine and Coarse Aggregates

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Abstract**—*****Most of the volume of concrete is aggregates. Replacing all or some portion of natural aggregates with steel slag would lead to considerable environmental benefits. Steel slag is currently used as aggregate in hot mix asphalt surface applications, but there is a need for some additional work to determine the feasibility of utilizing this industrial by-product more wisely as a replacement for both fine and coarse aggregates in a conventional concrete mixture. This paper present results of experimental investigations carried out to evaluate effects of replacing aggregate (coarse and fine) with that of slag on various concrete properties. In this study, concrete of M20 and M30 grades were considered for a replacements of 0, 25%, 35%. 45%, 55%, 65% and 75% of aggregates (Fine) by slag. Various test considered for investigation are compressive strength, flexural strength and Split tensile strength. The workability is measure with the slump cone test. A comparison of results of replacement of fine aggregate concrete with that of control mix concrete showedthethatslag could be effectively utilized as fine aggregates in all the concrete applications.***

Keywords**—*****Slag, GGBS, Industry by-product,***

I. INTRODUCTION

As a construction material, concrete is the largest production of all other materials. Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. Availability of natural aggregates is getting depleted and also its becoming costly. Hence, there has to be an emphasis on the use of wastes and by-products in all areas including construction industry. As 75% of concrete is composed of aggregates it is imperative that we look to maximize the use of waste as aggregate input in concrete making. The increase in demand for the ingredients of concrete is met by partial replacement of materials by the waste materials which is obtained by means of various industries. Slag is a byproduct of metal smelting and hundreds of tons of it are produced everyyearallovertheworldintheprocessofrefiningmetals and making alloys. Like other industrial byproducts, slag actually has many uses, and rarely goes to waste. It appears in concrete, aggregate road materials, as ballast, and is sometimes used as a component of phosphatefertilizer.

Firstly,slagrepresentsundesiredimpuritiesinthemetals, which float to the top during the smelting process. Secondly, metals start to oxidize as they are smelted, and slag forms a protective crust of oxides on the top of the metal being smelted, protecting the liquid metal underneath. When the metal is smelted to satisfaction, the slag is skimmed fromthe topanddisposedofinaslagheaptoage.Agingmaterialis an important part of the process, as it needs to be exposed to the weather and allowed to break down slightly before it can be used.

Sustainable construction mainly aims at reduction of negative environmental impact resulted by construction industry which is the largest consumer of natural resources. Over a period of time, waste management has become oneof the most complex and challenging problem in the world which is affecting the environment. The rapid growth of industrialization gave birth to numerous kinds of waste byproducts which are environmentally hazard and creates problems of storage. Always, construction industry has been at forefront in consuming these waste products in large quantities. The consumption of Slag in concrete not only helps in reducing green house gases but also helps in making environmentally friendlymaterial.

II. LITERATURESTUDY

VenuMalagavelliet. al. [1] Their paper focuses on investigating characteristics of M30 concrete with partial replacement of cement with Ground GranulatedBlastfurnace Slag (GGBS) and sand with the ROBO sand (crusher dust). The cubes and cylinders are tested for both compressive and tensile strengths. They found that by the partial replacement of cement with GGBS and sand with ROBO sand helped in improving the strength of the concrete substantially compared to normal mixconcrete.

David N. Richardson, [2] for a bridge pier and abutment mass concrete project, three mixes were studied: an ordinary Portland cement (OPC) mix (Type I PC) and two 70% by weight ground granulated blast furnace slag (GGBS) mixes (Type II Low Heat PC). One of the slag mixes contained a high range water reducer (HRWR) and tests for compressive strength, freeze thaw durability, etc. They concluded that although the optimum blast furnace slag proportion for strengthwas50%,blastfurnaceslagreplacementlevelsofup to 70% could be used to achieve moderate strength levels. Strength parity with zero slag mixes is possible with 70 % slag under properconditions,

III. MATERIALSUSED

A. Material and itsproperties

- Cement: PPC. Conforming IS 1489 Part 1(1991)
- Sand:fineaggregateconformingtozoneIIofIS383
- Aggregate: coarse aggregate of maximum size 20mm and 10mm.
- Slag : As per IS456:2000
- Admixture used: BASFGlenium

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B. GGBS

Ground Granulated Blast furnace slag (GGBS) is a byproduct for manufacture of pig iron and obtained through rapid cooling by water or quenching molten slag. If slag is properly processed then it develops hydraulic property and it can effectively be used as a pozzolonic material. However,if slag is slowly air cooled then it is hydraulically inert and suchcrystallizedslagcannotbeusedaspozzolonicmaterial.

TABLE I: PHYSICAL AND CHEMICAL PROPERTIES OF GGBS

Physical Properties	AS per BS:6699	Test Results
Loss of ignition (max) %	3.00	0.15
Moisture content (max) %	1.00	0.31
Chemical Composition		
CaO + MgO + SiO2 (min) %	66.66	80.31
Magnesium Oxide MgO (max) %	14	8.72
Sulphur Tri Oxide SO3 (max) %	2.5	0.19
Total Chlorides (max)%	0. 1	0.001

IV. EXPERIMENTALWORK

A. Following testing conducted onConcrete

a) Workability – Slumpcone
b) CompressiveStrength
c) FlexuralStrength
d) Split tensilestrength

Mix design parameters: Mix design for M20 and M 30 grade concrete

TABLE II: MIX PROPORTION FOR CONTROL MIX

	M20	M30		M20	M30
Cement(kg)	357.14	409.77	A/C	5.4	4.6
Water(kg)	189.29	180.30	W/C	0.53	0.44
CAII (kg)	482.14	527.78	CAII%	25%	28%
CAI (kg)	482.14	490.08	CAI%	25%	26%
FA (kg)	964.29	867.07	FA%	50%	46%

TABLE III: MIX PROPORTION

Fine aggregate to slag replacement proportions: shown in Table 3 (all weights in kg/cum)

Grade	M20		M30	
%	FA	GGBS	FA	GGBS
0%	964.3	0	867.1	0
25%	723.3	241.1	650.4	216.8
35%	626.8	337.5	563.6	303.5
45%	530.4	434.0	476.9	390.2
55%	434	530.4	390.2	476.9
65%	337.5	626.8	303.5	563.6
75%	241.1	723.3	216.8	650.4

Mix Proportions: The mix proportions were made for a control mix of final slump (10min) 100 ± 10 mm for M40 grade of concrete for w/c ratio of 0.40 by using IS-10262-2009 method of mix design.

B. TestSet-up

The 6 in.(150 mm) cubes with a set of 3 cubes, eachwere cast for compressive strength at 3, 7, 28days and 6 in cylinder with 3 set each were cast for split strength at 28, days' time. Beam moulds of size 6in x 6in x 27.56in i.e. (150x150x700mm) for flexure strength time respectively. After the cast, all the test specimens were put into the water tank for curing maintaining temperature of 89.6±35 F (27±2 ºC) as per IS requirements. The concrete was tested for slump cone test as per the IS-1199 –Methods of sampling and analysis of concrete, for each mix ofconcrete

V. GRAPHICALRESULTS

A. Workability

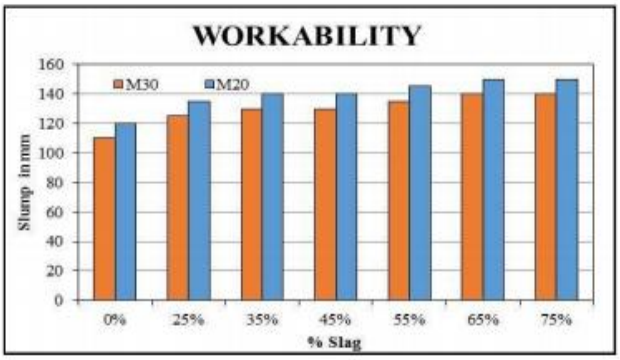

Fig. 1. Slump in mm comparison graph

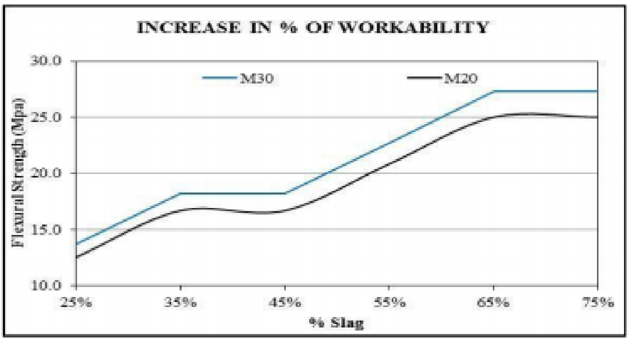

Fig. 2. Slump in mm % variation comparison graph

B. Compression strength

Following is the graphs from results of the Compressive tests performed.

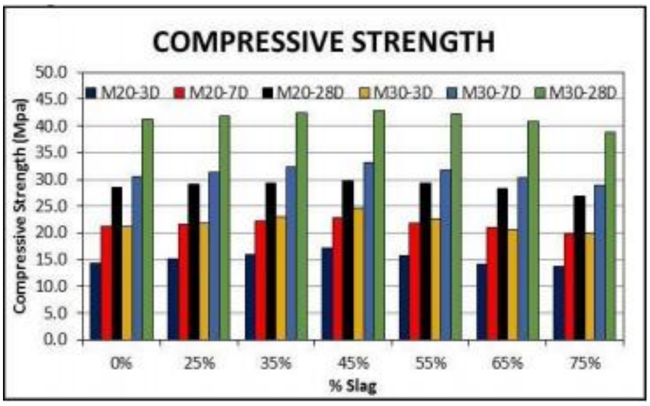

Fig. 3. Compressive Strength in MPa comparison graph

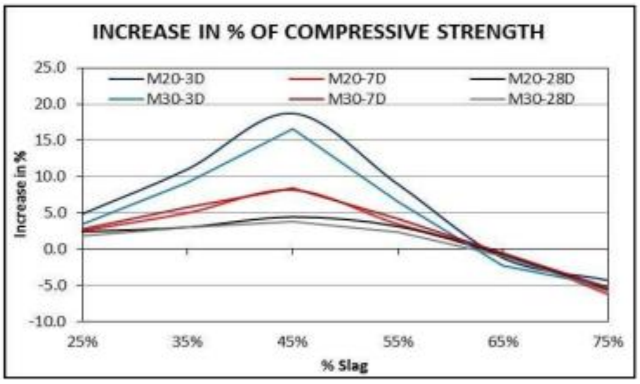

Fig. 4. Compressive Strength % increase comparison graph

C. *FlexuralStrength*

Following are the graphs from results of the Flexural tests performed.

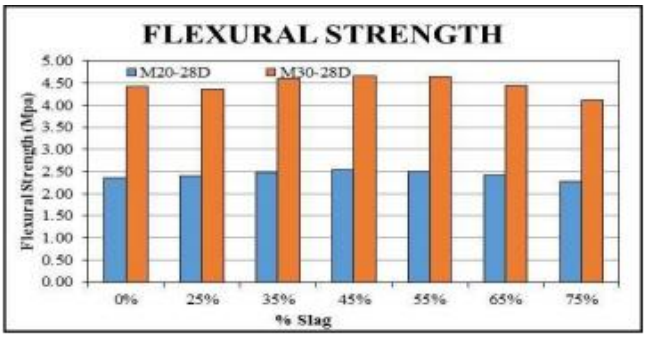

Fig. 5. Flexural Strength in MPa comparison graph

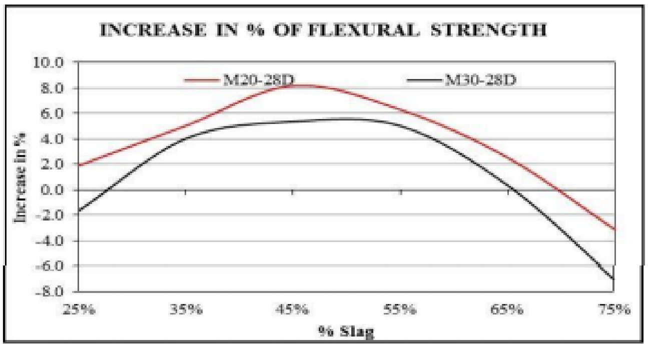

Fig. 6. Flexural Strength % increase comparison graph

D. *Split TensileStrength*

Following are the graphs from results of the Split tensile tests performed.

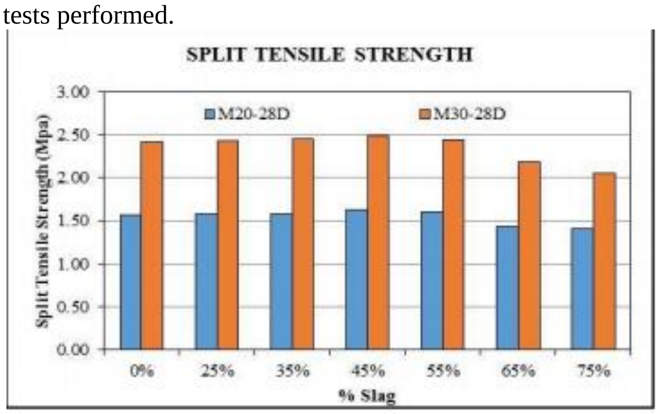

Fig. 7. Split tensile Strength in MPacomparison graph

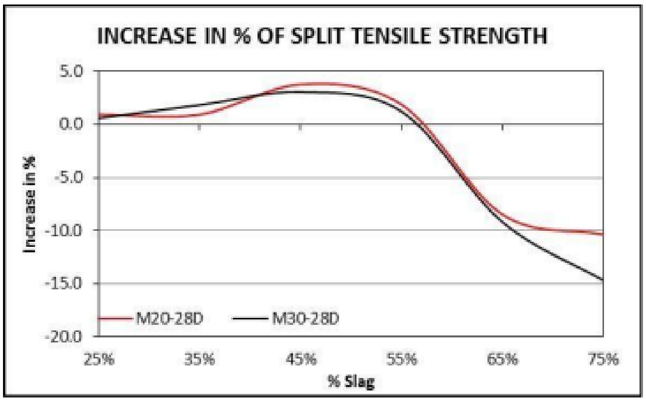

Fig. 8. Split tensile Strength % increase comparison graph

VI. CONCLUSION

A. *Workability : From fig 1 and2*

With addition of %slagthe Workability variation is as follows:

%Slag	25%	35%	45%	55%	65%	75%
M20	12.50	16.67	16.67	20.83	25.00	25.00
M30	13.64	18.18	18.18	22.73	27.27	27.27

B. *Compressive Strength: From fig 3 and4*

Compressive strength when compared with control mix for 3D, 7D & 28D 's goes on increasing .

With replacement of25% slagthe compressive strength goes on increasing as follows :

	3Days	7Days	28Days
M20	4.84	2.53	2.39
M30	3.36	2.67	1.76

With replacement of 35% slag the compressive strength goes on increasing as follow:

	3Days	7Days	28Days
M20	11.01	4.98	3.02
M30	9.17	5.78	2.95

With replacementof45% slag the compressive strength goes on increasing as follow:

	3Days	7Days	28Days
M20	18.72	8.14	4.42
M30	16.60	8.41	3.81

With replacement of with 55% slag the compressive strength goes on increasing as follow:

	3Days	7Days	28Days
M20	8.95	3.44	3.12
M30	6.58	4.18	2.34

With replacement of 65% slag the compressive strength goes on decreasing asfollow:

	3Days	7Days	28Days
M20	-1.23	-0.56	-0.83
M30	-2.24	-0.53	-0.90

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With replacement of with 75% slag the compressive strength goes on increasing as follow:

	3Days	7Days	28Days
M20	-4.32	-6.25	-5.62
M30	-5.11	-5.30	-5.86

C. Flexural Strength: From fig 5 and6

Flexural strength when compared with control mix for 28D ‘s goes on increasing.
With replacement of % of slagthe flexural strength goes on increasing as follows:

slag%	25%	35%	45%	55%	65%	75%
M20	1.89	5.03	8.18	6.29	2.52	-3.14
M30	-1.67	4.01	5.35	5.02	0.33	-7.02

It is observed that flexural strength at 28days increases with increasing quantity of slag.

D. Split tensile strength from fig7 and 8

Split Tensile strength when compared with control mix for 28D ‘s goes on increasing .

With replacement of % of slag the Split Tensile strength goes on increasing as follows:

slag%	25%	35%	45%	55%	65%	75%
M20	0.9	0.9	3.8	1.9	-8.5	-10.4
M30	0.6	1.8	3.1	1.2	-9.2	-14.7

It is observed that Split tensile strength at 28days increases with increasing quantity of slag.

E. OverallConclusion

1. Workability of Slag replacement concrete is higher than control mix and well as showed the bettercohesiveness.
2. The compressive Strength of concrete at 28 days is increased by 4.42% for M20 and 3.81% for M30 when the fine aggregate replaced by slag by 45% and further increase in replacement decreased thestrength.
3. The Flexural Strength of concrete at 28 days is increased by 6.29% for M20 and 5.02% for M30 when the fine aggregate replaced by slag by 55% and further increase in replacement decreased thestrength.
4. The Spilt tensile Strength of concrete at 28 days is increased by 1.9% for M20 and 1.2% for M30 when the fine aggregate replaced by slag by 55% and further increase in replacement decreased thestrength.
5. Hence, it could be recommended that slag aggregate could be effectively utilized as fine aggregate in all concrete applications either as partial or full replacements of normal crushed coarse and natural fineaggregates.

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