Impact Factor Value 4.046 e-ISSN: 2456-3463
International Journal of Innovations in Engineering and Science, Vol. 4, No.9, 2019
www.ijies.net

An Experimental Evaluation of Slump Test And Split Tensile Test on Concrete Using Blast Furnace Slag as A Replacement of Coarse Aggregate

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Abstract – *we are using both blast furnace slag and air cooled blast furnace slag as a replacement of coarse aggregate as we are using such artificial ingredients for making concrete as we know that pollutions are increasing now a days so that natural resources are highly diffusing day by day. The combined outcome of ACBFS as replacement for coarse aggregates and fly ash as a limited replacement of cement on the slump test and split tensile strength of concrete has been investigated. Six mixes were prepared at different replacement levels of ACBFS (0%, 20%, 40%, 60%, 80% and 100%) with coarse aggregate in all concrete mixes. The slump test of concrete and split tensile strength was tested after 3, 7 and 28 days of curing. Results indicate that the slump test and split tensile test are in phase with each other. The replacement of ACBFS with coarse aggregates up to 40% increases the slump and split tensile and of concrete and at 60% there is marginal decrease in both parameters. On further replacement up to 80% and 100% the slump and split tensile of concrete mix decreases significantly. As it was observed that the slump and split tensile test increases with replacement up to 40% ACBFS, it is recommended that up to 40% of ACBFS can be used as coarse aggregate in concrete.*

Keywords- *fly ash, ACBFS, workability test, split tensile strength test, slump test, significantly, replacements, artificial ingredients.*

I- INTRODUCTION

To meet the global demand of concrete in the future, it is becoming a more challenging task to find suitable alternatives to natural aggregates for preparing concrete. Therefore the use of alternative sources for natural aggregates is becoming increasingly important.

Table 1: Typical ACBFS Coarse Aggregate and Natural Aggregate Properties (Smith, Morian, and Van Dam 2012)

Property	ACBFS Aggregate	Natural Aggregate
Particle shape and texture	Angular and roughly cubical with rough to glassy texture	Well-rounded, smooth (gravels) to angular and rough (crushed stone)
Specific gravity	2.0–2.5	2.4–2.9
Absorption capacity	1–8%	0.5–4.0%
Angle of friction	40–45 degrees	30–45 degrees
Los Angeles abrasion test	35–45%	15–45%
California bearing ratio	>100	80–100
Mohs hardness	5–6	3–8

Some of the notable differences between the two different aggregate types include:

- Greater angularity of ACBFS, which can affect mix proportioning.
- Lower specific gravity of ACBFS, which can affect mix proportioning.

- Higher absorption of ACBFS, which can affect mix proportioning, workability, and early-age shrinkage.
- Lower abrasion resistance of ACBFS, which can affect mechanical load transfer behaviour at joints and cracks in concrete pavements.
- Highly vesicular aggregates that have low fracture energy/toughness, which leads to poor aggregate interlock at joints and cracks.

Influence on Fresh Concrete Properties

An important consideration in working with ACBFS as a coarse aggregate is its particle-to-particle variability. Individual ACBFS aggregate particles vary widely, from being highly porous and light to being extremely dense. The crushing and blending operations typically ensure that the variation of large batches of aggregate is relatively small (Wigdahl, 2009), but the variability of individual particles must be considered when testing small amounts of aggregate or concrete, and thus statistically representative samples must be collected.

Table 2: Influence of Slag on Properties of Concrete (28 to 56 day age)

Concrete Parameter	Typical Influence of Slag Aggregate (BFS) in Concrete	Typical Influence of GGBFS in Concrete
28 day Comp. Strength	Same as for good natural aggregates	Can be used in high performance concretes (such as 100 MPa characteristic strength)
Indirect Tensile Strength	Same as for good natural aggregates	Slight increase compared to Type GP cement
Flexural Strength	Same as for good natural aggregates	Slight increase compared to Type GP cement
Hardened Density	No significant influence when compared with good natural aggregate	Limited influence on density

A dominant characteristic of ACBFS is the rough, porous surface texture of the aggregate particles that results in increased surface area. One result of this is that additional mortar (cementitious materials, water, and sand) is often needed when proportioning concrete containing ACBFS to overcome the high angularity/surface area of the particles and maintain workability. The use of water-reducing admixtures can assist in this effort to some degree, but it has been observed that it is almost always necessary to have some additional mortar to "coat" the ACBFS surfaces to create a workable mixture.

It also depends on the method of formation of the relevant components, their shape, size and the sequence of crystallization. Moreover, the type of slag microstructure is influenced by the method and rate of alloy cooling, the age of the slag and the conditions of their deposition. This modifies the slag to be porous, void spacey, rough, irregular shape, hard and crystalline structure. Depending on the particle roughness or say surface porosity also results in a high water-absorption capacity for slag aggregate, as high as 6.5 to 8 percent. This will ultimately increase strength and reduce permeability of the concrete. Due to internal interconnected voids or pore system structure configuration the slag aggregate is light weight can be handy in preparing light weight concrete.

Figure 1: Blast Furnace slag from steel plant.

Highly recommendations are specified for the efficient use of grounded blast-furnace slag in concrete. The numerous practical benefits are accessible by the concrete user, such as reduced heat evolution, lower permeability and higher strength at later ages, decreased chloride ion penetration, increased resistance to sulphate attack and alkali silica reaction were affirmed.

Sustainable construction mainly aims at reduction of negative environmental impact resulted by construction industry which is the largest consumer of natural resources. Thus replacing the natural aggregates in concrete applications with blast furnace slag would lead to considerable environmental benefits along with the conservation of natural resources and at the same time the properties of concrete can be increased economically.

II- LITERATURE REVIEW

Concretes containing slag as a partial replacement of cement (up to 40%) had higher compressive and flexural strengths casting and curing at +42°C than those of concretes made with Portland cement alone (Siddique and Kaur, 2012).

The physical properties of crusher dust and blast furnace slag are satisfying the requirements of fine aggregate and coarse aggregate. The cost of concrete made with blast furnace slag and crusher dust is less than conventional concrete because the crusher dust and blast furnace slag which were less cast. At 30% replacement of coarse aggregate with blast furnace slag and fine aggregate with crusher dust there is no reduction in compressive strength with respect to controlled concrete. At 30% replacement of coarse aggregate with blast furnace slag and fine aggregate with crusher dust that shown only marginal increase in split tensile strength and flexural strength was observed (Dhanasri and Kumar, 2013).

Familusi et al. (2017) investigates the potential use of blast furnace slag as a partial replacement for cement in the production of concrete. After batching, 1:1.5:3 mix of concrete was produced in varying slag proportions of 5%, 10%, 15% and 20% by weight of cement. Findings revealed that the slag blended concrete which was produced at the chosen water-cement ratio of 0.5 has low workability compared to the conventional concrete. Method of curing by shading was adopted and the compressive strength of slag blended concrete with varying slag proportions of 5%, 10%, 15% and 20% at 28 days of curing was found to be 11.48 N/mm2, 17.98 N/mm2, 18.19 N/mm2, and 20.87 N/mm2 respectively. There are significant differences between the compressive strength values obtained and this actually justifies the use of the blast furnace slag in concrete production. The Compressive strength of 100% blast furnace slag concrete has been increased up to 2.8% in comparison to conventional concrete (Singh, 2014).

The compressive strength of concrete increases as BF Slag replacement increases up to 40% at all curing ages. The flexural strength of concrete also increases up to 40%, similar to the trend shown by compressive strength. The maximum increase in flexural strength at 28 days curing is 8.33% (Sandhu et al., 2015).

For the replacement of both coarse and fine aggregates from 30 to 50%, the compressive strength of concrete increased by 4 to 6%. However, in case of coarse aggregate the compressive strength increased by 5 to 7% over control mixes in M20, M30 & M40 grade of concrete (Nadeem, 2018).

The coarse aggregate was replaced by blast furnace slag at 10% to 100% and various tests were conducted to determine the optimum level of replacement of blast furnace slag in self compacting concrete (Krishnasami and Malathy, 2013).

The result obtained encourages the use of blast furnace slag in concrete as a partial replacement to fine aggregate up to 25%. The maximum compressive strength of 40.69 N/mm2 was obtained by replacing 25% of fine aggregate with BFS. Workability was found to be a problem with the fresh concrete, and hence usage of super plasticiser was recommended. The usage of BFS will reduce the cost of concrete by 8 to 10% (Babu and Mahendran, 2014).

It was observed that the compressive strength increased up to 35% replacement of coarse & Fine aggregate with slag and is gradually decreased for starting from 40% replacements. Hence replacement of coarse aggregate with 35% replacement will be reasonable (Harikumar et al., 2017).

Normal compressive strength of high quality concrete at age 1, 3,7,14, and 28 days respectively is 33.651 Mpa. 47.871 Mpa. 57.321 Mpa. 53.170 Mpa and 67.567 Mpa. While compressive strength of concrete with slag substitution at age 1, 3,7,14 and 28 days respectively is 43.896 MPa. 71.541 MPa. 77.282 MPa. 70.658 Mpa and 75.958. Thus it shows that high quality concrete made of steel slag as the main constituent aggregate has a compressive strength greater than that of conventional high-quality concrete. 2. The average tensile strength of high quality slag concrete with 28 days of concrete is 5.053 MPa. While the average tensile strength of conventional high quality concrete with 28 days of concrete is 5,435 Mpa. It shows that the tensile strength of conventional high quality concrete is stronger than the tensile strength of high quality concrete with slag steel replacement (Karolina and Putra, 2018). Some of the research reviews are presented in table 3, with optimum steel slag amount as replacement of natural aggregates with their findings.

Table 3: Replacement of aggregates by steel slag (Tiwari et al, 2016)

S. No	Author/Year	Optimum Replacement of steel slag.	Conclusions
1	Thangaselvi, 2015	60%	The increase in percentage of steel slag shows enhanced resistance to acid and sulphate attack in concrete.
2	Pajgade and Thakur, 2013	75%	It enhances the density concrete by 4 to 6% in all the concrete mixes.
3	Rajan, 2014	30%	Improvement in compressive strength is about 25%.
4	Murthi, et al., 2015	50 %	Concrete with steel slag provide high compressive strength and durability.
5	Chinnaraju, et al., 2013	60% and 40%	Total replacing of 60 percent for coarse aggregate and 40 percent for fine aggregate will suitable and not have any adverse consequence on the strength of the concrete.
6	Ravikumar, et al., 2015	60%	The 4 to 8% increase in split tensile strength and flexural strength of concrete is increases about 2 to 6% for all the grades. Steel slag can be used up to maximum of 60% replacement in all grades of concrete.
7	Padmapriya, et al., 2015	40%	Steel slag offers the maximum strength and is mostly suited for areas that are not exposed to marine conditions. Increase in strength initially is attributed to shape effect and decrease in strength beyond 40% is attributed to porosity of steel slag.
8	Saravanan, and Suganya, 2015	6%, 28% and 34%	Compressive strength of steel slag concrete increases in 6 %, Split tensile strength increases in 28 % and Flexural strength of steel slag concrete increases in 34 % steel slag replacement.
9	Subramani and Ravi, 2015	60%	Coarse aggregate replacement level of 60 % slag in concrete mixes was found to be the optimum level to obtain higher value of the strength and durability and cost reduction up to 39 %.
10	Warudkar and Nigade, 2015	75%	The optimum strength is obtained on 75% replacement by steel slag. Steel slag has increased the compressive strength, flexural strength and split tensile strength of concrete. Also it shows higher resistance to acid and sulphate attack.
11	Krishnasam and Malathy, 2014	32 %	It is found that 32 % of slag aggregate can be replaced for coarse aggregate to attain both self compactability and strength for concrete applications.
12	Kumar, and Vasudhevan, 2015	40%.	It is observed that 40% replacement level of natural sand with steel slag gives equal strength as conventional concrete.
13	Humam and Siddique, 2013	NA	Partial replacement of fine aggregates with iron slag considerably enhanced the compressive strength, splitting tensile strength, sulphate resistance and rapid chloride permeability test.
14	Bharath and Rao, 2015	50%	50% replacement of slag in M25 grade concrete offer additional strength then other proportions.
15	Jain et al.,	40 to 50%	GGBFS is found effective in reducing the expansion due to Aggregate-silica reaction in concrete due to higher alkalies binding capacity of hydration products of GGBFS.
16	Hirde et al., 2015	20%	Replacements of GGBS show considerable increase in strength and flexural tensile strength.
17	Devi and Gnanavel, 2014	40% and 30%	As fine and coarse aggregate replacement. Fine aggregate replacement gives better workability as compared to coarse aggregate replacement

III- PROBLEM IDENTIFICATION AND RESEARCH OBJECTIVES

Scope of present study:

The original scope of this research was to investigate the properties of concrete with steel slag aggregates. The mechanical properties of concrete were tested with steel slag as replacement of coarse aggregates, In addition to this work steel fibres are added to the optimum replacement level and several tests were also carried out such as compressive strength, split tensile strength, Young s modulus, flexural strength and the ultimate load carrying ‟ capacity of slag aggregate concrete with steel fibres at different volume fractions. The flexural properties are also determined for the beams with reinforcement. For this experimentation the percentage of the volume of natural aggregates normally used in concrete was replaced by steel slag. This replacement was done in 10% increments until all natural aggregates were replaced by the steel slag, then the optimum replacement level of the steel slag as coarse aggregates is determined. Thus replacing the natural aggregates in concrete applications with steel slag would lead to considerable environmental benefits and at the same time the strength properties of the concrete is increased and would be economical.

Thus, the objective of the present study are to determine the mechanical properties of the concrete using blast furnace slag as coarse aggregate replacement are to assess the

- Compressive strength of the slag aggregate concrete
- Flexural strength of the slag aggregate concrete
- Split tensile strength of the slag aggregate concrete
- Young s modulus of slag aggregate concrete

The objective of this research was to evaluate the influence of using the ACBFS aggregate (slag aggregate) as a replacement for natural aggregates on the properties of concrete designed to meet the standard specifications of the India.

IV-EXPERIMENTAL PROGRAMME

Fresh concrete properties:

Workability: Workability of a concrete is a term which consists of the following four partial properties of concrete namely mix ability, transportability, mould ability, and compact ability. Cohesiveness and consistency both are concurrent properties of fresh concrete. Cohesiveness is a measure of the compact ability and finish ability of concrete. Consistency is requirement of water to mix the concrete properly.

In general terms, workability represents the amount of work which is to be done to compact the concrete in a given mould. The desired workability for a particular mix depends upon the type of compaction adopted and the complicated nature of reinforcement used in reinforced concrete. A workable mix should not segregate. The partial properties of workability are discussed below:

1. Mix ability: It is the ability of the mix to produce a homogeneous green concrete from the constituent materials of the batch, under the action of the mixing forces. A less mixable concrete mix requires more time of mixing to produce a homogeneous and uniform mix.
2. Transportability: Transportability is the capacity of the concrete mix to keep the homogeneous concrete mix to keep the homogeneous concrete mix from segregating during a limited time period of transportation of concrete, when forces due to handling operations of limited nature act. Any segregation that is caused during the remaining operations that follows. In most of the countries, general recommendations for practice exist for transporting the concrete, which fact highlights the importance of this property.
3. Mould ability: It is the ability of the fresh concrete mix to fill completely the forms or moulds without losing continuity or homogeneity under the available techniques of placing the concrete at a particular job/ this property is complex, since the behaviour of concrete is to be considered under dynamic conditions.
4. Compatibility: Compatibility is the ability of concrete mix to be compacted into a dense, compact concrete, with minimum voids, under the existing means of compaction at the site. The best mix from the point of view of compatibility should close the voids to an extent of 99% of the original voids present, when the concrete was placed in the moulds.

Factors influencing Workability

Workable concrete is one which exhibits a very little internal friction between particle to the particle or which overcomes the frictional resistance offered by the form work surface or reinforcement contained in the concrete with just amount of compacting efforts forthcoming. Workability of concrete is mainly influenced by Water content, Size of aggregate, Shape of aggregate, Texture of aggregate, Grading of aggregate.

Water content: Water content in a given volume of concrete, will have significant influences on the workability. The higher the water content per cubic meter of concrete, the higher will be the fluidity of concrete, which is one of the important factors affecting workability. At the work site, supervisors who are not well versed with the practice of making good concrete resort to adding more water for increasing workability. This practice is often resorted to because this is one of the easiest corrective measures that can be taken at the site. It should be noted that from the desirability point of view, increase of water content is the last recourse to be taken for improving the workability even in the case of uncontrolled concrete. For controlled concrete one cannot arbitrarily increase the water content. In case all other steps to improve workability fail, only as last recourse the addition of more water can be considered. More water can be added, provided a correspondingly higher quantity of cement is also added to keep the water/cement ratio constant, so that the strength remains the same.

Slump cone test:

Workability of fresh concrete shall be carried out by performance of slump test. Slump value can be carried out according to the IS: 1199-1959. To determine the consistency or workability of steel slag, slump cone test has been performed in the laboratory. Before conducting the experiment, apply de-mould agent i.e., oil/grease inside the cone for avoidance of further sticking of the fresh concrete. Unsupported fresh concrete flows to the sides and a sinking in height takes place. This vertical settlement is known as slump. In this test fresh concrete is filled into a mould of specified shape and dimensions, and the settlement or slump is measured when supporting mould is removed. Slump increases as water-content is increased. For different works different slump values have been recommended. The slump is a measure indicating the workability of cement concrete. It gives an idea of water content needed for concrete to be used for different works. A concrete is said to be workable if it can be easily mixed, placed, compacted and finished. A workable concrete should not shown any segregation or bleeding. By this test we can determine the water content to give specified slump value. In this test water content is varied and in each case slump value is measured till we arrive at water content giving the required slump value. This test is not a true guide to workability.

Figure 7: Conducting Slump cone test

Splitting Tensile Strength of Concrete:

The splitting tensile strength of the concrete specimens was tested at 7 and 28 days. The dimensions of the cylindrical specimens are of diameter 100mm and the height of the cylindrical specimen is 200mm were moulded at the same time as the compressive strength specimens and the specimens were cured in curing tank. Three specimens were tested at each age, on a Compressive testing machine of capacity 2000 KN. The splitting tensile strength can be obtained from the following equation:

ft =2Pl

Where

ft = splitting tensile strength (MPa)

P = maximum applied load (N)

l = length (mm)

d = diameter (mm)

For this research the length (l) was equal 200mm and the diameter (d) of was taken as

100 mm.Three specimens were tested at 7 and 28 days for each experimental mixture.

Concrete mix design:

The mixture proportioning was done according the Indian Standard Recommended Method IS 10262- 2009 and with reference to IS 456-2000. The target mean strength was 31 N/mm2 for the OPC control mixture, the total cement content was 372 Kg/m3, fine aggregate was taken 790 Kg/ m3 and coarse aggregate was taken 1063.902 Kg/m3. The water to binder ratio was kept constant as 0.5. The total mixing time was 5 minutes; the samples were then casted and left for 24 hrs before de-moulding. They were then placed in the curing tank until the day of testing cement, sand and coarse aggregate were properly mixed together in the ratio 1:2.86:2.12 by weight before water was added and properly mixed together to achieve homogenous material.

Water absorption capacity and moisture content were taken into consideration. Cube and cylindrical and prism moulds were used for casting. The concrete was left in the mould and allowed to set for 24 hours before the specimens were demoulded and placed in a water tank for curing. The specimens were cured in the tank for 7 and 28 days. The details of the quantity of the constituent materials were given in the below. The determination of the quantity of the constituent materials for the M25 grade of concrete designed as per the IS method.

MIX DESIGN AND PROPORTION OF CONVENTIONAL CONCRETE

STIPULATIONS FOR PROPORTIONING	
a) Grade designation : M25	25
b) Type of cement : conforming IS 8112	OPC 43 Grade
c) Maximum nominal size of aggregate :	20mm
d) Minimum cement content : (IS 456:2000)	320 kg/m3
e) Maximum water-cement ratio : (Table 5 of IS 456:2000)	0.5
f) Workability : 50-100 mm slump (Medium)	100 mm
TEST DATA FOR MATERIALS	
a) Cement used : OPC 53 Grade conforming IS 12269	
b) Specific gravity of cement :	
c) Chemical admixture : Super Plasticizer conforming to IS 9103 (ECMAS HP 890)	
d) Specific gravity of	
1) Coarse aggregate 20mm :	2.74
2) Fine aggregate :	2.57
e) Water absorption:	
1) Coarse aggregate :	0.90%
2) Fine aggregate (Midium sand) :	1.08%
f) Free (surface) moisture:	
1) Coarse aggregate :	Nil
2) Fine aggregate :	Nil
g) Sieve analysis:	
1) Coarse aggregate: Conforming to all in aggregates of Table 2 of IS 383	
2) Fine aggregate : Conforming to Grading Zone II of Table 4 of IS 383	
TARGET STRENGTH FOR MIX PROPORTIONING	
f'ck=fck + 1.65 s	
where	
f 'ck= target average compressive strength at 28 days,	
fck = characteristics compressive strength at 28 days,	
s = standard deviation.	
From Table I of IS 10262:2009,Standard Deviation, s =	4
Therefore, target mean strength =	31.6 N/mm2

SELECTION OF WATER-CEMENT RATIO		
Adopted maximum water-cement ratio = 0.5. From the Table 5 of IS 456 for Moderate Exposure maximum Water Cement Ratio is 0.5, Hence ok.		
SELECTION OF WATER CONTENT		
From Table 2 of IS 10262:2009, maximum water content for 20 mm aggregate = 186 litre (for 25 to 50 mm slump range) assumed 100 mm slump		186.03 L
CALCULATION OF CEMENT CONTENT		
Adopted w/c Ratio =		0.5
Cement Content =	w/wc =	372.06 kg/m3
Cement Content @ 2% for hand mixing =		380 kg/m3
From Table 5 of IS 456, Minimum cement content for 'Severe' exposure conditions		320 kg/m3
380 kg/m3 > 320 kg/m3 hence ok.		
PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT		
From Table 3 of (IS 10262:2009) Volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.5 = 0.62 .		
In the present case water-cement ratio is 0.5. Therefore, volume of coarse aggregate is not required to be increased to decrease the fine aggregate content.		
Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.5 = 0.62		
For pumpable concrete these values should be reduced up to 10%. Therefore, volume of coarse aggregate =		0.558 kg/m3
Volume of fine aggregate content = 1 – 0.567	=	0.442 kg/m3
MIX CALCULATIONS		
The mix calculations per unit volume of concrete shall be as follows:		
a) Volume of concrete = 1 m3		
b) Volume of cement = [Mass of cement] / {[Specific Gravity of Cement] x 1000}		0.118
c) Volume of water = [Mass of water] / {[Specific Gravity of water] x 1000}		0.186 litres/ m3
d) Volume of all in aggregate = [a-(b+c)] =		0.696
e) Mass of coarse aggregate= e x Volume of Coarse Aggregate x Specific Gravity of Fine Aggregate x 1000 =		1063.90 kg/m3
f) Mass of fine aggregate= e x Volume of Fine Aggregate x Specific Gravity of Fine Aggregate x 1000		790.45 kg/m3

MIX PROPORTIONS			
Cement =			372.06 kg/m3
Water =			0.19 litres/ m3
Fine aggregate =			790.45 kg/m3
Coarse aggregate 20mm =			1063.902 kg/m3
Density of concrete =			2226.60 kg/m3
Water-cement ratio =			0.50
Mix Proportion By weight =	1	2.12	2.86

Table 4.2: Details of the quantity of the constituent materials

Material	Quantity (Kg/m3)	Proportions
Cement	372.06	1
Sand	790.45	2.12
Coarse aggregate (20 mm)	1063.902	2.86
Water	186.03	0.5

Concrete mix proportions for samples:

Mixture	Fine aggregate (Kg/m3)	Coarse aggregate (Kg/m3)	Steel slag aggregate (Kg/m3)	Cement content (Kg/m3)	W/C ratio (%)
CCM	790.5	1063.90	0	372	0.5
SLAG 10%	790.5	957.5	106.4	372	0.5
SLAG 20%	790.5	861.8	95.8	372	0.5
SLAG 30%	790.5	775.6	86.2	372	0.5
SLAG 40%	790.5	698.0	77.6	372	0.5
SLAG 50%	790.5	628.2	69.8	372	0.5
SLAG 60%	790.5	565.4	62.8	372	0.5
SLAG 70%	790.5	508.9	56.5	372	0.5
SLAG 80%	790.5	458.0	50.9	372	0.5
SLAG 90%	790.5	412.2	45.8	372	0.5
SLAG 100%	790.5	371.0	41.2	372	0.5

From the above concrete mix proportions the ideal mix is to be known after conducting the compression test on the cube specimens for 7 days and 28 days.

V-METHODOLOGY

Overview

The main objective of this research was to utilize the blast furnace slag aggregate in the concrete mixture and identify the mechanical and flexural properties of the mixture. The experimental study started by replacing the percentage of the volume of natural aggregates, normally used in the manufacture of concrete , with blast furnace slag in increments of 10% until all the natural aggregates were replaced by the steel slag to find the possible optimum replacement level for the steel slag in concrete. All materials testing and concrete mixing was performed in the materials testing laboratory of the civil engineering department of the institute.

Blast furnace Slag aggregates:

Slag is a co-product of the iron and steel making process. Iron cannot be prepared in the blast furnace without the production of its co-product, blast furnace slag. Similarly, steel cannot be prepared in the basic oxygen furnace (BOF) or in an electric arc furnace (EAF) without making its co-product, steel slag. The use of steel slag aggregates in concrete by replacing natural aggregates is a most promising concept. Steel slag aggregates are already being used as aggregates in asphalt paving road mixes due to their mechanical strength, stiffness, porosity, wear resistance and water absorption capacity.

Figure 4: Steel slag aggregates

Studies and tests are being conducted on ways to use this steel slag as an aggregate in concrete. Steel slag is currently used in bituminous asphalt paving, the manufacture of Portland cement, and in roadway construction as a base course, along with some agricultural applications. The only potential problem with steel slag aggregate is its expansive characteristics and undesirable reactions between slag and components of concrete. This might be a perception, but most of the information is anecdotal in nature rather than documented in published research studies. The chemical and physical properties of the steel slag are given in the below tables 8 and 9.

Water:

Water is required for the purpose of hydration of cement and to give workability during mixing and furthermore setting of concrete. For this study convenient water with pH7 and adjusting to the determinations of IS456-2000 is utilized for cementing and additionally curing of the specimens. Portable water available in laboratory is used in this study.

For this experimentation the percentage of the volume of natural aggregates normally used in concrete was replaced by blast furnace slag. This replacement was done in 10% increments for the optimum replacement level of the blast furnace slag as coarse aggregates is determined. To that optimum mix the steel fibres are added at volume fractions of 0.50%, 1.00% and 1.50%. For this the following experiments have to be conducted in the laboratory:

1. Characterization of natural aggregates (Coarse and fine)
2. Characterization of blast furnace slag
3. Characterization of cement
4. Selection of mix proportion
5. Preparation of concrete cubes, cylinder, and beam for strength analysis

VI- EXPERIMENTAL RESULTS

. The test results and slump and compaction factor with different replacements of steel slag aggregate are shown in tables 10.

Table 10: Table showing the results of workability of SSAC

S. No.	Mix ID	% replacement of steel slag	Slump (mm)
1	CC	0	160
2	SLA 20%	20	150
3	SLA 40%	40	140
4	SLA 60%	60	135
5	SLA 80%	80	120
6	SLA 100%	100	115

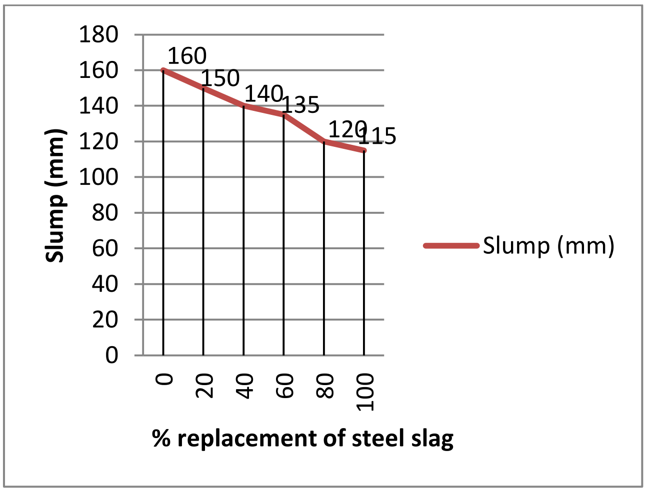

Figure 14: Workability of steel slag aggregate concrete

Workability of concrete is determined by its shape, size, surface texture and water absorption. The maximum size of aggregates used is 20 mm with various percentage of steel slag as a replacement of natural aggregates. From the above graph it is observed that the increase in the replacement of the steel slag aggregate increases the slump value of concrete. While concretes containing slag have a similar, or slightly improved consistence to equivalent Portland cement concrete, fresh concrete containing slag tends to require less energy for movement. This makes it easier to place and compact, especially when pumping or using mechanical vibration. In addition, it will retain its workability for longer.

Splitting Tensile Strength

The splitting tensile strength of the concrete specimens was determined at 28 days. As previously mentioned the specimens were moulded at the same time as the compressive strength specimens. Cylinders were moulded with a diameter of 100 mm and a length of 200 mm. Table 13 displays the average splitting tensile strength of the samples at 28 days. The ideal splitting tensile strength of concrete specimens at the end of 28 days was approximately about 3.26 N/mm2 attained for 1.5 Vf.

Table 13: Split tensile strength

Mix ID	% Replacement of steel slag	Split tensile strength (MPa)
CC	0	3.3
SLA10%	10	3.01
SLA20%	20	3.09
SLA30%	30	3.10
SLA40%	40	3.26

SLA50%	50	2.98
SLA60%	60	2.56
SLA70%	70	2.38
SLA80%	80	2.26
SLA90%	90	2.19
SLA100%	100	2.20

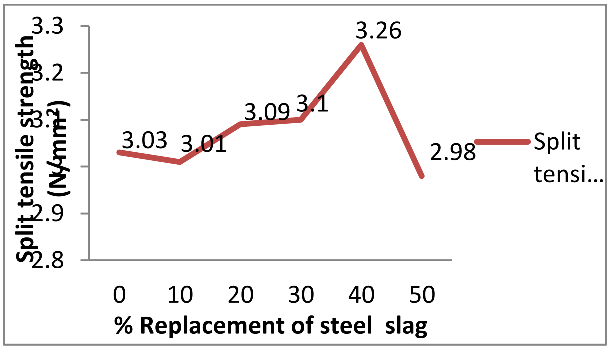

Figure 17: Split tensile strength of SSAC.

The split tensile strength is also greatly enhanced therein such as observed that when the strength of a concrete cube reached maximum characteristic applied load in N/mm2 after 28 days. Initial length readings of the concrete cylinder were taken using a standard comparator before testing. The percentage increase in strength is seen from 3.03 N/mm2 to 3.26 N/mm2 due to the interlinked micro structure of slag material.

VII- CONCLUSION

1. The utilization of slag aggregate is possible which is beneficial for the environment where the slag can be impregnated partially in concrete rather than the soil. Hence, better sustainable concrete can be produced.
2. The compressive strength of concrete first increases faintly with increasing of steel slag up to 40% and then after it decreases.
3. The split tensile strength of concrete are increasing faintly with increase of steel slag up to 50% and then after it decreases..
4. An application of 100% steel slag has an unfavourable effect on the workability and stability of but this consequence decrease by the partial introduction of slag in the matrix mixes.
5. From the result of compressive strength test, split tensile test and flexure test strength of M25 grade concrete increases by partially adding steel slag aggregate.
6. Higher percentage substitution (above 35%) can also be used but may require more materials like, cement, micro silica, and admixtures. Such use would result in increase in the costs of the mixes with decrease in durability and strength. It is economical to use the steel slag, as the costs of steel slag are just about 45% of that of conventional aggregates
7. The application of steel slag aggregate in concrete increases the void having air content, as specific gravity is lower than normal aggregate and thus making it slightly light weight.

VIII- SCOPE OF FUTURE WORK

A more engineered field study with various parameters on concrete structure made with steel slag aggregates as partial replacement should be conducted and changes in durability and mechanical properties should be investigated.

Also, investigation on sulphates attack, alkali silica reactions, carbonation, sea water attack, harmful chemicals and leaching study to analyse the release of toxic metals from slag concrete are needed. The behaviour of steel slag aggregate concrete under corrosive environments and its fire resistance capacity should also be investigated. The results of such studies would directly benefit the construction industry and broader use of steel slag in concrete would improve overall properties and cost effective solution.

It is also suggested to do Petro graphic examinations of concrete samples with steel slag aggregates to get insight of the actual behaviour of concrete. The relationship between entrained air and entrapped air in concrete should be studied. A comprehensive chemical analysis of steel slag aggregates should to be carried out before using in construction.

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