iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 Issue: XII Month of publication: December 2024
DOI: https://doi.org/10.22214/ijraset.2024.66181

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue XII Dec 2024- Available at www.ijraset.com

Experimental Study on Utilization of Blast Furnace Slag in Concrete

Aparna B P[1], Roopakala C G[2], Vikram M K[3]
[1]Senior Lecturer, Department of Civil Engineering, Government Polytechnic, Ramanagara, Karnataka, India
[2]Senior lecturer, Department of Civil Engineering, Government Polytechnic, Sira, Karnataka, India
[3]Senior Lecturer, Department of Civil Engineering, Government Polytechnic, Channapatna, Karnataka, India

Abstract: Slag is one of the non metallic product which is formed in the manufacture of pig iron and steel in blast furnace. The constituents of slag are silicates of calcium, manganese and aluminium in different compositions. The molten slag is insoluble having lower density and floats on the pig iron. Slag is one of the essential by product obtained in the manufacture of iron, which is considered as the industrial waste product. But this waste product will be considered as one of the useful product in the construction industry. Hence this slag can be used as alternative material for coarser aggregates and finer aggregates in construction activities. The study can be carried out by partial replacements of steel slag for fine aggregates to know the concrete strength parameters. The different types of steel slag are listed below: Blast furnace slag (BFS) and steel furnace slag (SFS) are being use as an industrial by product. For the cement composites and cementitious components of concrete, Ground granulated blast furnace slag (GGBS) has been used. BFS and SFS have distinctive chemical and physical properties hence they are well suited for use in various construction and civil engineering projects Air-cooled BFS provides a strong aggregate that can be used in the production of concrete, Portland cement as well as asphalt-concrete. Water Cooled slag with gives lightweight aggregates which can be uses in the production of masonry blocks and lightweight concrete. Pelletized & granulated BFS are grouted and used in production slag cement. Slag cement shows low heat of hydration and better resistance to alkali-silica reaction, chloride penetration, and sulphate attack when compared to ordinary Portland cement. It shows reduced risk of thermal cracking and highly electrolytic resistant. The chief applications of SFS and BFS are listed below Air-cooled BFS:

- ***The uncrushed aggregates are used as filler materials and for embankments areas which are subject to extreme loads.***
- ***Graded aggregates are used for road base either blended with different forms of slag's or with natural sands and rocks.***
- ***Crushed aggregates with graded form are used as replacements for both fines (sand) and coarser aggregates (natural coarse aggregate), and used below concrete slabs as a platform.***

GGBS and GBS (granulated BFS):

- ***The well grounded aggregates are used as a replacement for Cement which replaces up to 30 to 50% of Portland cement in normal conventional concrete, further it can be replaced up to 70% in unique applications such as marine concreting.***
- ***GGBS is the most applicable material in cement manufacturing industry. In slag cement production, GBS aggregates are grounded separately or together with calcium sulphate and Portland cement clinker. Usually, GGBS is grounded to maximum fineness to obtain an increased early strength than that of ordinary Portland cement.***
- ***Ungrounded GBS can be used as a base and sub-base layer material in construction of roads.***
- ***Grounded GBS can be used as Filler material due to its sand-like texture. It sets up over time due to its self cementing property.***
- ***Can be used as stabilising binder material in pavement due to slow rate of the cementation process. The re work of pavement material can be done in two to three days.***
- ***Other uses of GBS are in glass making, production of concrete block, as a filtration medium, in reinforced earth embankments and backfilling of mines.***

Basic oxygen steel slag (BOS):

- ***BOS is used as pavement material by blending with other products such as lime, fly ash and granulated slag.***
- ***Other uses of BOS are in unconfined construction fills, as soil conditioner, ballast asphaltic concrete aggregate and skid-resistant asphalt aggregate rail.***

Electric arc furnace slag (EAF):

- ***EAF'S are blended with lime, fly ash and granulated slag, to form pavement material and unconfined construction fill.***
- ***SFS is majorly used for asphalt application. Because SFS gives better impact resistance, abrasion and strength.***
- ***SFS is more suitable for areas which are subjected to more shear and heavy vehicle loads.***

Bond strength: In most composite members, including reinforced concrete, composite action requires that loads be transferred from one material to another through bond. This interface where bond occurs has the potential to be the weakest part of the member. This RC members specifically used on the assumption that there is bond link between steel and concrete when the members are loaded. The behaviour of RC members is defined on steel-concrete bond.

Definition of bond strength: The ability of concrete to hold the steel rebar from pulling out of hardened concrete is known as bond and the resultant stress is called bond stress.

The withstand offered by the bars is due to these following factors:

- ***The adhesion b/w steel rebar and the concrete***
- ***The friction offered by rebar due to the ribs present on surface the rebar***

The bond strength can be increased by,

- ***Providing rough surface of steel deformed bars***
- ***By giving effective cover***
- ***Providing rich mix concrete***

I. INTRODUCTON

The main aim of the experimental work carried out is that the concrete was tested for the partial replacements of Natural or river sand by slag. The basic tests were conducted on the materials used in the experimental study. The concrete with partial replacements of slag were tested for the concrete strength parameters like cylinder compression, split tensile tests were conducted. The replacements percentages were 0% & 20% of Slag. The diameter of bars used was kept constant for reinforcement to check the influence of the bond between steel rebar and the hardened concrete.

II. LITERATURE REVIEW

In this chapter, the experimental/theoretical studies carried out on various properties of concrete by various authors have been presented.

P. Sathish Kumar et al., (2015), carried out experimental study to evaluate the strength and durability parameters of concrete. In this study fine aggregates were partially replaced by steel slag. The concrete parameters like compression, tensile and flexure strengths were studied. The study concluded that, compressive strength increases with increase in replacement of steel slag.

Dr. B. Krishna Rao et al., (July2015), carried out an experimental investigation by replacing natural fine aggregate with air-cooled furnace slag. In this investigation M30 grade of concrete was considered. The percentages of slag replacements were 0%, 12.5%, 25%, 37.5%, and 50%. These concrete specimens were tested for 7days, 28days and 56days. In this study the target strength achieved was found for 25% replacement of slag for 7days, 28days, 56days and 90days.

M. C. Nataraja et al., (2013), carried out a study on replacement fine aggregate (sand) in cement mortar using GGBS to limit the causes generated in disposal of industrial waste. Partial replacements were carried out for 0%, 25%, 50%, 75% and 100%. Mix ratio of 1:3 and W/C ratio 0.5 was considered. The compressive strength and flow characteristics for different mix proportions for 3, 7 and 28days strength were carried out. The study concluded that higher compressive strengths of cement mortar can be attained with increase in replacement percentage of GGBS.

Juan Murcia-Delso et al., 2013, evaluated the properties of bond strength on normal concrete by pullout test method. The bond behavior was studied for 36, 43, and 57mm diameter bars. Bond failure was observed by splitting of concrete specimens. Bond strength was observed to be decreased with increase of bar diameter. The various parameters studied were, the effect of bar diameter, the effect of strength of concrete, direction of pulling (vertical pull) and loading pattern. Pullout of bars was observed in all the concrete specimens. It was concluded from the study that the bond strength tend to increase with increase in bar diameter and compressive strength.

Mohammad Nadeem et al., (2012), carried out a study to investigate the effects of replacements for aggregates with steel slag in concrete. M20, M30 and M40 grades of concrete with Water to cement ratios of 0.40, 0.45 and 0.55 was considered. The replacement percentages were of 0%, 30%, 50%, 70% and 100% for both Fine and coarse aggregates. Strength properties like compression, split-tensile and flexure strength were determined. This study concluded that compressive strength was increased by about 4 to 7 % for all various different replacements.

G. Apparao et al., (2010), carried out a laboratory investigation in order to know the bond strength of the concrete by carrying out pullout test. The various parameters like the effect of bar diameter, and the effect of strength of concrete were studied. The diameters of steel bar were of 16mm and 20mm. OPC of 53 grade was used. Good bond strength was found in the confined region and it was due to shear failure. The ultimate strength was found to be 10.8MPa and 11MPa for 16 and 20mm bars respectively.

III. CONCRETE PROPORTIONING USING TRIAL MIXES

Trial mixes were carried out in order to decide exact water content and admixture dosage for required slump value of 60 mm with respect to the fixed cement content of300kg/m^3. Based on results obtained from trial mixes, suitable water and admixture contents have been selected to satisfy both workability and strength aspects of Concrete.
The mix design adopted is stipulated as follows.

A. Proportioning For Mix Design

a. Cement type: OPC 53 grade
b. Max. nominal size of aggregate: 20mm
c. Min. cement content: 300 kg/m3
d. Max. water to cement ratio: 0.48
e. Workability: 60 mm slump
f. Exposure condition: Severe
g. Aggregate type: Angular aggregate
h. Max. cement content: 300 kg/m3
i. Chemical admixture: Plasticizer

B. Test data of materials

a. Specific gravity of cement = 3.15
b. Specific gravity of fine aggregate (river sand) = 2.65
c. Specific gravity of coarse aggregate = 2.70
d. Specific gravity of slag = 3.48
e. Water absorption of natural sand = 2%
f. Water absorption of slag = 0.80 %
g. Water absorption of coarse aggregate = 0.4%
h. Sieve analysis: Fine aggregate (river sand) conforming to zone II
Fine aggregate (slag) conforming to zone II

1) Step 1: Proportion of volume of coarse aggregate and fine aggregate content

As per IS:10262 2009- table 3, volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate (zone II) for water cement ratio of 0.5 = 0.62. In present study water to cement ratio is 0.48.
Hence Volume of Coarse aggregate = 0.62
Volume of Fine aggregate = 0.38

2) Step 2: Mix Calculations

The mix calculation per unit volume of concrete shall be as follows
a) Volume of concrete = 1 m3
b) Volume of cement = 0.095m3
c) Volume of water = 0.144m3
d) Volume of chemical admixture = 0.5% = 1.5 litre = 0.0014
e) Volume of all in aggregate = 1 - (0.095+0.144+0.0014) = 0.7596 m3
f) Volume of coarse aggregate = 0.7596×0.62×2.7×1000 = 1272 kg/m3
g) Volume of fine aggregate (natural sand) = 0.7596×0.38×2.60×1000 = 765kg/m^3

3) Step 3: Mix Proportions

a. Cement = 300 kg/m3
b. Water = 174.6 kg/m3 (2.8 % absorption for fine aggregates)
c. Fine aggregate (R sand) = 765 kg/m3
d. Coarse aggregate (60%) 20mm = 763.2 kg/m3
e. Coarse aggregate (40%) 12mm = 508.8 kg/m3

C. Replacement Of Natural Sand Is Done By Slag For 60%

a. Cement = 300 kg/m3
b. Water = 156.23 kg/m3
c. Coarse aggregate (60%) 20mm = 763.2 kg/m3
d. Coarse aggregate (40%) 12mm = 508.8 kg/m3
e. Fine aggregate (R sand) = 305.96 kg/m3
f. Slag = 597.51 kg/m3

IV. PRODUCTION OF CONCRETE SPECIMENS

The required materials (Coarse and fine aggregates, LD Slag, and cement) for production of concrete were batched by dry weight. All the ingredients were mixed in a drum mixer in dry condition until uniform mix appears, then the required amount of water and admixture were added.

All the ingredients were mixed in drum mixer for about 10 minutes until a uniform dense cohesive mix of fresh concrete is obtained, later this fresh mix was poured into cast iron moulds and then compacted for optimum compaction. Concrete specimens with constant restricted cement content were produced by utilizing LD Slag aggregates in proportions, are as follows:

K60: 60% Slag - (Cement content – 300 kg/m3)

- Coarse Aggregate: Natural crushed angular coarse aggregates of size passing 20 mm and retained on12.5mm IS Sieves
- Fine Aggregate: Natural fine aggregate (River sand) of size passing 4.75mm and retained on 75 IS Sieve. (Zone – II)
- LD Slag: LD Slag of size passing 4.75mm IS Sieve. (Zone – II)
- Cement: Ordinary Portland Cement – 53 Grade – Birla premium A1
- Water: 0.48 times of Cement content + Extra water for water absorption of aggregates
- Admixture: Plasticizer @ maximum 2% of cement content, dosage depends on mix proportion of LD Slag

A. Curing of Concrete Specimens

The produced concrete cubes, cylinders were carefully de-moulded after a period of 24 hours. The specimens were cured in a curing tank by immersing completely in it. Clean portable water was used for curing to ensure that the specimens do not become dry at any point until they were tested for the respective days.

B. Testing of Concrete Specimens

The produced concrete specimens were tested for Compression, Split Tensile and Bond strength. These specimens were tested only after the required period of curing (28 Days).

Before the testing of the specimens, the surfaces are completely cleaned. The obtained results from tests performed on hardened concrete specimens were evaluated and compared with other conventional concrete.

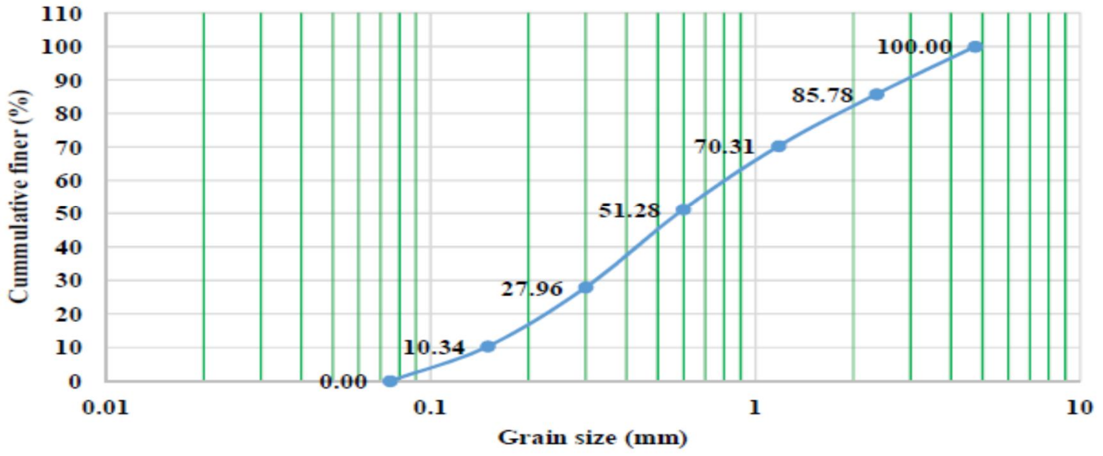
V. TESTS ON MATERIALS

River sand used during the course of work was tested for the desirable properties and the results obtained are presented below.

A. Grain Size Distribution

Particle size distribution of river sand was found by conducting Wet Sieve Analysis as per IS 383: 1970.

Quantity of river sand = 500g



Grain Size Distribution of Natural fine aggregates

% of Gravel = 3.28%
% of Sand = 93.66%
% of Fines = 3.06%

1) Specific Gravity

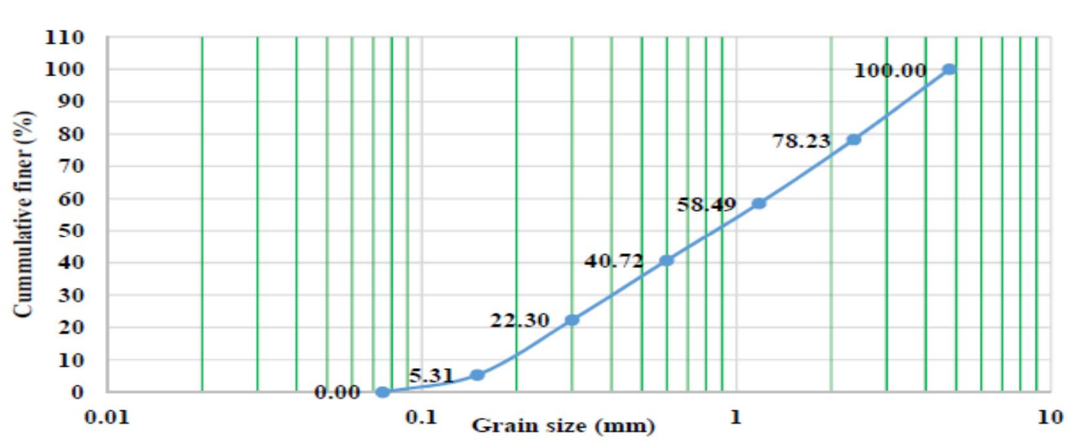
As per IS 2386 (Part III): 1963, Specific Gravity of Natural river sand (fine aggregates) was determined and the results are tabulated.
Specific Gravity = 2.65
Apparent Specific Gravity = 2.79
Water Absorption = 2.00 %

2) Properties of LD Slag

LD Slag used during the course of work was tested for the following desirable properties and the results obtained are presented below.

B. Grain Size Distribution

Wet Sieve Analysis was conducted to found the particle size distribution of LD Slag as per IS 383: 1970.
Quantity of LD Slag = 500 g



Grain Size Distribution of LD Slag fine aggregates

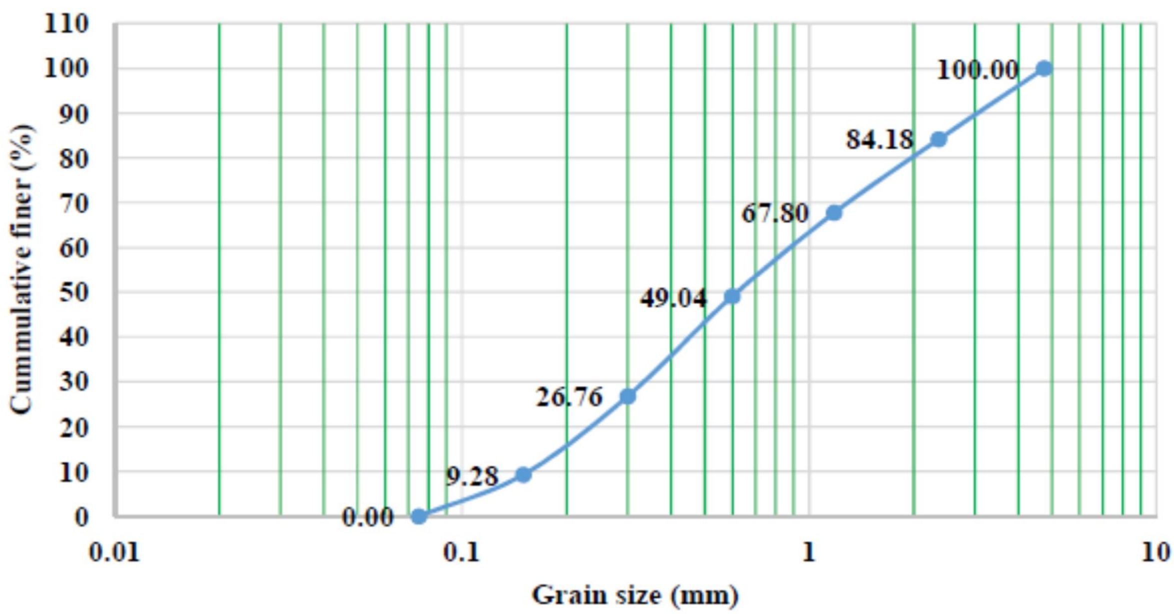
International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue XII Dec 2024- Available at www.ijraset.com

1) Specific Gravity

As per IS 2386 (Part III): 1963, Specific Gravity of LD slag fine aggregates was determined and the results are tabulated.
Specific Gravity = 3.48
Apparent Specific Gravity = 3.57
Water Absorption = 0.801 %

C. Grain Size Distribution for combined fine aggregates for specimen type K60 (40% River sand and 60% Slag):

As per IS 383: 1970, Particle size distribution was found by conducting Wet sieve analysis of combined fine aggregates (River sand and LD slag).
Quantity of LD Slag = 500 g



Grain Size Distribution of combined fine aggregates for specimen type K60

1) Tests on Hardened Concrete

Laboratory tests such as Compression and Split tensile conducted on concrete specimens (Slag Utilized) of all the proportions.
Average Compression Test results of Concrete Cylinders o 28 das curing period.

Sl no	Specimen Type	28 Days average compressive strength of cylinder, Mpa
1	K0	25.08
2	K60	31.14

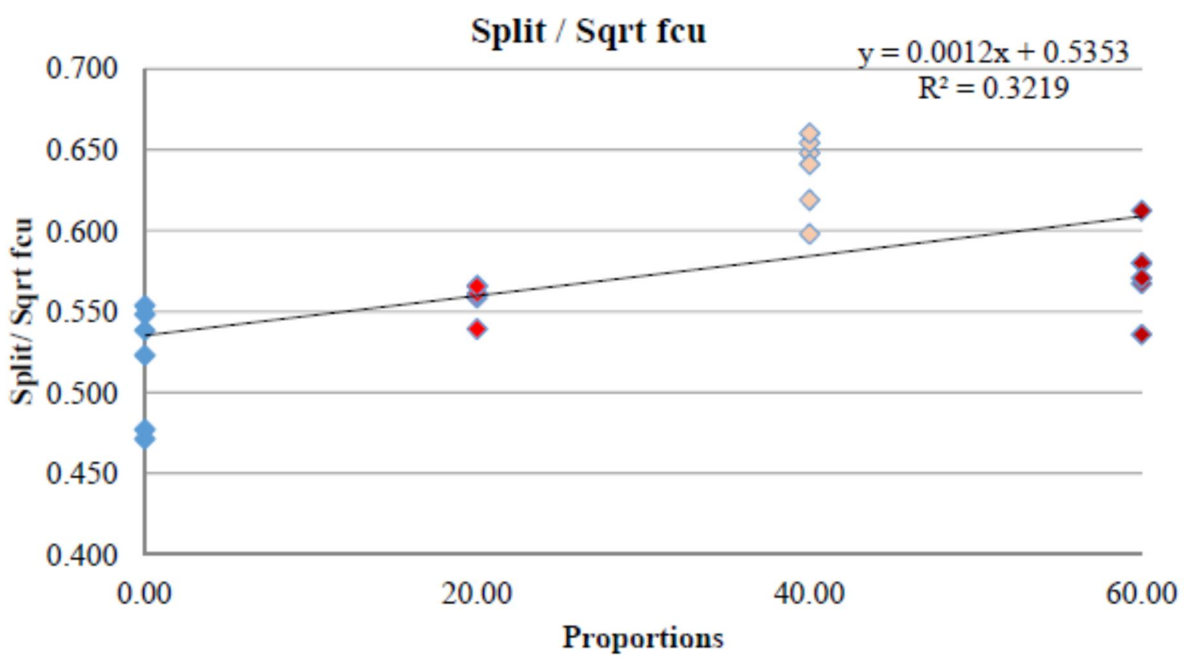
2) Split Tensile Test

The brittle nature of concrete exhibits its weakness under tensile loads and cracks are developed. Hence, it is much necessary to carryout tensile test indirectly to determine the peak load at which the specimens may crack.
Apparatus: Weigh balance, Compressive testing machine (CTM), loading attachments, other required accessories
Preparation: Concrete specimens prepared were taken out from curing condition and kept for drying before testing for the respective tests. During testing, all undulations on both testing surfaces were smoothened to ensure proper contact surface for testing.
Procedure: Test specimens were placed such that the two metal plates were placed as shown in figure to ensure uniform loading and then placed in compression testing machine. The uniform rate of axial loading of 14MPa per minute was applied until complete failure of block occurs. Ultimate load at failure condition was noted down. Based on the ultimate failure load and specimen surface area, split tensile strength of cylinders was calculated.

Sl no	Specimen Type	Average Split Tensile Strength N/mm^2
1	K0	2.9
2	K60	3.72

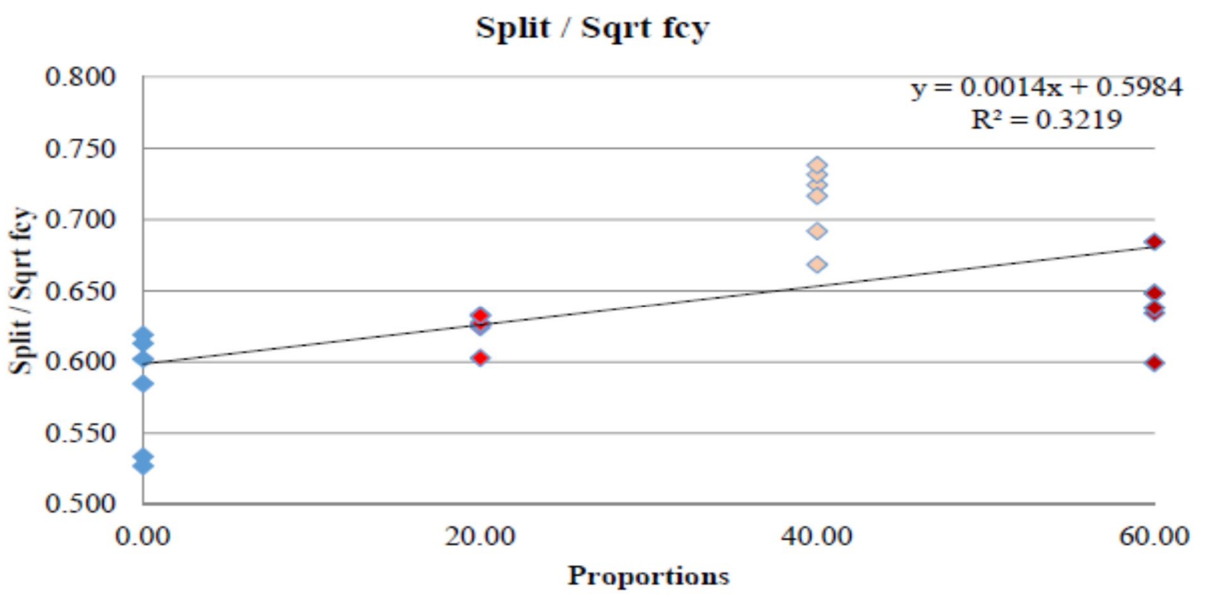
VI. CORRELATION OF PARAMETERS

Relation b/w Split-tensile strength and comp. Strength of Cube



The relation b/w the Split-tensile strength and comp. strength of cube has been presented in the graph 15. It shows a slight increase in split-tensile strength with increase in percentage replacements of slag.

Relation b/w Split-tensile strength and comp. strength of Cylinder



The relation b/w the Split-tensile strength and comp. strength of cylinder has been presented in the graph. It shows a slight increase in split-tensile strength with increase in percentage replacements of slag.

VII. CONCLUSIONS

1) Cylindrical Compressive strength of increased with increase in replacement of fine aggregates with steel slag.
2) Split tensile strength increased with increase in replacement of fine aggregates with steel slag.

REFERENCES

[1] S.T.Borole et al., "Replacement of Fine Aggregate by Steel Slag", International journal of innovative research in science and engineering, Volume 2, Issue 3, March-2016.
[2] Xiaobin Song et al., "Bond behaviour of reinforcing steel bars in early age concrete", Department of Structural Engineering, Tongji University, Construction and Building Materials ,2015, 209–217.
[3] Jiqiu Yuan et al., "Bond of Reinforcement in Ultra-High-Performance concrete", ACI Structural Journal, Volume112, NO 6, November-December-2015.
[4] T. Subramani et al., "Experimental investigation of coarse aggregate with steel slag in concrete", IOSR journal of engineering, Volume 3, Issue 5, pp. 64-73, May-2015.
[5] K.A. Olonade et al., "Performance of Steel Slag as Fine Aggregate in Structural Concrete" Nigerian Journal of Technology (NIJOTECH) Vol. 34 No. 3, July 2015.
[6] P.Sateesh Kumar et al., "Study on Behaviour of Concrete Mix Replaceing Fine Aggregate With Steel Slag At Different Properties", International Journal of Engineering Research and Applications, Vol. 5, Issue 11, (Part - 4) November 2015, pp.39-46
[7] Dr. B. Krishna Rao et al., "Replacement of natural fine aggregate with air cooled furnace slag", Volume 3, Issue 7(part 1), pp. 36-40, July-2015.
[8] M C Nataraja et al., "Use of Granulated Blast Furnace Slag as Fine Aggregate in Cement Mortar", International journal of structural and civil engineering research, Vol. 2, No. 2, May 2013.
[9] Juan Murcia-Delso et al., "Bond Strength and Cyclic Bond Deterioration of Large- Diameter Bars", ACI Structural Journal/July-August 2013.
[10] Mohammed nadeem et al., "Experimental investigation of using slag as an alternative to normal aggregate in concrete", International journal of civil and structural engineering, Volume 3, September-2012.
[11] Appa Rao G., Faiz Sultana., and Pandurangan K., "Bond strength and bond stress slip response in reinforced concrete", Journal of Structural Engineering, Vol. 36, No. 5, Dec 2009-Jan 2010, pp. 347-353.

Standard Codes and Reference Books:
[1] M. S. Shetty, Concrete technology theory and practice, S Chand & Company Ltd, 2011.
[2] Indian Standard 2386 (Part 4) -1963, (Tenth Revision), Methods of test for aggregates for concrete, Bureau of Indian standards, New Delhi.
[3] Indian Standard 383: 1970, Specification for Coarse and Fine aggregate from natural sources for Concrete (Second Revision), Bureau of Indian standards, New Delhi.
[4] Indian Standard 2386 (Part 1) -1963, (Tenth Revision), Methods of test for aggregates for concrete, Particle size and Shape,Bureau of Indian standards, New Delhi.
[5] IS: 2386 (Part 3) -1963, "Methods of Test for Aggregates for Concrete ,Specific Gravity, Density, Voids, Absorption and Bulking. Indian standard" Bureau of Indian standards, New Delhi.
[6] IS 10262 – 2009, "Guidelines for concrete mix design proportion", Bureau of Indian standards, New Delhi.
[7] IS 456 – 2000, "Indian code of practice for plain and reinforced concrete", Bureau of Indian standards, New Delhi.
[8] IS 516 – 1959, "Indian Standard Methods of Tests for Strength of Concrete (Incorporating Amendment Nos. 1 & 2)", Bureau of Indian standards, New Delhi.
[9] IS 4031 (Part 1) – 1996, "Method of physical tests for hydraulic cement", Bureau of Indian standards, New Delhi.
[10] IS 4031 (Part 5) – 1988, "Determination of initial and final setting times", Bureau of Indian standards, New Delhi.
[11] IS 4031 (Part 4) – 1988, "Determination of consistency of standard cement paste", Bureau of Indian standards, New Delhi.
[12] IS 2250 – 1981, "code of practice for preparation and use of masonry mortars", Bureau of Indian standards, New Delhi.
[13] IS 1498 – 1970, "Classification and identification of soils for general engineering purposes", Bureau of Indian standards, New Delhi.
[14] IS 1786: 2008, "High strength deformed bars and wires for concrete reinforcement", Bureau of Indian standards, New Delhi.
[15] IS 2270-1: 1967, "Method for testing bond in reinforced concrete", Bureau of Indian standards, New Delhi.