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Experimental Investigations to Demonstrate the Influence of GGBS on Compressive Strength of Medium and High Strength Concrete

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Abstract: **Concrete is a widely-used material in construction industry, because it has naturally and easily available ingredients like cement aggregate and water. Production of cement creates environmental problem like emission of CO2 in the production process of cement. So, there is serious need to find ways and means to reduce CO2 emission. To overcome this problem Ground Granulated Blast Furnace Slag, which is a pozzolanic material can be used as a partial replacement to cement. In the present study, GGBS was replaced with cement to obtain the influence of GGBS in normal and high strength concrete on durability properties. Comparisons were made with different percentage of replacements of GGBS for cement, which helped to arrive at the optimum percentage of replacement.**

***Index Terms*— Compressive Strength, GGBS replacement, Optimum replacement.**

I. INTRODUCTION

Concrete is a widely-used material in construction industry, because it has naturally and easily available ingredients like cement aggregate and water. It has numerous applications because of its strength, ease of moulding and also cheap availability of its ingredients. Cement is one of the most important ingredients of concrete because of its binding properties. Increase in production of cement creates environmental problem like emission of CO 2 in the production process of cement [6]. One tonne of C 2 is released to atmosphere when one tonne of OPC is manufactured which has very harmful effect on the environment. The emission of CO2 depends upon the type of production processes, their efficiency; fuel used, yet concrete is a desirable construction material with relatively low embodied energy, very useful thermal mass and high potential durability. [7]. so, there is serious need to find replacements for cement. To overcome this problem GGBS which is a pozzolanic material can be used as a partial replacement to cement. As GGBS is a waste from the iron industry and has chemical and physical properties like cement. So, it serves 2 purposes. 1. To replace cement partially. 2. To overcome the problem of disposal of GGBS. From structural point of view, GGBS replacement reinforced lower heat of hydration, higher endurance and higher obstructed to sulphate and chloride intrusion when contrasted with normal ordinary concrete. On the farther hand, it also enriches to environmental resistance because it curtails the use of cement during the production of concrete. The main components of blast furnace slag are CaO (30-50%), SiO2 (28-38%), Al2O3 (8-24%), and MgO (1- 18%). In general, booming the CaO content of the slag terminates in raised slag basicity and a rise in compressive strength. GGBS is used to make reliable concrete structures. GGBS has been broadly used in Europe and progressively in Japan and Singapore for its Excellency in concrete durability, continuing the lifetime of buildings from fifty years to a hundred years' strength. [7]

GGBS SLAG

GGBS Slag which is commonly referred as GGBS is a pozzolanic supplementary cementitious material is obtained by quenching molten iron slag (a by product of iron and steel industry) in water or steam, to produce a glassy, granular product that is afterwards dried and ground into a fine powder [19]. Thirty eight years later, after the patent of Portland cement was first lodged by John Aspdin in 1824, Emil Langin discovered the GGBS cement in the year 1862 [20]. By 1865, the commercial production of the lime activated GGBS had begun in Germany and since 1880 GGBS is being utilized along with the Portland cement as an activator [20].

II. MATERIALS AND EXPERIMENTS

CEMENT

In the current investigation, Zuari 43 grade OPC conforming to IS 8112-2013 has been utilized. The physical properties of the cement were found to be as per IS 8112-2013 and has been mentioned below (Table 1).

FINE AGGREGATES

Natural river sand is the most preferred choice as a fine aggregate material. It is mined from river beds and sand mining has disastrous environmental consequences. River sand is becoming scarce and its use needs to be stopped or reduced. Use of other alternatives to River sand has become necessary. Manufactured sand (M-sand) is proving to be a great alternative for river sand and has gained immense popularity in India in recent years. Specific gravity, bulk density and particle size distribution of M-sand is almost similar to River sand. The fine aggregates satisfied the specifications as per IS 383-1970.

Table 1: Requirements of cement properties as per IS 8112: 2013

Sl. No	Properties	Requirements as per IS 8112 : 2013
1	Fineness	Not more than 10%
2	Soundness	Not less than 10 mm
3	Initial Setting Time	Not less than 30 min
4	Final Setting Time	Not more than 600 min
5	3 days Compressive Strength	Not less than 23 N/mm^2
6	7 days Compressive Strength	Not less than 33 N/mm^2
7	28 days Compressive Strength	Not less than 43 N/mm^2

COARSE AGGREGATES

Coarse aggregates are important to concrete as they play an important role in the attainment of strength in concrete. The strength of the concrete depends on the size and the grading of the coarse aggregates. Small sized coarse aggregates produce higher strength of concrete as the amount of stress concentrated around the aggregate particles is much lesser which is caused due the differences between the elastic moduli of the paste and aggregate. The coarse aggregates used in the current studies were found conforming to the codal provisions in IS 383-1970.

GGBS

GGBS used for the present investigation was borrowed from RMC Ready-mix India.

SUPER PLASTICIZER

Conplast SP 430 which is commercially marketed by Fosroc Chemicals India Pvt Ltd was used as the super plasticizer in M60 grade High Strength Concrete.

WATER

As per IS 456:2000 for both mixing and curing of concrete, potable water free from harmful salts was used.

MIX PROPORTION USED IN THE STUDY

Based on the results observed from the trial mixes following mix proportions for HSC and MSC was adopted for the present investigation as shown below in table 2.

Table 2: Mix proportions of HSC and MSC

MATERIALS	MSC	HSC
Water binder ratio	0.4	0.29
Cement (kg/m^3)	420	504.21
Fine Aggregate (kg/m^3)	710	663.26
Coarse Aggregate(kg/m^3)	1123	1108.13
Water (kg/m^3)	168	146.28
Super plasticizer (kg/m^3)	-	7.563

As the grade of concrete increased the cement content also increased and water content in high strength concrete was decreased. Super plasticizer was used only in the M60 grade concrete and not in the medium strength concrete.

III. EXPERIMENTAL INVESTIGATION

COMPRESSIVE STRENGTH

The compressive strength of M60 and M40 grades of concretes were determined using cube specimens of size 100mm x 100mm x 100mm according to IS: 516-1959. Compressive strength of all the 10 sets of concrete mixes was tested at the age of 7, 14, 28, 56 and 90 days. A minimum of 3 specimens were tested for the compressive strength of each set of concrete at their respective curing periods. Fig 1 shows the experimental setup of compression test of concrete cube. Specimen was loaded at the rate of 140 kg/sq.cm/min.

Fig 1: Compressive Strength test setup

Fig 2: Failure pattern of cubes tested for compressive strength

A non explosive failure of all the specimens took place. From the failure of the specimens, it was observed that equal and vertical zigzag cracks appeared on all the vertical faces, there was no damage on top and bottom faces and vertical faces broke down leaving the pyramid in between. Fig 2 shows the failure pattern of the cubes tested.

IV. RESULTS AND DISCUSSIONS

Discussions of results over benchmarking with literatures and validation of obtained data add value to thesis work. Results from the experiments are discussed in this chapter.

COMPRESSIVE STRENGTH TEST RESULTS
Compressive Strength Results of M40 Grade concrete
A total of 60 cubes with M40 grade concrete were casted of size 100mm x 100mm x 100mm. The cubes were water cured and tested for compressive strength at the age of 7, 14, 28 and 56 days for all the five mixes of Medium Strength Concrete. All the specimens of five mixes were tested to determine the compressive strength at their respective curing ages and the results of compressive strength of M40 mixes are tabulated in the Table 3 below,

Table 3.Compressive Strength of MSC mixes at different curing periods

MSC Mix	Compressive Strength in MPa			
	7 days	14 days	28 days	56 days
0% GGBS (control mix)	39.73	47.57	49.54	50.03
20% GGBS	42.18	48.07	52.48	55.91
30% GGBS	41.2	46.59	56.4	59.84
40% GGBS	39.73	46.59	54.45	56.41
50% GGBS	38.26	45.61	52.97	56.89

From the test results it was observed that at the age of 7 days, compressive strength of MSC mix increased by 6.2%, 3.7% for 20% and 30% GGBS replacement respectively, but there was a decrease in compressive strength by 3.7% for 50% replacement level compared to control mix. Compressive strength at 7 days for 40% replacement was same as that of control mix. At the age of 14 days, compressive strength increased by 1.1% for 20% replacement but decreased by 2.1%, 2.1% and 4.1% for 30%, 40% and 50% GGBS replacement levels respectively. At the age of 28 days, it was observed that compressive strength increased by 5.9%, 13.8%, 9.9%, and 6.9% for 20%, 30%, 40% and 50% GGBS replacements respectively. At the age of 56 days, strength increased by 11.8%, 19.6%, 12.8% and 13.7% for 20%, 30%, 40% and 50% GGBS replacement levels respectively.

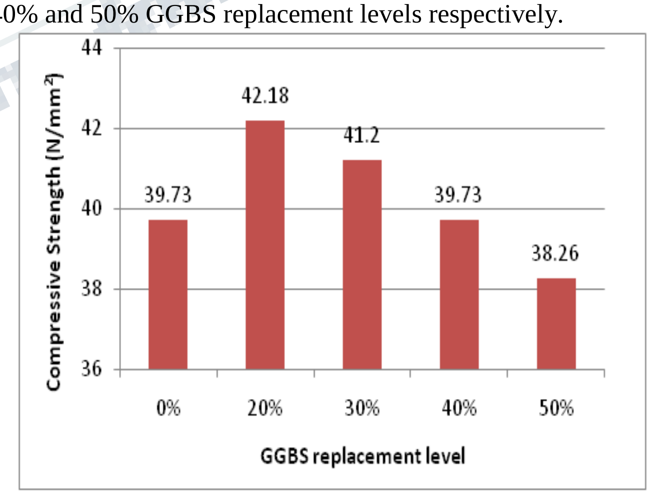

Fig 3 Variation of compressive strength at 7 days for M40 Concrete

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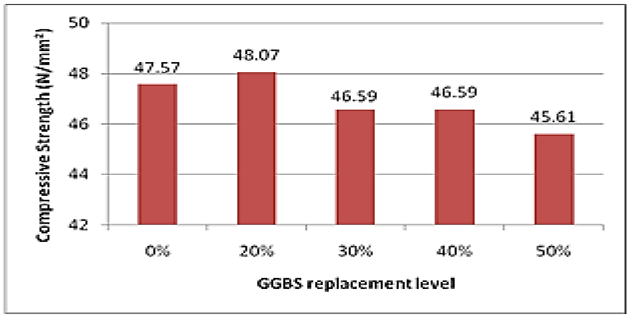

Fig 4 Variation of compressive strength at 14 days for M40 Concrete

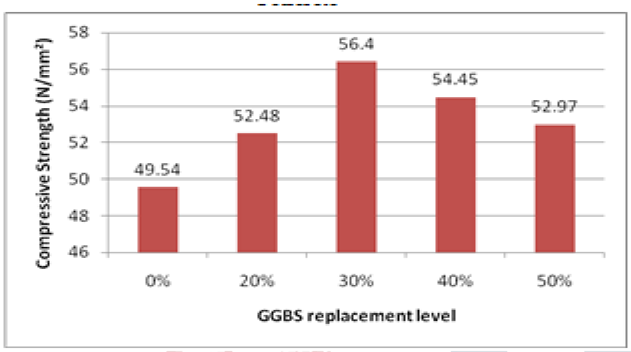

Fig 5 Variation of compressive strength at 28 days for M40 Concrete

Variation of compressive strength of MSC mixes at various curing periods and various GGBS replacement levels are shown in Fig 3, Fig 4, Fig 5, and Fig 6. From the test results, it was observed that at the age of 7 and 14 days mix containing 20% GGBS had optimum strength and at the age of 28, and 56 days, mix containing 30% GGBS had achieved the optimum compressive strength.

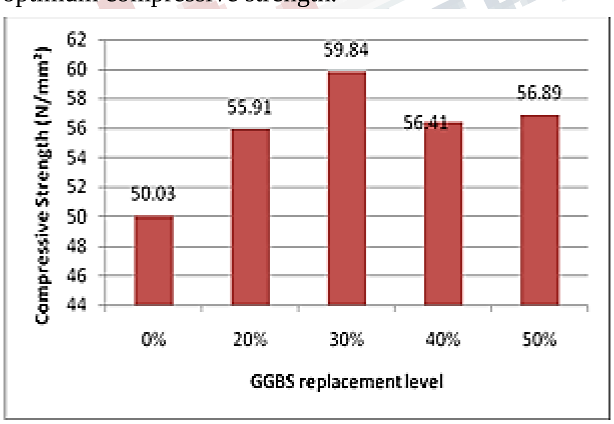

Fig 6 Variation of compressive strength at 56 days for M40 Concrete

Compressive Strength Results of M60 Grade concrete

A total of 60 cubes with M60 Grade concrete were casted of size 100mm x 100mm x 100mm. The cubes were water cured and tested for compressive strength at the age of 7, 14, 28, and 56 days for five mixes of High Strength Concrete. All the specimens of five mixes were tested to determine the compressive strength at their respective curing ages and the results of compressive strength of M60 mixes are tabulated in the Table 4 shown below,

Table 4: Compressive Strength of M60 mixes at different curing periods

HSC Mix	**Compressive Strength in MPa**			
	7 days	**14 days**	**28 days**	**56 days**
0% GGBS (control mix)	53.46	56.41	63.76	66.22
20% GGBS	54.96	60.33	65.72	67.68
30% GGBS	52.48	63.27	68.67	70.63
40% GGBS	52	69.7	72.59	76.52
50% GGBS	51.01	69.1	70.63	75.05

From the test results it was observed that at the age of 7 days, compressive strength of M60 mix increased by 2.8% for 20% GGBS replacement, but there was a decrease in compressive strength by 1.8%, 2.7% and 4.6% for 30%, 40% and 50% replacement levels respectively compared to control mix. At the age of 14 days, compressive strength increased by 6.9%, 12.2%, 23.6% and 22.5% for 20%, 30%, 40% and 50% GGBS replacement levels respectively. At the age of 28 days, it was observed that compressive strength increased by 3.1%, 7.7%, 13.8%, and 10.8% for 20%, 30%, 40% and 50% GGBS replacements respectively. At the age of 56 days, strength increased by 2.2%, 6.7%, 15.6% and 13.3% for 20%, 30%, 40% and 50% GGBS replacement levels respectively.

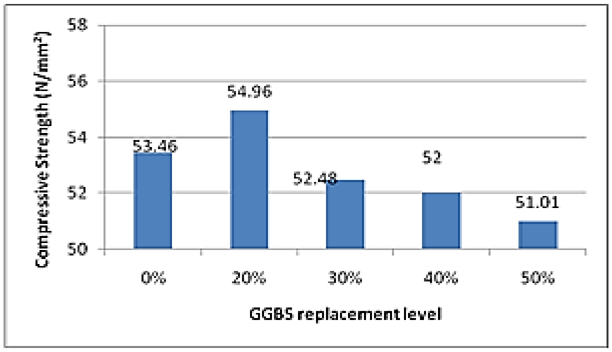

Fig 7 Variation of compressive strength at 7 days for M60 Concrete

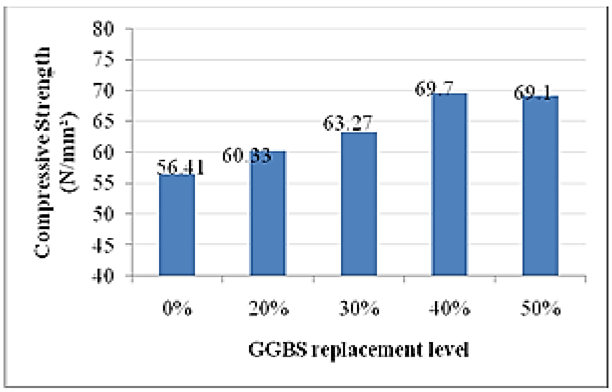

Fig 8 Variation of compressive strength at 14 days for M60 Concrete

Variation of compressive strength of High Strength Concrete mix at various curing periods and various GGBS replacement levels are shown in Fig 7, Fig 8, Fig 9, and Fig 10. From the test results, it was observed that at the age of 7 days mix containing 20% GGBS had optimum strength and at the age of 14, 28 and 56 days, mix containing 40% GGBS had achieved the optimum strength.

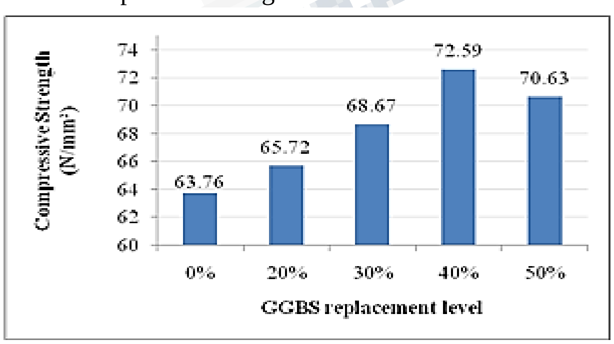

Fig 9 Variation of compressive strength at 28 days for M60 Concrete

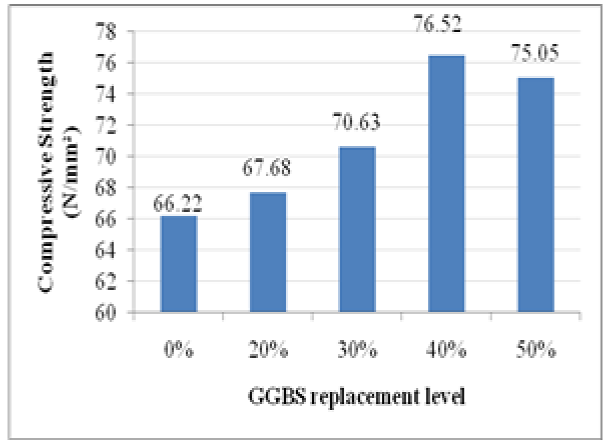

Fig 10 Variation of compressive strength at 56 days for M60 Concrete

IV. CONCLUSIONS

1. As the percentage of cement replacement of GGBS increased, percentage of weight reduction in both M40 and M60 grade concrete decreased.

2. Based on compressive strength criteria, the optimum level of GGBS replacement was observed to be 30% for M40 grade and 40% for M60 grade.

3. For 40% and 50% replacement levels, it was observed that there was no significant weight loss for high strength concrete.

REFERENCES

1. Ajay Kumar Singh, (2016) "Strength and Durability Test of Fly Ash and GGBS Based Geopolymer Concrete" Int. Journal of Engineering Research and Application ISSN: 2248-9622, Vol. 6,Issue 8, (Part -1), pp.139-142

2. V.Nagendra, (2016) "Effect on strength properties of concrete by using GGBS by Partial Replacing cement with GGBS" International Journal of Recent Trends in Engineering & Research (IJRTER) ISSN: 2455-1457, Volume 02, Issue 08,

3. Andriya Annal, Priya Rachel, (2016)"Experimental Study on Behaviour of High Performance Concrete using GGBS and M Sand" International Journal of Engineering Research

& Technology (IJERT) ISSN: 2278-0181, Vol. 5 Issue 02

4. T.H Patel, J M Shreeshaila, Prahlada V, (2016)"Experimental Study on Durability Properties of High Performance Self Compacting Concrete", International Journal of Innovative Research in Science, Engineering and Technology ISSN (Print): 2347-6710,Vol. 5, Issue 08 DOI:10.15680/IJIRSET.2016.0508107

5. Aishwarya Asha,(2016) "Strength Characteristics of Concrete with Addition of Steel Fibre and Partial Replacement of Cement with Ground Granulated Blast Furnace Slag" International Journal of Engineering Science and Computing, ISSN 2321 3361 DOI 10.4010/2016.1305

6. Shankar Mishra, Pankaj Kumar Choudhary, Pawan Taneja, Naman Gupta, Manoj Olla, Kamlesh Saini (2016) "Studies on Utilisation of GGBS and Fly Ash to Make Green Concrete" SSRG International Journal of Civil Engineering (SSRG-IJCE), ISSN: 2348 – 8352volume 3 Issue 5 http://www.internationaljournalssrg.org/IJCE/2016/Volume3-Issue5/IJCE-V3I5P107.pdf

7. Maria Rajesh Antonyamaladhas, Selvamony Chachithanantham and Anandkumar Ramaswamy, (2016) "Performance and Behaviour of Ground Granulated Blast Furnace Slag Imparted to Geopolymer Concrete Structural Elements and Analysed with ANSYS" Advances in Materials Science and Engineering Volume, Hindawi Publishing Corporation http://dx.doi.org/10.1155/2016/7023897

8. C. S. Poon and L. Lam, (2006) "Compressive strength, chloride diffusivity and pore structure of High performance Metakaolin and silica fume concrete" Construction and Building Materials, 20 858–865 DOI: 10.1016/j.conbuildmat.2005.07.001

9. Chaohua Jiang, Xiaobin Zhou, Guilan Tao,and DaChen, (2016), "Experimental Study on the Performance and Microstructure of Cementitious Materials Made with Dune Sand" Advances in Materials Science and Engineering Volume 2016 (2016), Article ID 2158706, 8 pages, Hindawi publishing http://dx.doi.org/10.1155/2016/2158706

10. M. Saillio, V. Baroghel-Bouny and S. Pradelle "Various Durability Aspects of Cement Pastes and Concretes with Supplementary Cementitious Materials" Second International Conference on Concrete Sustainability ICCS16 Madrid 2016

11. Matthieu Bergin, and Othman Omicron Metalssi "Changes in microstructure and pore structure of low-clinker cementitious materials during early stages of carbonation" DOI 10.4010/2016.1305 ISSN 2321 3361, 2016 IJESC

12. Luca Bertolini and Maddalena Carsana "Corrosion of Steel in Concrete and Its Prevention in Aggressive Chloride-Bearing Environments" DOI 10.4010/2016.1305 ISSN 2321 3361, 2016 IJESC

13. Wei-Chung Yei and Jiang-Jay Chang "Corrosion of Rebar Under Carbonation and Salt Environment" Second International Conference on Concrete Sustainability ICCS16 Madrid 2016

14. M. Pavan Kumar, Y. Mahesh (2015) "The Behaviour of Concrete by Partial Replacement of Fine Aggregate with Copper Slag and Cement with GGBS" IOSR Journal of Mechanical and Civil Engineering, Volume 12, Issue 3 Ver 3, PP 51-56

15. R. Prasanna Venkatesan, K.C. Pazhani (2015) "Strength and Durability Properties of Geopolymer Concrete made with GGBS and Black Rice Husk Rice" KSCE Journal of Civil Engineering, ISSN 1976-3808

16. Kishan Lal Jain (2016) "To effect on strength properties of concrete of by using GGBS by Partial Replacing cement and addition of GGBS without replacing cement" SSRG International Journal of Civil Engineering (SSRG-IJCE) – volume 3 Issue 5ISSN: 2348 – 8352 pp 144-149http://www.internationaljournalssrg.org/IJCE/2016/Volume3-Issue5/IJCE-V3I5P131.pdf

17. A.I. Tamboli, Aishwarya Saha, Tejas Parakh, Nilesh Mane, Ashutosh Singh, Sufiyan Tamboli, (2016), "Strength Characteristics of Concrete with Addition of Steel Fibre and Partial Replacement of Cement with Ground Granulated Blast Furnace Slag", International Journal of Engineering Science and Computing, ISSN 2321 336, Volume 6, Issue No. 05 DOI 10.4010/2016.1305

18. T. Divya Bhavana, Etaveni Madhavi, (2016), "Strength and Workability Properties of Concrete Replaced by Quarry Dust and GGBS", International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Vol. 5 Issue 03

http://dx.doi.org/10.17577/IJERTV5IS030067

19. Backus, J., McPolin, D. (2016). Effect of Cyclic Carbonation on Chloride Ingression in GGBS Concrete. ASCE, Journal of Materials in Civil Engineering. 10.1061/(ASCE)MT.1943-5533.0001529

20. Deven Shinde, Mangesh chaudhari, Vaibhav Korgaonkar, Kunal Patil, Pritee Mistry, (2016), "Detail Study of High Performance Concrete using GGBS", International Journal on Recent and Innovation Trends in Computing and Communication ISSN: 2321-8169, Volume: 4 Issue 4 http://www.ijritcc.org/download/conferences/ICMTEST_2016/ICMTEST_2016_Track/1462176536_02-05-2016.pdf

21. Christina Mary V. and Kishore C H, (2015) "Experimental Investigation on Strength and Durability Characteristics of High Performance Concrete Using GGBS And M Sand", ARPN Journal of Engineering and Applied Sciences, VOL. 10, NO. 11 http://www.arpnjournals.com/jeas/research_papers/rp_2015/jeas_0615_2177.pdf

22. Bureau of Indian Standards "Method of Tests for Aggregate for Concrete" IS: 2386-1963

23. Bureau of Indian Standards "Ordinary Portland Cement 43 Grade – Specification" IS: 8112-2013

24. Bureau of Indian Standards "Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete", IS: 383-1970

25. Bureau of Indian Standards "Plain and Reinforced Concrete – Code of Practice", IS: 456-2000

26. ASTM "Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars", C 989-04

27. American Concrete Institute "Guide for Selecting Proportions for High-Strength Concrete with Portland Cement and Fly Ash", ACI 211.4R-93