FEASIBILITY STUDY OF ELECTRIC ARC FURNACE SLAG AS FINE AGGREGATE IN GGBS INCORPORATED CONCRETE

Anchu Ajayakumar[1], Jaseela K.H[2]

[1] *PG student, Department of Civil Engineering, Toc H Institute of Science and Technology, Kerala, India*
[2]*Assistant. Professor, Department of Civil Engineering, Toc H Institute of Science and Technology, Kerala, India*

ABSTRACT

Over the past few years, ground granulated blast furnace slag (GGBS) have been considered as an alternative material for ordinary portland cement (OPC) in conventional concrete for attaining sustainability in construction industry. The GGBS can be used as an alternative material for OPC since it has binding properties. Also it reduces the problems due to the production of OPC like emission of carbondioxide, utilization of high amount of natural resources etc. This research investigates the feasibility of electric arc furnace slag (EAFS) as fine aggregate in GGBS incorporated concrete. Use of industrial byproducts like GGBS and EAFS makes their reutilization in concrete and hence reduces the cost of cement production, concrete manufacturing, reduction in landfill cost as well as reduction in solid waste. Characteristics of EAFS like pH, loss of drying, calorific value and presence of heavy metals like Zn, Cd, Ni, Pb, Cu were studied according to central pollution control board (CPCB) limit. Concrete cubes with different percentages of replacement (0, 10, 20, 30, 40, and 50) of fine aggregates with EAFS in GGBS incorporated concrete was tested to find the optimum percentage. EAFS was found to be a non hazardous industrial byproduct of steel industry, which is suitable to be used as a material for construction. It was observed that compressive strength of concrete cubes was improved up to 30% of replacement of EAFS. It is concluded that utilization of EAFS in concrete will reduce the requirement for conventional fine aggregate and manufactured fine aggregate thereby resulting a sustainable way to utilize industrial by-products.

Keyword: - *EAFS, GGBS incorporated concrete, Optimum percentage*

---

1. INTRODUCTION

Economic development of any country is controlled to a great extent by the development of infrastructure. Many other countries like India, is witnessing a rapid growth in the construction industry, involving the use of natural resources for the development of infrastructures. Natural resources are depleting worldwide, while at the same time the generated wastes from the industry are increasing substantially. Sustainable development has become a key aspect in society, economics and development. Sustainable development shall meet the needs of the present without compromising ability of future generation to meet their own needs.

Manufactured sand that is produced by stone crushing creates a new way to reduce the exploitation of natural river sand. The main pollution problem associated with this is particulate matter <10 lm (PM10) emissions which directly affect human health while other impacts include noise, vibration and landscape deterioration when the relief of the land is modified [16, 17]. With boulders being scarce as more rock quarrying is carried out, alternate sources of aggregates like artificial aggregates need to be sought such that natural resources are conserved. From an environmental viewpoint, one such alternative is the use of industrial by-product namely slag, a non-hazardous waste from scrap metal processing for the manufacture of thermo mechanically treated steel bars. Recycling scrap metal is carried out in electric arc furnace (EAF). From the metal recycling process, slag, dust, scale and sludge are the waste materials being produced. Mauthoor et al. [8] showed that EAF slag is generated in the highest amount at a rate of 250 kg per ton of steel bars produced.

Oner and Akyuz, (2011), [1] studied on optimum level of GGBS on compressive strength of concrete and concluded that the optimum level of GGBS content for maximizing strength is at about 55–59% of the total binder content. Venu Malagavelli, (2010), [13] studied on high performance concrete with GGBS and ROBO sand (crusher dust). They focuses on investigating characteristics of M30 concrete with partial replacement of cement with Ground Granulated Blast furnace Slag (GGBS) and sand with the ROBO sand. 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 mix concrete. They concluded that the percentage increase of compressive strength of concrete is 11.06 and 17.6% at the age of 7 and 28 days by replacing 50% of cement with GGBS and 25% of sand with ROBO sand.

From the reviewed journals, it is observed that GGBS and EAFS, which are the byproducts from steel industries, can be incorporated in concrete to improve its mechanical properties. In this paper, feasibility of EAFS as fine aggregate in GGBS incorporated concrete was investigated. The physical and chemical characteristics of EAFS were analyzed and studied the mechanical properties of GGBS incorporated concrete with EAFS as fine aggregate.

1.1 Objectives

The aim of the research is to assess the performance of EAFS as fine aggregate in GGBS incorporate concrete. Based on the above, the specific objectives are:

1. To assess the physical properties of EAFS.
2. To determine the optimum level of replacement of EAFS as fine aggregate in GGBS incorporated concrete.

To evaluate the compressive strength of GGBS incorporated concrete with EAFS as partial replacement of fine aggregate

2. MATERIAL PROPERTIES

For the present study, EAFS, GGBS, cement, fine aggregate and coarse aggregates were used. The sample EAFS was collected from Paragon steel industries (P) Ltd. Kanjikode, Palakkad and GGBS was collected from JSW steel at Manapullikave, Palakkad. Other materials like cement, fine aggregate (Manufactured Sand) and coarse aggregate were obtained from nearby locality. Initially, the EAFS is crushed and sieved into required size. Properties of each material were listed in the tables below. Specific gravity of EAFS was found to be 2.93, which is higher than that of both fine aggregate and coarse aggregate. GGBS is found to be finer than cement. Also presence of GGBS will retard the setting time of concrete compared to concrete containing OPC.

Table-1: Properties of Electric Arc Furnace

Properties	Values
Specific gravity	2.93
Uniformity coefficient, Cu	7.06
Los Angeles abrasion	51.68%
Impact value	47.34
Angle of internal friction	47^0

Table-2: Properties of GGBS and Cement

Properties	GGBS	Cement
Specific Gravity	2.5	3.15
Standard Consistency	30%	36%
Fineness	2.8%	5%
Initial Setting Time	55 min	75 min

Table-3: Properties of Aggregates

Properties	Fine Aggregate	Coarse Aggregate
Specific Gravity	2.62	2.75
Uniformity coefficient, Cu	10.52	1.08
Fineness Modulus	3.34	3

3. CHARACTERISTIC ANALYSIS OF EAFS

The pH, paint filter liquid test(PFLT), loss on drying (LOD), calorific value(Cv) and presence of heavy metals of EAFS is find out and the results are shown in table 4. Atomic absorption spectrometer is used to find out the presence of heavy metals. It was found that all the test results are within the permissible limits of central pollution control board (CPCB). EAFS has a pH of 10.7, which represents alkaline characteristic of the industrial byproduct. Metals like Cd, Pb and Ni were found to be below detection level. Hence it can be inferred that EAFS is suitable for utilizing as a construction material.

Table-4: Characteristic Analysis of EAFS

Sl.No.	Tests	Results	CPCB limits
1	pH	10.7	4-12
2	PFLT	Fails	Absence of filtrate
3	LOD	20%	1-95%
4	Cv	27.89 Kcal/Kg	20-1000 Kcal/g
5	Zn content	2.6 ppm	<10 ppm
6	Cd content	BDL*	<0.2 ppm
7	Cu content	5.3 ppm	<10 ppm
8	Pb content	BDL*	<2 ppm
9	Ni content	BDL*	<0.3 ppm

*BDL- Below Detection Level

Fig- 1: Atomic Absorption Spectrometer for metal detection

4. PREPARATION OF SPECIMEN FOR STRENGTH ANALYSIS

The cubes were casted in the mould of size 150 x 150 x 150 mm for compressive strength analysis and cylinders were casted in the mould of size 150mm diameter and 300mm height for the analysis of split tensile strength. The amount of GGBS was fixed as 50% of cement from the literature reviewed. Cubes and cylinders of M30grade were casted with varying proportion of 10,20,30,40 and 50% EAFS as fine aggregates for GGBS incorporated concrete. The specimens were water cured after 24 hours of casting for 7 days and 28 days strength analysis.

5. RESULTS AND DISCUSSIONS

The following are the results obtained by performing the strength tests in the specimens with varying percentage of EAFS as fine aggregate in GGBS incorporated concrete.

5.1 Compressive Strength Test

Figure 2 shows the compressive strength testing of cubes. The maximum 7day compressive strength was obtained for the control specimen were as for 28 days the same was found to be 39.742 N/mm² for 30% replacement of fine aggregate with EAFS. It was found that a gradual increment in 7 days compressive strength within the specimens having replacement with EAFS. The compressive strength of the specimen with replacement above 30% of fine aggregate with EAFS shows a reduction which was mainly due to the expansive nature of the EAFS. Chart 1 represents the variation of compressive strength in 7 days and 28 days. Table 5 gives the concluded compressive strength test results.

Fig -2: Compressive Strength Testing of Cube

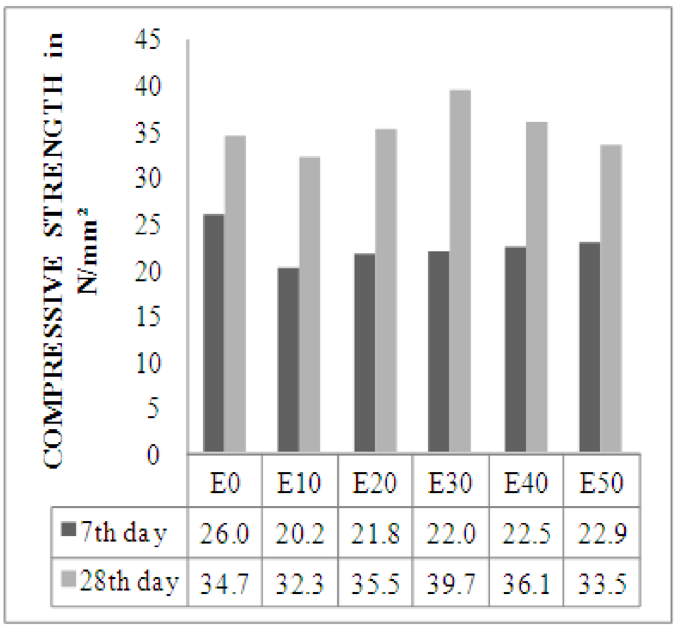

Chart-1: Compressive Strength Results of Cubes

Table- 5: Concluded Compressive Strength of cubes

Days	Compressive strength of Control Specimen in N/mm²	Proportion	
		Maximum Compressive strength in N/mm²	Minimum compressive strength in N/mm²
7	26.037	E50- 22.957	E10- 20.247
28	34.702	E30- 39.742	E10- 32.218

5.2 Split Tensile Strength

Figure 4 shows the split tensile strength testing for cylinder specimen. The maximum 7days and 28 days split tensile strength was obtained for 50% replacement of fine aggregate with EAFS as 3.807 N/mm² and 3.844 N/mm² respectively. Chart 2 represents the variation of split tensile strength in 7 days and 28 days. Table 6 gives the concluded split tensile strength test results.

Fig- 3: Split Tensile Testing of cylinder

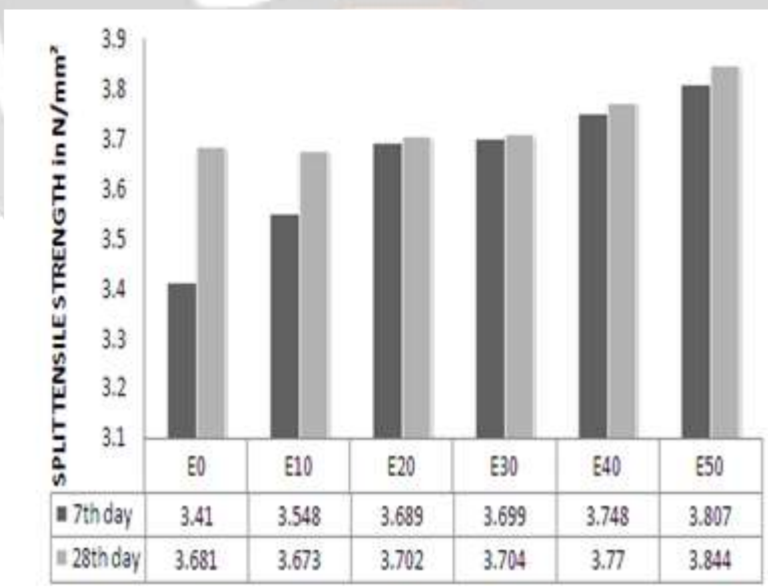

Chart-2: Split Tensile Strength Results of Cylinders

Table-6: Concluded Split Tensile Strength of cylinders

Days	Split tensile strength of Control Specimen in N/mm²	Proportion	
		Maximum split tensile strength in N/mm²	Minimum split tensile strength in N/mm²
7	3.41	E50- 3.807	E0- 3.41
28	3.681	E50- 3.844	E10- 3.673

6. CONCLUSION

The conclusions of present study are as follows:

EAFS, byproduct of steel industry is non-hazardous and hence it can be reutilized as a material for construction. The optimum percentage of EAFS as fine aggregate in GGBS incorporated concrete was found to be 30%. The compressive strength of concrete containing EAFS shows expansion which results in the reduction in compressive strength beyond the optimum limit. Split tensile strength of concrete is improved by the addition of EAFS is due to the yielding property shown by the EAFS.

7. REFERENCES

[1] A. Oner and S. Akyuz., (2007) “An experimental study on optimum usage of GGBS for the compressive strength of concrete”, Cement and Concrete Compsites, Issue 29, pp 505-514.

[2] A. S. AI-Gahtani, Rasheeduzzafar and S. S. A1-Saadoun, (2015), “rebar corrosion and sulfate resistance of blast-furnace slag cement, Journal of Materials in Civil Engineering, Issue. 6,pp 223-240.

[3] Caijun Shil.,(2014).“Steel slag-its production, processing, characteristics and cementitious properties”, ASCE Journals of materials in Civil Engineerg,Vol 16(3), pp 230-236.

[4] Ganapati Naidu. P, A.S.S.N.Prasad, S.Adiseshu, and P.V.V.Satayanarayana, (2012), “ A Study on Strength Properties of Geopolymer Concrete with Addition of G.G.B.S”, International Journal of Engineering Research and Development , Issue 4, PP. 19-28

[5] Gulden Cagin Ulubeyli and Recep Artir, (2015), “Sustainability for Blast Furnace Slag: Use of Some Construction Wastes” Social and Behavioral Sciences, Vol.195,pp 2191-2198.

[6] Juan Lizarazo-Marriaga Peter Claisse and Eshmaiel Ganjian.,(2011) “ Effect of steel slag and Portland cement in the rate of hydration and strength of blast furnace slag paste”, ASCE Journals of materials in Civil Engineerg,Vol 23, pp 153-160.

[7] Juan M. Manso, Javier J and Juan A Polanco.,(2004).“Electric Arc Furance slag in Concrete”, ASCE Journals of materials in Civil Engineerg,Vol 16(66), pp 9-645.

[8] Mauthoor Sumayya, Mohee Romeela, and Kowlesser Prakash, (2016), “Characterisation Of Electric Arc Furnace Slags As Concrete Aggregate In A Small Island Developing State: A preliminary study”, Construction and Building Materials, Vol.105, pp 459–464.

[9] M. Shariq, J. Prasad and A.K. Ahuja, (2008), “Strength Development Of Cement Mortar And Concrete Incorporating GGBFS”, Asian Journal Of Civil Engineering (Building And Housing), Issue. 9,pp 61-74.

[10] Nourredine Arabi and Raoul Jauberthie., (2012) “Calcium Silicate Materials: Substitution of Hydrated Lime by Ground Granulated Blast Furnace Slag in Autoclaving Conditions”, ASCE Journals of materials in Civil Engineerg,Vol 24 (9), pp 1230-1236.

[11] Rui Luoa, Yuebo Caib, Changyi Wangb and Xiaoming Huang, (2003), “Study of chloride binding and diffusion in GGBS concrete”, Cement and Concrete Research, Issue. 33, pp 1-7.

[12] Sundeep Inti, Megha Sharma, and Dr.Vivek Tandon, (2016) “Ground Granulated Blast Furnace Slag (GGBS) and Rice Husk Ash (RHA) Uses in the Production of Geopolymer Concrete” ASCE Journals of materials in Civil Engineerg,Vol 24 (9), pp 621-632.

[13] Venu Malagavelli, (2010), “High Performance Concrete With GGBS And Robo Sand”, International Journal of Engineering Science and Technology, Vol. 2(10),pp5107-5113.

[14] Wen-Ten Kuo, Chun-Ya Shu, and Ye-Wei Han., (2014) , “Electric Arc Furnace Oxidizing Slag Mortar With Volume Stability For Rapid Detection”, Construction and Building Materials, Vo. 53,pp 635–641.

[15] Xiaolu Guo and Huisheng Shi.,(2013) “ Utilization of steel slag powder as combined admixture with ground granulated blast-furnace slag in cement based materials”, ASCE Journals of materials in Civil Engineerg,Vol 25, pp 1990-1993.

[16] MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT, PROPOSED ROCK QUARRY AT SAINT JULIEN D’HOTMAN NON-TECHNICAL SUMMARY, 2011.

[17] V.K. Nartey, J.N. Nanor, R.K. Klake, Effects of quarry activities on some selected communities in the lower Manya Krobo District of the Eastern Region of Ghana, Atmos. Clim. Sci. 02 (2012) 362–372, http://dx.doi.org/10.4236/acs. 2012.23032.