MECHANICAL PROPERTIES OF GROUND GRANULATED BLAST FURNACE SLAG MADE CONCRETE

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ABSTRACT

In recent scenarios, waste management is a great concern for all countries. Other side manufacturing industries of cement is produced carbon-dioxide in the environment. The utilization of industrial waste as a by-product of cement is a great opportunity for researchers. Keeping this thing in mind used industrial waste of iron factories as an alternative to cement in concrete. This investigation used waste ground granulated blast furnace slag (GGBFS) acquired from iron industries. The GGBFS used as a binder and partial cement replacing material in concrete with 1% superplasticizer and a constant 0.48 w/c ratio. GGBFS used as 2.5%, 5%, 7.5%, 10% and 12.5% in interval of 2.5% by weight of cement. Mechanical behavior evaluated in terms of compressive strength, flexural strength, and splitting tensile strength. From the results, it is detected compressive, flexural, and splitting tensile strength for GGBFS mix was better to compare to control concrete. Maximum compressive strength was achieved at 10% replacement of cement with GGBFS. Overall performance of GGBFS made concrete is satisfactory and it can be recommended for the production of sustainable concrete.

Keywords: GGBFS, Concrete, Compressive Strength, Flexural Strength, Splitting Tensile Strength

1. INTRODUCTION

Concrete is assortment of cement, sand, aggregate, water and admixture. Two types of admixtures are used in concrete industries for production of sustainable concrete. Mineral admixture is used in most of case for betterment of concrete production. Cement industries is producing CO₂ in the
process of manufacturing of cement and it’s create problem regarding to health and environment issues. As per calculation one ton cement produced around 0.95 ton CO₂ in environment [1]. This kind of issues resolved by many researcher by using supplementary cementitious materials (SCMs) as part of cement. Some of SCMs such as Ground-granulated blast-furnace slag (GGBFS), fly ash (FA), silica fume (SF), steel slag preferred in concrete by many expert [2]. In India around 600 million tones (Mt) concrete manufactured every year form different manufacturing plants of concrete [3]. Current scenario of cement production is also increased in India as per calculation of 320 Mt cement produced during the year of 2019 [4]. This kind of issues resolved by using waste industries material and same decreases the production of cement [5]. Waste GGBFS produces in many state which creates problem regarding to health and environmental [6]. The production of GGBFS in India around four million tons from different industries [7]. Many literatures are available about use of GGBFS in concrete as cement replacing material few of them are mentioned here. The concrete manufactured with GGBFS and fly ash as cement and sand replacing material improved mechanical and durability performance of concrete. Maximum compressive strength was achieved at 10% replacement of GGBFS as cement. Filling ability and self-compacting properties of GGBFS is probable reason of improvement in performance [8]. GGBFS use as 3%, 5%, 7%, 10%, 13%, 15% & 18% by weight of cement improved behavior of concrete in terms of mechanical and durability aspects [9]. Prepared concrete with micro silica and GGBFS increased mechanical and durability behavior of blended mixes. The increased compressive strength was 13.36 % greater than the control specimen [10]. Studied on effect of GGBFS on self-compacting concrete the study explored the use of the Ground-granulated blast-furnace slag powder in concrete. With increase in amount of the fines achieved self – compatibility of concrete [11]. Investigated use of pond fly ash as a partial replacement fine aggregate and GGBS as cement in high strength concrete improved mechanical properties of concrete. Compressive strength for using 6% Ground-granulated blast-furnace slag as a cement replacement and 10% pond ash as a replacement in fine aggregate achieved preferred high strength [12]. Investigated incorporation of GGBFS and fly ash as partial replacement of OPC-53 grade in concrete improved behavior of specimen against adverse effect [13]. Concluded that high-performance concrete, with mixing of GGBFS and fly ash as partial replacement of cement by weight improved compressive & flexural strength [14]. Reported use of waste GGBS with fibre improved the performance of concrete in
terms of compressive and flexural strength. In the same improved durability performance of concrete like water permeability and water absorption [15-16].

Above mentioned literature indicated waste GGBFS as binder proved most suitable substitute of cement in concrete. Waste GGBFS is available in large amount in many state of India. The objectives of this experimental work is optimum use of waste industrial material as cement replacing material. Also the main aim to reduce the emission of CO2 due to manufacturing of cement form industries. Performance of concrete is noted in terms of compressive strength, flexural strength and splitting tensile strength.

2. MATERIALS

Ordinary Portland cement (OPC) 43 grade used in this experimental work was specified as per IS [17]. Properties of OPC 43 grade cement is specified in Table 1. Fine aggregate (FA) (sand) used after sieving of 4.75mm sieve prescribed code was [18]. The zone of sand was decided II after sieve analysis. Coarse aggregate (CA) 20mm down and above 4.75mm size were used in this study. The CA is obtained from nearby area of Kishangarh, Jaipur, Rajasthan, India. Properties of coarse and fine aggregates are shown in Table 1. GGBFS used (after sieving 90-micron sieve) in this study accrued form iron industries Panchkula, Goa, India. Physical and chemical properties of GGBFS presented in Table 1 and Table 2. The practical size distribution curve for fine aggregate and coarse aggregate are shown in Fig.2. Super plasticizer used in this study obtained by Wonder cement office, Jaipur, Rajasthan, India used as 1% of mass of cement. The SEM image pattern of OPC-43 grade and GGBFS is shown in Fig.1.
Fig. 1 SEM image of OPC-43 grade cement and GGBFS

Fig. 2: Particle size distribution curve of coarse and fine aggregate

Table 1: Properties of cement, CA, FA and GGBFS

| Material | Water Absorption (%) | Specific Gravity | Bulk Density (Kg/m³) | Fineness Modulus (%) | Initial Setting Time (Min) | Final Setting Time (Min) |
|----------|----------------------|------------------|----------------------|----------------------|---------------------------|-------------------------|
| Cement   | -                    | 3.14             | 1445                 | 2.47                 | 40                        | 145                     |
| FA       | 1.25                 | 2.63             | 1578                 | 3.10                 | -                         | -                       |
| CA       | 0.98                 | 2.68             | 1589                 | 7.25                 | -                         | -                       |
| GGBFS    | 1.26                 | 2.92             | 1590                 | 0.85                 | -                         | -                       |
Table 2 Chemical oxide of cement and GGBFS

| Oxide          | Cement (%) | GGBFS (%) |
|----------------|------------|-----------|
| CaO            | 63         | 33        |
| SiO₂           | 21         | 35        |
| Al₂O₃          | 5          | 19        |
| Fe₂O₃          | 4          | 2         |
| MgO            | 2          | 6         |
| SO₃            | 2          | 3         |
| Na₂O           | 0.3        | -         |
| Gypsum (CaSO₄.2H₂O) | 2.5%     | -         |

2.1 Mix design procedure

Mix design was calculated as per the specification given in [19]. Performance of concrete evaluated by using waste GGBFS and casted various specimen in terms of cube and cylinder for different size. In mix design specific gravity of cement and GGBFS used different as per given in Table 1. Mix design of GGBFS content concrete are given in Table 3.

Table 3: Mix design of GGBFS concrete

| S.No | Mix Name     | Cement (Kg) | GGBFS (Kg) | Coarse Aggregate (Kg) | FA (Kg) | Water (Kg) | Admixture (Kg) |
|------|--------------|-------------|------------|-----------------------|---------|------------|----------------|
| 1    | Control      | 410         | 0          | 710 474               | 680     | 168        | 0.0            |
| 2    | GGBFS 2.5    | 399         | 11         | 710 474               | 680     | 168        | 3.0            |
| 3    | GGBFS 5      | 389         | 21         | 710 474               | 680     | 168        | 3.0            |
| 4    | GGBFS 7.5    | 379         | 31         | 710 474               | 680     | 168        | 3.5            |
In this research work, Total forty-two cube of 100mm * 100mm * 100mm size were casted for compressive strength and 500mm* 100mm *100mm beam were casted for flexural strength test. Splitting tensile strength were checked by casting cylinder of 300mm length and 150 mm diameter.

3. RESULTS AND ANALYSIS

3.1 Slump test results

Slump results indicated in Fig. 3. From the results it was noted that increment of GGBFS in concrete decreased the slump value. The use of 12.5% GGBFS showed minimum slump value compare to control concrete. Reason may be fine surface area of GGBFS comparison of cement surface area [5]. Slump of 12.5% GGBFS made concrete was 73 mm and control concrete slump was 90 mm.

![Slump test results](image)

3.2 Compressive strength test results
IS Code 516:1959 [20] used for method of tests for compressive strength of concrete. The size of specimens was 100mm x 100mm x 100mm. The specimens were tested after deep curing in fresh water for 28 days. Results shown in Fig.4 indicated that compressive strength of GGBFS sample was increased with increase in percentage of waste. The maximum compressive strength was observed on 10% replacement of cement with GGBFS. The reason was filler effect and more CSH gel formation of GGBFS made concrete [7]. Compressive strength of GGBFS 12.5 % sample was observed 43 N/mm².

![Compressive strength test results](image)

Fig.4 Compressive strength test results

### 3.3 Flexural strength test results

Flexural strength was checked by flexural strength testing machine for that 500 mm* 100 mm * 100 mm size specimen were casted. IS 516 [20] code was preferred for checked the flexural strength. The specimens were tested after deep curing 28 days in normal water. The maximum flexural strength was observed on 12.5% replacement of cement with GGBFS. The reason was proper bonding between aggregate and binding material that’s why improved the flexural strength [12].
3.4 Splitting tensile strength results

Splitting tensile strength was checked for that 300 mm* 100 mm size specimen and code referred 5816 [21]. The specimens were tested after deep curing 28 days. The maximum splitting tensile strength was observed on 12.5% replacement of cement with GGBFS. The reason was proper bonding between aggregate and binding material that’s why improved the flexural strength [8].
Conclusion

After conducting all test following conclusion were recommended

- Compressive strength of GGBFS made concrete increased with increased the percentage of waste. The maximum compressive strength was observed on 10% replacement of cement with GGBFS. The reason was proper filling and CSH gel formation.

- The maximum flexural and splitting strength was observed on 12.5% replacement of cement with GGBFS. The reason was proper bonding between aggregate and binding material that’s why improved the flexural strength

- The results indicated GGBFS concrete improved the behavior of concrete due to its reactive power and filler effect.

Fig. 6 Splitting tensile strength test
References

1. Belaidi, A.S.E., Azzouz, L., Kadri, E. and Kenai, S., 2012. Effect of Natural Pozzolana and Marble Powder on the Properties of Self-Compacting Concrete. Construction and Building Materials, 31, pp.251-257.

2. Carette, G., Chevrier, A.B.R.L. and Malhotra, V.M., 1993. Mechanical Properties of Concrete Incorporating High Volumes of Fly Ash from Sources in the US. Materials Journal, 90(6), pp.535-544.

3. Deval Soni, Suhasini Kulkarni and Vilin Parekh (2013) “Experimental Study On High-Performance Concrete, With Mixing Of Ground-Granulated Blast-Furnace Slag And Flyash” Paripex - Indian Journal of Research, Issn - 2250-1991, volume 3, issue 4, pp. 84-86, May 2013.

4. Gautam, N., Krishna, V. and Srivastava, A., 2014. Sustainability in the Concrete Construction. International Journal of Environmental Research and Development, 4(1), pp.81-90.

5. IBEF, India Brand Equity Foundation. www.ibef.org/industry/cement-india.aspx, 2016 (accessed 17.11.16).

6. Jay Patel1, Kunal Patel and Gaurav Patel (2013) “Utilization Of Pond Fly Ash As A Partial Replacement In Fine Aggregate With Using Fine Fly Ash And Ground-granulated blast-furnace slag In Hsc” International Journal of Research in Engineering and Technology, eISSN: 2319-1163 & pISSN: 2321-7308, volume 2, issue 12, pp.600-606, Dec 2013

7. M.S. Pawar and A.C. Saoji (2013)“Effect Of Ground-Granulated Blast-Furnace Slag On Self Compacting Concrete” The International Journal of Engineering and Science, eISSN: 2319-1813 pISSN: 2319 – 1805, volume 2, issue 6, pp. 5-9, 2013.

8. Naik, T.R., 2008. Sustainability of concrete construction. Practice Periodical on Structural Design and Construction, 13(2), pp.98-103.

9. P. J. Patel and H. S. Patel (2013) “Effect On Compressive And Flexural Strength Of High-Performance Concrete Incorporating Ground-granulated blast-furnace slag And Fly Ash” International Journal of Civil, StructureGGBS, Environmental and Infrastructure Engineering Research and Development, ISSN 2249-6866 volume. 3, issue 2, pp.109-114, 2013.
10. P.P. Pathak, Inclusion of Portland and pozzolana (fly ash waste) cement in specifications, Ind. Highw. 37 (2009) 23-29.

11. Praveen Nayak S, H.S. Narashimha and Raghunandan V. Kadaba (2014) “Hardened Properties Of Concrete Made With Micro Silica And Ground-granulated blast-furnace slag –A Performance Optimization Based Comparative Study” International Journal of Engineering Research and Development, eISSN: 2278-067X & pISSN: 2278-800X, volume 10, issue 8, pp.1-9, August 2014.

12. R.D. Woodson, Concrete Materials, in Concrete Portable Handbook, Elsevier Inc., Oxford, 2012, pp. 5-18.

13. Siddharth P. Upadhyay and M. A. Jamnu (2014) “Effect on Compressive Strength of High Performance Concrete Incorporating Ground-granulated blast-furnace slag and Fly Ash” International Journal Of Innovative Research & Development, ISSN 2278 – 0211, volume 5, Issue 2, pp.124-128, February 2014.

14. Saurav and Ashok Kumar Gupta (2014) “Experimental Study of Strength Relationship of Concrete Cube And Concrete Cylinder Using Ultrafine Slag Ground-Granulated Blast-furnace Slag” International Journal of Scientific & Engineering Research, ISSN 2229-5518, Volume 5, Issue 5, pp.102 -107, May-2014.

15. Saravana, Raja Mohan and Sumathi (2017) Effect of Fly Ash in Fiber Reinforced Concrete Composites Jordan Journal of Civil Engineering, Volume 11, No. 1, 2017.

16. Yang, K.H., Jung, Y.B., Cho, M.S. and Tae, S.H., 2015. Effect of Supplementary Cementitious Materials on Reduction of CO2 Emissions from Concrete. Journal of Cleaner Production, 103, pp.774-783.

17. IS: 8112-2013, Ordinary Portland Cement, 43 Grade — Specification, Bureau of Indian Standards, New Delhi, Bur. Indian Stand. Delhi. (2013).

18. IS 383-1970, Course and Fine Aggregates from Course and Fine Aggregates from Natural Sources for Concrete, Bureau of Indian Standards (New Delhi, India), 1997.

19. IS 10262, Guidelines For Concrete Mix Design Proportioning, Bur. Indian Stand. Delhi. (2009) 1–21.

20. IS 516 Guidelines For Concrete Strength, Bur. Indian Stand. Delhi. (2009) 1–21.

21. IS 5816 Guidelines For splitting tensile strength, Bur. Indian Stand. Delhi. (2009) 1–21.