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Fresh and Hardened Properties of Ground Granulated Blast Furnace Slag Made Concrete

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--ABSTRACT--
This research work was carried out on concrete specimens made with different proportion of Ground Granulated Blast Furnace Slag (GGBFS) as a cement substitution in concrete. To accomplish the goal of the research work, overall 75 cubes and 60 cylinders were made. Out of 75 cubes and 60 cylinders, 15 cubes and 12 cylinders were cast for control concrete, and 60 cubes and 48 cylinders were cast by replacing 5,10,15 and 20% of cement with GGBFS. The cubes and cylinder specimens were 100x100x100 mm and 100x200 mm respectively, and mix design was done for 28 Mpa. All specimens were tested at 3. 7, 28 and 90 days of curing ages. The fresh properties such as workability and hardened properties such as compressive and tensile strength of all mixes were determined. Tests results showed that the workability of the concrete mixes made with GGBFS was higher than control mix. As the percentage of GGBFS increased the workability also increased. Hardened properties of concrete mixes made with GGBFS was lower than control concrete at early ages of curing. At the later age, hardened properties of GGBFS made concrete was more than control concrete. Furthermore, water absorption and density of GGBFS made concrete was lower than control concrete.

INDEX TERMS: *OPC, GGBFS, cubes, Cylinders, Workability, Compressive strength, Tensile strength, water absorption,*

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I. INTRODUCTION

Concrete has natural essential ingredients, cheaply priced and easily available such as water, cement, fine and coarse aggregates. Cement is the most significant constituent of concrete and it is manufactured from lime and silica like raw materials. Cement is 2nd most used material within the world after water. Overutilization of lime may lead to the situation when there will be no lime on the earth for manufacturing of cement [2]. The fast manufacturing of cement made an influence on huge environmental problems. The emission of CO2 during the manufacturing of cement is the first environmental problem and the consumption of raw material is the 2nd problem related to the production of cement. All researcher working in construction-related research have focused on to explore and discover cementitious waste materials for the replacement of cement and use of this material in high-performance concrete [8].

Ground Granulated blast furnace slag is a waste product of steel production industry. The mixture of limestone, iron ore and coke are entered in the kiln. Consequential melted slag hangs over the melted iron at 1500^{0}C to 1600^{0}C temperature. Melted slag contains about 35% to 45% silicon dioxide (SiO2) and Calcium oxide about 45%. The chemical composition of molten slag as nearly the same as that of ordinary Portland cement (OPC). When the melted iron is removed then the melted slag, which contains siliceous aluminous scum is rapidly submerged in liquid, resulting in the creation of glassy granulate. The glassy granulated is dehydrated and then crushed into the required size [1-10]. This grounded slag is known as ground granulated blast furnace slag. The little amount of extra energy is required to produce Ground Granulated blast furnace slag as compared to the energy required to produce cement. Ground granulated blast is co-environmental construction material. Caron dioxide emission can be controlled up to some extent by substitution of cement by Ground granulated blast furnace slag. GGBFS improve the impermeability of concrete and improved resistance to corrosion and sulfate attacks. Due to these properties of GGBFS concrete, the service duration of assembly is increased, and maintenance charge is decreased. Substitution of cement by a high percentage of co-environmental GGBFS leads to concrete which not only utilized waste materials but also protects natural resource and energy depletion [1-6].

II. LITERATURE REVIEW

Cervantes and Roesler (2007) examined the effect of GGBFS on the compressive and flexural strength of concrete. From the results concluded that GGBFS have the positive effect on the mechanical properties of concrete at 28 days of curing. The compressive and flexural strength of GGBFS made concrete in the 7 days of curing ages is slightly lower than Portland cement concrete. The compressive and flexural strength of GGBFS made was about equal to normal concrete after curing age range from 7 to 14 days. Karrri et al. (2015) conducted a study on the effect of GGBFS on the fresh and hardened properties of concrete. In this study M20 and M40 grade concrete made with 30%, 40% and 50% cement replacement by GGBFS were investigated. Compressive strength split tensile strength and flexural strength of cubes, cylinders and prism were tested after 28 and 90 days of curing ages. Tests result show that the workability of concrete increases with increasing GGBFS replacement level. For both M20 and M40 grade concrete, compressive strength increases with GGBFS replacement. Both M20and M40 grade concrete attain maximum compressive strength at 40% replacement. Flexural and Split tensile strength is improved when cement is substituted by cement.

Flexural and compressive strength of M20 grade and M40 grade concrete attain maximum strength at 40% replacement. Shoubi et al. (2013) revised the Specification, making technique and the mark of usefulness of GGBFS, fly ash and silica fume like industrial by-product as a cement substitution to accomplish high performance and sustainable concrete. The replacement of cement by industrial by-products not individually improving the performance of concrete but also to lessen the emission of CO_2 by dropping the quantity of Portland cement. This replacement of cement by waste by-product affect social, economic and environmental aspects positively. Takekar and patil (2017) studied the hardened properties of Fly ash and GGBS made Geopolymer concrete. Fly ash was replaced in geopolymer concrete with a different percentage (0%,25%, 50%, 75%, and 100%) by GGBFS and for alkaline activator NaOH and Na_2SiO_3 were used. Geopolymer concrete of M25 grade tests for mechanical properties like compressive, tensile and flexural strength after 3, 7 and 28 days of curing and their result was compared with normal M25 grade OPC concrete. From results, it was concluded that the compressive strength of Geopolymer concrete improved with increasing fly replacement by GGBFS. The Compressive, tensile, and flexural strength increasing rate was very high at 7 days of curing. Specimens cured by oven curing gives high strength than specimens cured by ambient curing.

Ling et al. (2004) evaluated the act of GGBFS having different fineness. The compressive strength of GGBFS concrete rises with an increase of GGBFS fineness for the same replacement by cement at all ages of curing. From the analysis of the results, it is concluded that curing temperature is the key factor for GGBFS based concrete. GGBFS concrete characterized by high strength, lesser heat of hydration and resistance to corrosion. Elchalakani et al. (2014) conducted a study sustainable concrete with a high percentage of GGBFS to construct Masdar city in UAE. Total 13 mixes were prepared in this research with different percentage of ground granulated blast furnace slag (GGBFS). Cement was replaced with 50, 60, 70 and 80 percent by GGBFS to reduce the carbon dioxide emission. Replacement of cement with 30% fly ash in normal concrete was also checked. Mechanical, plastic and Durability properties test were performed for all mixes. From the results concluded that the substitution of cement with Ground granulated blast furnace slag significantly reduce carbon footprints and meets to the requirement Masdar city. An economical mix made with 20% OPC and 80% GGBFS was decided for the construction of Masdar city.

III. EXPERIMENTAL INVESTIGATION

Material used: Various materials like Cement, GGBFS, Fine aggregate, coarse aggregates, and water were used for the preparation of all concrete mixes. The description and details of the materials are given in the Table 1.

Table 1: Materials for Mix Design

S. No	Material Description	Material Source
1	GGBFS	Faizan Steel Mill Site Karachi
2	Cement	Lucky Cement Factory
3	Fine Aggregates	Bholari Sand
4	Coarse Aggregates	Noori Abad Crush deposits
5	Water	Fresh water accessible in Structural Research laboratory

Tests on Materials: The tests which were performed on coarse aggregates and fine aggregates are shown in the Table 2.

Table 2: Physical Properties of Fine & Coarse Aggregates

S. No	Description	Fine Aggregate	Coarse Aggregate
1	Max size	4.75mm, Zone-II	20mm
2	Specific Gravity	2.67	2.60
3	Water Absorption	1.24	1.02
4	Unit Weight	1767Kg/m^3	1396 Kg/m^3

Mix Design: DOE British mix design method was used in this study work to find out the proportions of concrete ingredients. In the light of DOE mix design from the materials properties, the Mix design was done for 28 Mpa. The ratio was found out as: 1: 1.56: 2.54 @ 0.54 w/c.

Mix Proportions : Different mixes were prepared for replacement of cement with GGBFS. The detail of the mixes is given in Table 3.

Table 3: Details of All Mixes

S.NO	Mix. ID	Cement (%)	GGBFS (%)	F.A (%)	C.A (%)	W/C
1	CM	100	0	100	100	0.54
2	G5%	95	5	100	100	0.54
3	G10%	90	10	100	100	0.54
4	G15%	85	15	100	100	0.54
5	G20%	80	20	100	100	0.54

IV. RESULTS AND DISCUSSION

Workability : The workability of all concrete mixes is presented in the Table 4 and shown in Figure 1. The test results indicate that workability of all concrete mixes made GGBFS was higher than the control mix, with the increase in % of GGBFS as a partial replacement of cement,the workability of concrete was incresed. Replacement of cement with 20% GGBFS showed higher workability.

Table 3: Result of Workability of Concrete mixes

S.NO	Mix. ID	slump value (mm)
1	CM	70
2	G5%	75
3	G10%	81
4	G15%	85
5	G20%	95

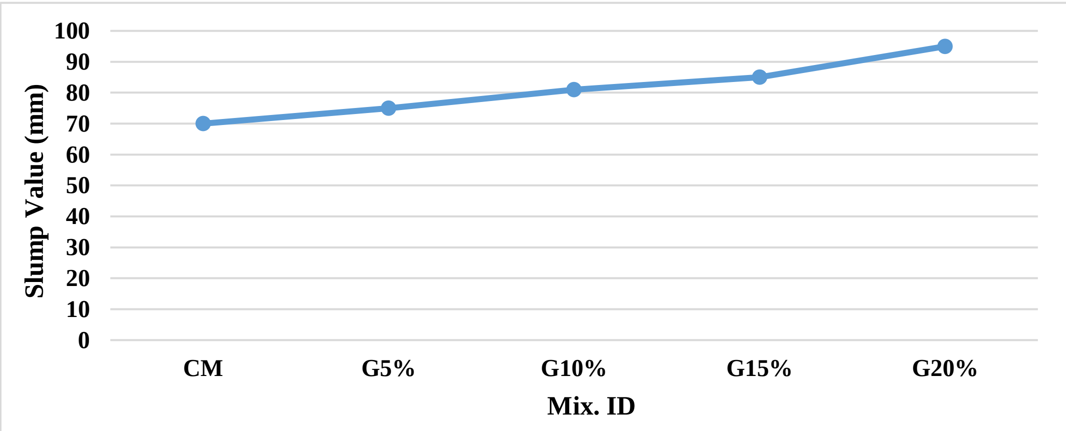

Fig 1: Graphical Representation of Workability of All concrete Mixes

Compressive Strength : Compressive strength results at different ages of curing of all concrete mixes are summarized in the Table 5 and shown in Fig. 2. The compressive strength of concrete made with GGBFS was increased with increasing curing ages. Concrete made with GGBFS gain minimum compressive strength than control concrete after 3 and 7 days of curing. Early ages Compressive strength of concrete made with GGBFS decreases with increase in GGBFS content. Concrete made with GGBFS gain higher strength at later age than control concrete. Concrete made with GGBFS later age compressive strength increases with increase in GGBFS content .

Table 5: Compressive Strength of All Mixes at Different Ages

S. No	Mix. ID	Compressive Strength (Mpa)			
		3days	7days	28days	90days
1	CM	19.76	25.09	29.69	30.29
2	G5%	17.48	22.75	29.75	30.55
3	G10%	14.56	21.85	29.85	30.99
4	G15%	14.03	21.45	30.25	31.45
5	G20%	12.92	20.95	30.95	32.012

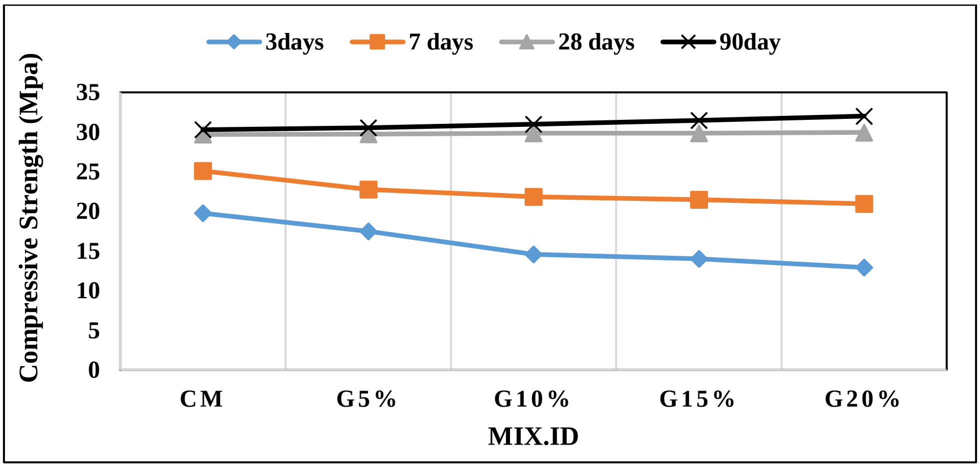

Figure 2: Comparison Compressive Strength of All Mixes at Different Ages

Tensile Strength : Split tensile strength results at different ages of curing of all concrete mixes are summarized in the Table 6 and shown in Fig. 2. Tests results shows that the split tensile strength of concrete made with GGBFS was increased with increasing curing ages. Concrete made with GGBFS gain minimum split tensile strength than control concrete after 3 and 7 days of curing. Early ages split tensile strength of concrete made with GGBFS decreases with increase in GGBFS content. Concrete made with GGBFS gain higher strength at later age than control concrete.

Table 6: Spit Tensile Strength of All Concrete Mixes at Different Ages

S. No	Mix. ID	Tensile Strength (Mpa)			
		3days	7days	28days	90days
1	CM	2.16	2.27	2.60	2.63
2	G5%	1.50	2.20	2.73	2.75
3	G10%	1.48	1.97	2.80	2.82
4	G15%	1.33	1.93	2.82	2.84
5	G20%	1.04	1.91	2.86	2.87

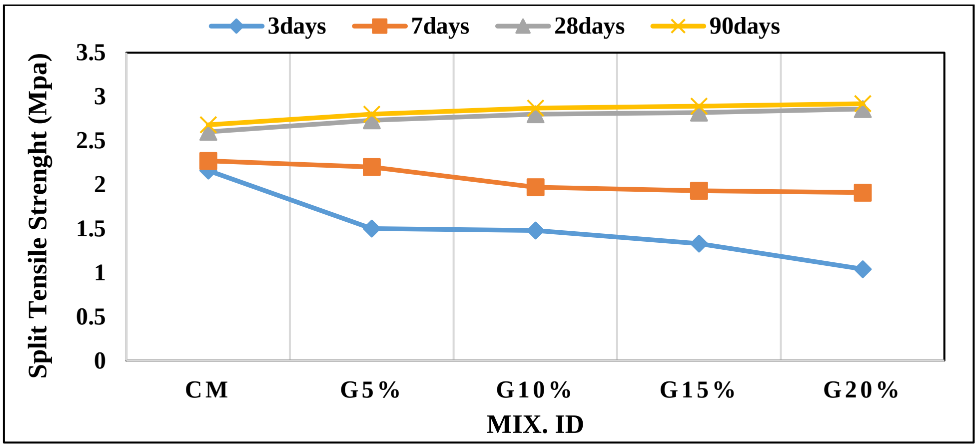

Figure 3: Spit Tensile Strength of All Concrete Mixes at Different Ages

Water Absorption Test : Water absorption test results of all concrete mixes at 28 days of curing age are summarized in Table 7 and shown shown in Fig. 4. From results it was clear that water absorption of the GGBFS based concrete was lower than the control concrete. As the percentage of cement replacement with GGBFS increases water absorption of the concrete decrease. 20% replacement of cement with GGBFS shows the lowest water absorption value.

Table 7: Water Absorption of Concrete Mixes After 28-Days of Curing

S. No	MIX ID	Water Absorption (%)
1	CM	3.52
2	G5%	3.34
3	G10%	3.00
4	G15%	2.98
5	G20%	2.90

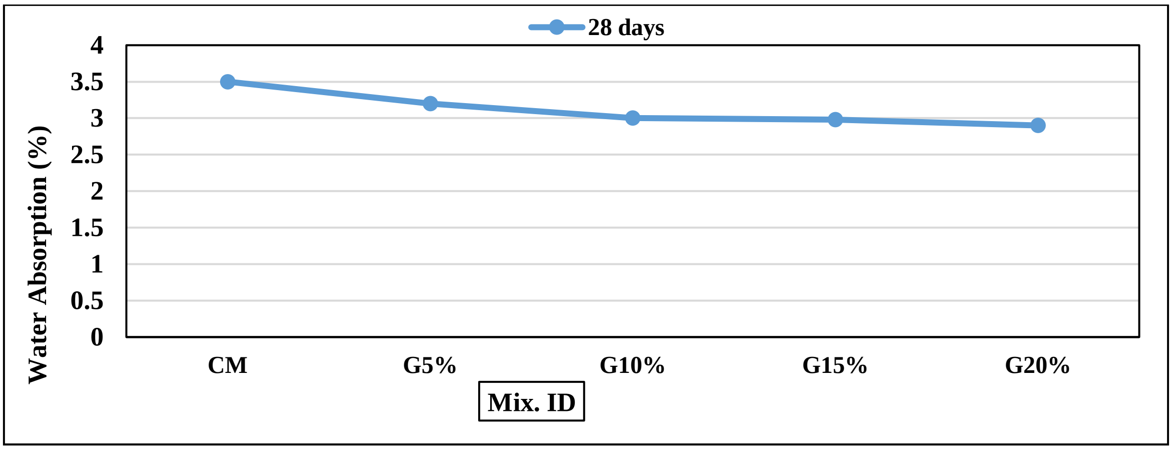

Figure 4: Water Absorption of Concrete Mixes After 28-Days of Curing

Density Test : The density of all mixes at 28 days of curing age are summarized in table 8 and shown in Fig. 5. Test results shows that the density of the GGBFS based concrete was low than the control concrete. As the percentage of cement replacement with GGBFS increases density of the concrete decrease. 20% replacement of cement with GGBFS shows lowest density value.

Table 8: Density of Concrete Mixes After 28-Days of Curing

S. No	MIX ID	Density of Concrete (kg/m^3)
1	CM	2382
2	G5%	2353
3	G10%	2333
4	G15%	2315
5	G20%	2304

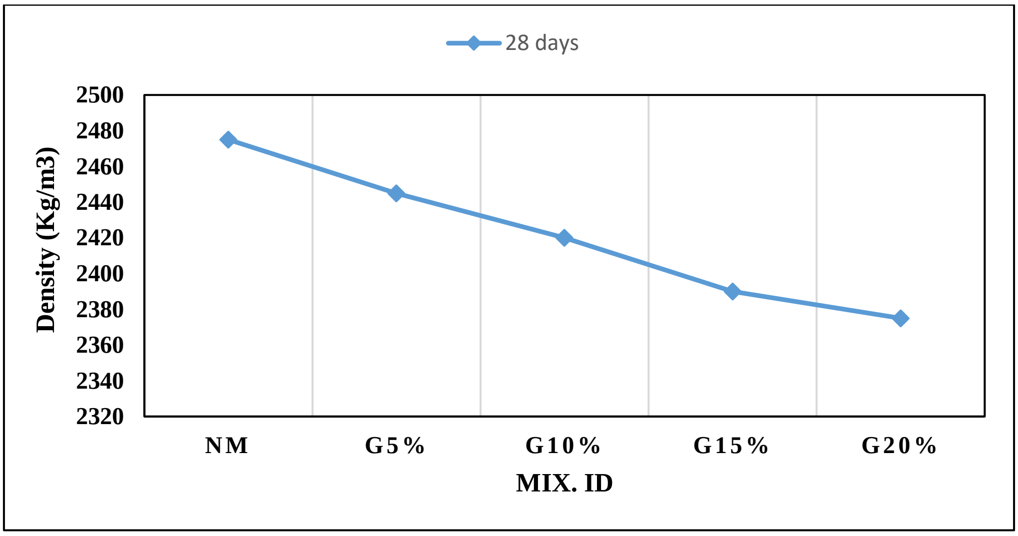

Figure 5: **Density of Concrete Mixes Ater 28 Days of Curing**

V. CONCLUSION

From the test results of concrete made with Ground Granulated Blast Furnace Slag by replacing cement, the following conclusion has been drawn.

- Concrete made GGBFS show higher workability than control concrete. The increase in workability advocate that GGBFS can use as water reducer admixture.
- Replacement of cement with 20% GGBFS workability is higher than all mixes. Workability increased 36.76% at 20% GGBFS replacement with cement.
- Concrete made with GGBFS provide lower strength at early ages of curing than control concrete, while concrete made with GGBFS provide relatively higher strength than control concrete at later ages.
- 20% replacement of cement with GGBFS in concrete gave 5.68% higher compressive strength than control concrete after 90 days of curing age.
- 20% replacement of cement with GGBFS in control concrete gave 9.12% higher split strength than control concrete after 90 days of curing age.
- Concrete made GGBFS show relatively low density and lower water absorption than control concrete.

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