



**Article Title: An Experimental Study of Mechanical and Durability Properties of Concrete Incorporating Glass Powder and GGBS as Supplementary Cementitious Materials**

## **An Experimental Study of Mechanical and Durability Properties of Concrete Incorporating Glass Powder and GGBS as Supplementary Cementitious Materials**

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### **ABSTRACT**

Ground granulated blast furnace slag (GGBS) was used in this study to replace Portland cement and also investigate the effect of glass powder (GP) on the behaviour of mechanical and durability properties of concrete as a partial replacement in cement. Cement can be used as a mortar to bind large stones or bricks. When sand and stones are added to cement, the aggregate is called concrete. The mechanical properties were examined by the tests of compressive strength, flexural strength, bond strength and split tensile strength. Durability behaviour was carried out by water absorption and sorptivity. 3/8 Replacement of cement by glass powder was from 5% to 45% in step of 5% and the GGBS with range of replacement from 45% to 5% in step of 5% respectively.

**Key words:** Glass Powder (GP), Ground granulated blast furnace slag (GGBS), Mechanical properties, Durability properties.

### **1 Introduction**

Concrete is a compound material made from sand, gravel and cement and is used in building construction. The cement is a mixture of various minerals which when mixed with water, hydrate and rapidly become hard binding the sand and gravel into a solid mass. The other major part of concrete besides the cement is the aggregate. Glass is a mixture of silica, soda, and lime. Other materials are sometimes added to the mixture to “frost” or cloud the glass or to add color. The recycled glass saves on raw materials and energy. However, impurities in the cullet can lead to product and equipment failure. Finely ground glass has the appropriate chemical composition including SiO<sub>2</sub> to react with alkalis in cement (Pozzolanic Reaction) and form cementitious products that help contribute to the strength development. Alkali silica reaction (ASR) of glass aggregate concrete can be minimized by the use of the suppressants including pulverized fuel ash (PFA) and metakaolin. GGBS is used to make durable concrete structures in combination with ordinary portland cement and or other pozzolanic materials. Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement (OPC), depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions. This results in lower heat of



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hydration and lower temperature rises, and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required.

## 2 Recent Works

A brief review of literature on influence of mineral admixtures on the fresh and hardened concrete, strength and durability aspects are reported and discussed. Ika Bali et al., (2015), carried an investigation work on the reactive powder concrete (RPC) with glass powder substitute in cement. The objective of this study is to investigate the influence of GP in the mechanical behaviour of RPC. Mahsa Kamali et al., (2015), done an experimental work on the mechanical strength and durability behaviour of cementitious materials modified with two types of glass powders and a class F fly ash at various levels of cement replacement. Anant Parghi et al., (2016), investigate the possibility of utilizing recycled GP in along with supplementary cementitious materials, such as fly ash and silica fume as partial replacements of cement. Bashar Taha et al., (2008), performed an experimental work on recycled glass sand (RGS) and pozzolanic glass powder (PGP) in concrete as sand and cement replacement, respectively. Tung-Chai Ling et al., (2014), had an investigation on use of 100% recycled glass as aggregates in architectural mortar. This paper investigated the feasibility of using large volumes of GGBS (ranging from 15% to 75% white cement replacements) to produce self-compacting based architectural mortars.

## 3 Materials and Methods

This part briefly explains the methodology adopted in this experimental work. It also includes material collection, testing of materials, casting of conventional test specimen, testing of conventional specimen, casting of the GP and GGBS concrete test specimen, testing of the specimen, Result analysis and conclusion. The materials that are used for the preparation of GP and GGBS concrete and conventional concrete are cement, fine aggregate, coarse aggregate, glass powder, ground granulated blast furnace slag.

## 4 Proposed Work Explanation

A total number of 93 specimens were cast, in which number of cubes were 50, cylinders were 40 and 3 numbers of beam. Then the casted specimens were tested for their strength and durability properties.

**Table 1: The design mix of the concrete**

| mix      | cement | m sand | w/c ratio | GGBS    | GP      |
|----------|--------|--------|-----------|---------|---------|
| GP& GGBS | 1      | 3      | 0.45      | 5%- 45% | 45%- 5% |



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## 5 Results and Discussion

### 5.1 Compression Test

All the test parameters are compared to the control specimens. Compressive strength, tensile strength and pullout test results show that the 50:15:35 mix (50% binder + 15% glass powder + 35% GGBS) replacement gives the finest results compared to other replacements.

Dimension of Specimen: 150 x 150 x 150 mm

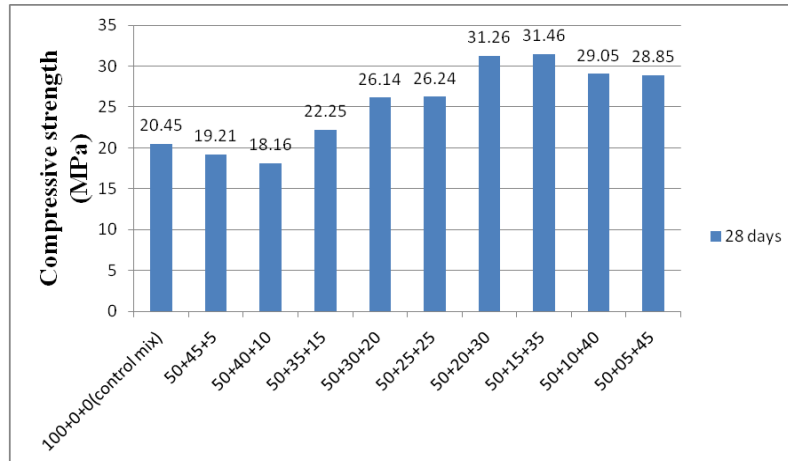
Days of Curing: 28 Days.

**Table 2: Compression test on Cubes**

| Percentage of cement Replacement<br>(Cement, GP & GGBS) | Compressive strength (MPa) |        |         |
|---------------------------------------------------------|----------------------------|--------|---------|
|                                                         | 3 days                     | 7 days | 28 days |
| 100+0+0(control mix)                                    | 9.78                       | 12.77  | 20.45   |
| 50+45+5                                                 | 7.02                       | 8.37   | 19.21   |
| 50+40+10                                                | 5.12                       | 6.58   | 18.16   |
| 50+35+15                                                | 11.12                      | 13.85  | 22.25   |
| 50+30+20                                                | 12.43                      | 14.53  | 26.14   |
| 50+25+25                                                | 12.58                      | 15.69  | 26.24   |
| 50+20+30                                                | 13.20                      | 16.71  | 31.26   |
| 50+15+35                                                | 13.38                      | 17.12  | 31.46   |
| 50+10+40                                                | 12.85                      | 16.54  | 29.05   |
| 50+05+45                                                | 12.65                      | 16.01  | 28.85   |



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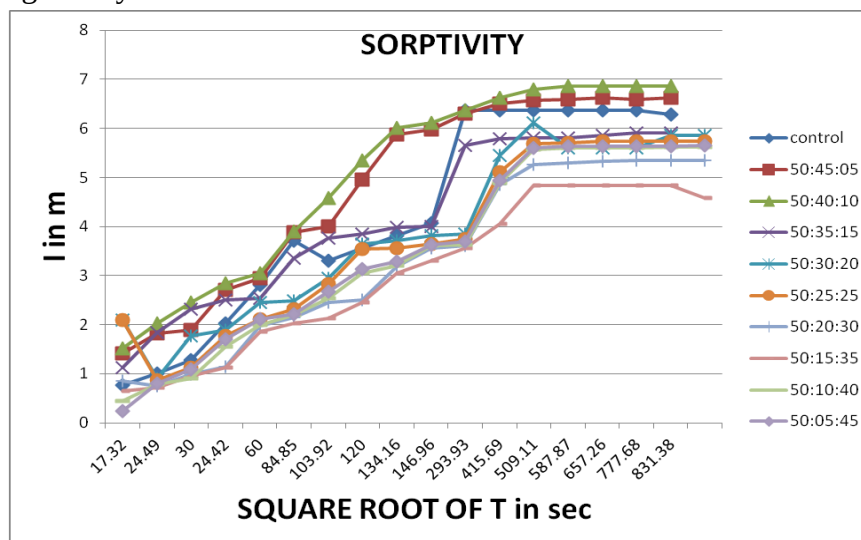
**Figure 1: Compression Test Result for 28 days**

## 5.2 Sorptivity Test on Cylinder

The rate of water absorption with respect to time was presented in Figure 5.3. From the results it was observed that the water absorption of concrete in the first 6 hours is high and after that it gets linear variation. After 48 hours duration the concrete attained the saturated condition in all concrete mixtures. There was a remarkable improvement in water absorption capacity in concrete made with 50:15:30 mix.

Dimension of Specimen: 100mm Diameter, 50mm Height

Days of Curing: 7 Days



**Figure 2: Sorptivity Test**



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**Table 3: Sorptivity test on Cylinders**

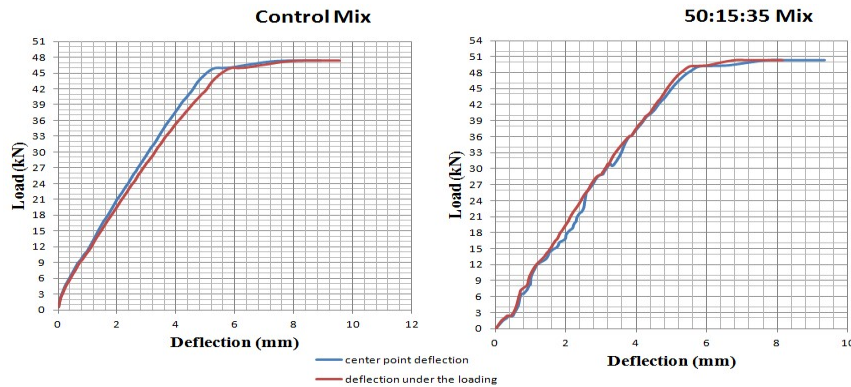
| Interval of time | Square root of time | Water absorption $I = \Delta m / (a \times d)$ |          |          |          |          |          |          |          |          |          |
|------------------|---------------------|------------------------------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
|                  |                     | control mix                                    | 50:45:05 | 50:40:10 | 50:35:15 | 50:30:20 | 50:25:25 | 50:20:30 | 50:15:35 | 50:10:40 | 50:05:45 |
|                  |                     |                                                |          |          |          |          |          |          |          |          |          |
| 5min             | 17.32               | 0.76                                           | 1.42     | 1.52     | 1.12     | 0.9      | 0.87     | 0.75     | 0.71     | 0.79     | 0.81     |
| 10min            | 24.49               | 1.01                                           | 1.82     | 2.03     | 1.84     | 1.78     | 1.12     | 0.99     | 0.95     | 0.9      | 1.09     |
| 15min            | 30                  | 1.27                                           | 1.89     | 2.45     | 2.32     | 1.89     | 1.78     | 1.14     | 1.12     | 1.55     | 1.71     |
| 30min            | 24.42               | 2.03                                           | 2.71     | 2.85     | 2.51     | 2.46     | 2.12     | 1.98     | 1.86     | 2        | 2.11     |
| 1hr              | 60                  | 2.81                                           | 2.95     | 3.05     | 2.54     | 2.48     | 2.31     | 2.15     | 2.03     | 2.19     | 2.21     |
| 2hr              | 84.85               | 3.71                                           | 3.89     | 3.9      | 3.35     | 2.94     | 2.82     | 2.45     | 2.13     | 2.54     | 2.68     |
| 3hr              | 103.92              | 3.31                                           | 4.01     | 4.58     | 3.77     | 3.64     | 3.54     | 2.51     | 2.45     | 3.05     | 3.14     |
| 4hr              | 120                 | 3.56                                           | 4.95     | 5.34     | 3.85     | 3.72     | 3.56     | 3.18     | 3.05     | 3.21     | 3.29     |
| 5hr              | 134.16              | 3.82                                           | 5.87     | 6.01     | 3.98     | 3.81     | 3.64     | 3.56     | 3.31     | 3.61     | 3.63     |
| 6hr              | 146.96              | 4.07                                           | 5.98     | 6.11     | 4.01     | 3.85     | 3.75     | 3.61     | 3.56     | 3.63     | 3.69     |
| 24hr             | 293.93              | 6.36                                           | 6.3      | 6.36     | 5.65     | 5.45     | 5.1      | 4.85     | 4.05     | 4.88     | 4.94     |
| 48hr             | 415.69              | 6.36                                           | 6.5      | 6.62     | 5.79     | 6.11     | 5.69     | 5.27     | 4.83     | 5.57     | 5.61     |
| 72hr             | 509.11              | 6.36                                           | 6.58     | 6.79     | 5.8      | 5.6      | 5.7      | 5.29     | 4.83     | 5.61     | 5.64     |
| 96hr             | 587.87              | 6.36                                           | 6.59     | 6.87     | 5.81     | 5.6      | 5.73     | 5.33     | 4.83     | 5.61     | 5.64     |
| 120hr            | 657.26              | 6.36                                           | 6.62     | 6.87     | 5.85     | 5.6      | 5.73     | 5.34     | 4.83     | 5.61     | 5.64     |
| 168hr            | 777.68              | 6.36                                           | 6.59     | 6.87     | 5.9      | 5.85     | 5.74     | 5.34     | 4.83     | 5.62     | 5.64     |
| 192hr            | 831.38              | 6.29                                           | 6.62     | 6.87     | 5.9      | 5.85     | 5.74     | 5.34     | 4.58     | 5.62     | 5.65     |

### 5.3 Load vs. Deflection

The load vs Displacement for control specimens clearly shows 50:20:30 mix has lesser displacement at peak load whereas 50:15:35 mix showed lesser deflection compare to that of 50:20: 30 mix and control mix.



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**Figure 3: Load vs deflection**

**Table 4: Flexural test behaviour**

| Description                         | Control mix | 50:20:30 | 50:15:35 |
|-------------------------------------|-------------|----------|----------|
| Peak load (kN)                      | 47.4        | 48.2     | 50.4     |
| First crack load (kN)               | 24          | 24.8     | 26.1     |
| Max deflection (mm) @ CENTER        | 8.9         | 7.38     | 8.14     |
| Max deflection (mm) @ LOADING POINT | 9.57        | 9.22     | 9.35     |

## 6 Conclusion

The compressive strength and split tensile strength after 28 days for control mix was found to be 20.45 N/mm<sup>2</sup> and 2.14 N/mm<sup>2</sup> respectively. The peak load in flexural strength for control mix was 47.4 kN. The combined mix replacement in cement with glass powder and GGBS in 50:15:35 and 50:20:30 increased the compressive strength by 44.20 % and 43.08 % respectively. For pull out test, specimen contain 15% of glass powder and 35% of GGBS gives 31.9 % more than the control mix. From the sorptivity test for durability aspect, the two ratios of cement, glass powder and GGBS (50:15:35 and 50:20:30) were found to absorb less water than the control mix by 37.3% and 17.7% respectively, which indicated that the two mix ratios were good in durability criteria. For the water absorption test also, the two ratios of cement, glass powder and GGBS (50:15:35 and 50:20:30) were found to absorb less water than the control mix by 15.15% and 6.1% respectively. From the bending test on the two mix ratios (50:15:35 and 50:20:30) of concrete indicated that there was an increase of 6.3% and 1.6% in comparison with that of control mix.



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