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# Strengthening of Self Compacting Concrete Using Ground Granulated Blast Furnace Slag (GGBS) for Cost Efficiency

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**Abstract:** ***To improve the concrete composites and its quality with an economical approach there is a need of some material to reused . Hence, this study focus on achieving towering strength concrete by using these Ground Granulated Blast Furnace Slag which is the waste from iron industry. It is obtained from blast Furnace in water or steam by quenching molten iron Slag. GGBS is used to make durable concrete structure in combination with ordinary Portland cement and other materials. Different test are performed and the percentage of the ground granulated blast furnace slag is varied from 20%, 30% and 40%. The percentage increase in the compressive strength at 30% addition of GGBS is 1.74%. Thus, it can be concluded that maximum compressive strength of self compacting concrete with the combination of admixtures (SP+VMA) may be obtained by adding 30% GGBS which is a waste material of Iron industry.***

**Keywords:** Ground Granulated Blast Furnace Slag (GGBS), Self Compacting Concrete.

## 1. Introduction

In present scenario construction industry, use of concrete is going on increasing speedily. Cement is most important constituent material of the concrete which formed by natural raw material like lime and silica. As these materials are non-renewable therefore situation may occurs when there will be no lime on earth for production of cement. This situation leads to think all people/researchers working in construction industry to do research work on cement replacing material and options to use it productively. Industrial wastes like Ground Granulated Blast Furnace Slag (GGBS) show chemical properties similar to cement. Use of GGBS as cement replacement will simultaneously reduces cost of concrete [1] and help to reduce rate of cement consumption. Hence, this study focus on achieving towering strength concrete by using these Ground Granulated Blast Furnace Slag which is the waste from iron industry.

The research reported in their study work which aimed to develop a framework for mixture proportions of different materials used for self compacting concrete. In particular two main phases as laboratory phase and plant phase which gives overall idea about how to define different mixes, batches and materials. Masahiro Ouchi [2] has described background and basics of self compacting concrete and its development stages in the proposed study. The investigations of self compacting concrete and different testing method are main focused in the work. These method are then adopted in laboratory for testing of self compacting concrete. It also describes applications of SCC regard with construction sector.

A research work is also done on testing the compressive strength of PCC and concrete with GGBFS [4]. It also defined the amount of GGBFS to be used in percentage to achieve maximum compressive strength. The research work also included different method of mix designing with materials used. Finally concluded with comparison between PCC and PCC with GGBFS and presenting PCC with GGBFS is better option for gaining strength in concrete.

Effort are also made to quantify the strength of ground granulated blast furnace slag (GGBS) at various replacement levels and evaluate its efficiencies in concrete [6]. This research evaluates the strength and efficiency of strengthening factors to harden the concrete, by partially replacing cement by various percentages of ground granulated blast furnace slag for M35 grade of concrete at different ages [3]. From this study, it can be concluded that, since the grain size of GGBS is less than that of ordinary Portland cement. The optimum GGBS replacement as cementation material is regarded by higher compressive strength, lower heat of hydration, resistance to chemical attack, better efficiency, good durability and economic.

"Ground Granulated Blast-Furnace Slag" (GGBFS) is formed following the process for grinding "Granulated Blast Furnace Slag" (GBFS) that is a kind of by product produced via blast furnace operated in our steel works [2]. GGBFS is hydraulic, mixed in other cement products, and utilized as the material for blast furnace cement, soft concrete mixture material, etc. As GGBFS is utilized for such a purpose above, compared with ordinary Portland cement, GGBFS utilization dispenses with the energy consumed to burn limestone and $CO_2$ gas emission from burning fuel and limestone itself coincidently [5]. Therefore, GGBFS is definitely the "globally eco-wise" product.

As GGBFS is mixed in cement products, it increases chemical resistance of concrete, intensity, mobility, and strength over a long term. Moreover, it also enhances a remarkable effect on crack control (exothermic control) and alkali aggregate reaction control. It absolutely suggests that for cement GGBFS is the best partner of all. GGBFS is produced in the site of JFE Steel East (Chiba) and West (Kurashiki) by member manufacturers of JFE group.

## 2. Benefits of GGBS in Concrete

### 2.1 Sustainability

It has been generally stated that the manufacture of one tonne of Portland cement would require approximately 1.5 tonnes of mineral extractions together with a amount of 5000 MJ of energy, and would generate 0.95 tonne of CO2 equivalent. When GGBS is a by-product of steel manufacturing is done, it is reported that the production of one ton of GGBS would generate only about 0.07 tonnes of CO2 equivalent and consume only about 1300 MJ of energy [4].

### 2.2 Color

Color of Ground granulated blast furnace slag is off-white. This whiter color is also seen in concrete made with GGBS, especially at replacements superior than 50% [6]. The additional aesthetically pleasing appearance of GGBS concrete can aid soften the visual impact of large structures for example bridges and retaining walls [9].

### 2.3 Setting Times

The setting time of concrete is influenced by many factors, in particular temperature and water/cement ratio. With GGBS, the setting time will be somewhat extended, perhaps by about 30 minutes. The effect will be more prominent at high levels of GGBS and/or low temperatures [8]. An extended setting time is beneficial in that the concrete will remain workable for longer periods, therefore resulting in fewer joints. This is particularly useful in warm weather.

To check the change in strength of concrete according to the proportional change in the concrete contents number of test have to be conducted. Here in this research work the test included are slump flow test, L box test, Compressive Strength Test, Flexural Strength Test [4] [6] [8].

**Figure1:** Slump flow Test Apparatus

**Figure 2:** L Box Apparatus

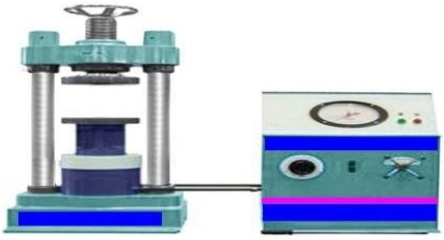

**Figure 3:** Compression Testing Machine

## 3. Results

### 3.1 Test Results Of Self Compacting Concrete Containing GGBS & The Combination Of Admixtures (SP+VMA)

The following tables give the test results of effect of addition of GGBS in various percentages on the properties of self compacting concrete containing an admixture combination (SP+VMA)
Compressive strength test results of self compacting concrete containing the combination of admixtures (SP+VMA) with various percentages of GGBS

**Table 1:** Compressive strength of SCC with **30% GGBS** and with combination of admixtures (SP+VMA)

| Specimen Identification | Wt. of Specimen (N) | Density (N/cum) | Average density (N/cum) | Failure Load (KN) | Compressive Strength (MPa) | Average compressive strength (MPa) |
|---|---|---|---|---|---|---|
| C1 | 82.2 | 24355.5 | 24177.7 | 951.75 | 42.30 | 41.30 |
| C2 | 83.8 | 24829.6 | | 900.90 | 40.04 | |
| C3 | 78.8 | 23348.1 | | 935.55 | 41.58 | |

**Table No.2:** Compressive strength of SCC with **40% GGBS** and with combination of admixtures (SP+VMA)

| Specimen Identification | Weight of specimen (N) | Density (N/cum) | Average density (N/cum) | Failure Load (KN) | Compressive strength (MPa) | Average compressive strength (MPa) |
|---|---|---|---|---|---|---|
| D1 | 84 | 24888.8 | 24533 | 889.88 | 39.55 | 39.81 |
| D2 | 81.2 | 24059 | | 900.22 | 40.01 | |
| D3 | 83.4 | 24711.1 | | 897.07 | 39.87 | |

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**Overall Results of Compressive Strength**

The following table gives the overall results of compressive strength of self compacting concrete containing the combination of admixtures (SP+VMA) for various percentage addition of GGBS

**Table 3:** Overall Result of Compressive Strength

| *Percentage addition of GGBS* | *Compressive strength (MPa)* | *Percentage increase or decrease of Compressive strength w.r.t. ref mix* |
|---|---|---|
| 0(Ref) | 40.59 | - |
| 20 | 41.20 | +1.50 |
| 30 | 41.30 | +1.74 |
| 40 | 39.81 | -1.92 |

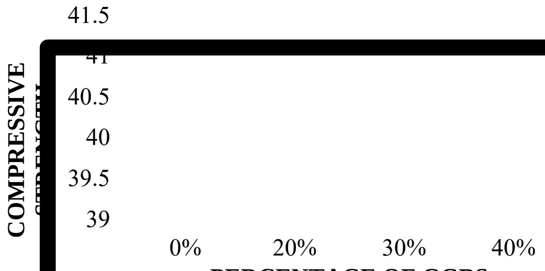


**Figure 4:** The variation of compressive strength of SCC containing GGBS.

The variation of compressive strength can be depicted in the form of graph as shown in Figure No. 4

**Tensile Strength Test Results Of Self Compacting Concrete Containing The Combination Of Admixtures (SP+VMA) With Various Percentages Of GGBS**

**Table 4:** Tensile strength of SCC with **30% GGBS** and with combination of admixtures (SP+VMA)

| Specimen identification | Failure Load (KN) | Tensile strength F=2P/ $\pi dl$ (MPa) | Average tensile strength (MPa) |
|---|---|---|---|
| C1 | 330 | 4.66 | |
| C2 | 320 | 4.52 | 4.55 |
| C3 | 318 | 4.49 | |

**Table No.5:** Tensile strength of SCC with **40% GGBS** and with combination of admixtures (SP+VMA)

| Specimen identification | Failure Load (KN) | Tensile strength F=2P/ $\pi dl$ (MPa) | Average tensile strength (MPa) |
|---|---|---|---|
| D1 | 228 | 3.22 | |
| D2 | 236 | 3.34 | 3.33 |
| D3 | 242 | 3.42 | |

**Overall Results of Tensile Strength**

The following gives the overall results of tensile strength of self compacting concrete containing the combination of admixtures (SP+VMA) for various percentage addition of GGBS

**Table 6:** Overall Result of tensile Strength

| Percentage addition of GGBS | Tensile strength (MPa) | Percentage increase or decrease of tensile strength w.r.t. ref mix |
|---|---|---|
| 0(REF) | 3.34 | - |
| 20 | 3.50 | +4.79 |
| 30 | 4.55 | +36.22 |
| 40 | 3.34 | 0 |

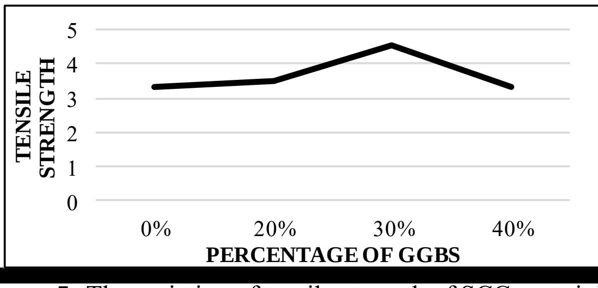


**Figure 5:** The variation of tensile strength of SCC containing GGBS

The variation of tensile strength can be depicted in the form of graph as shown in SS Figure No. 5

**Flexural Strength Test Results Of Self Compacting Concrete Containing The Combination Of Admixtures (SP+VMA) With Various Percentages Of GGBS**

**Table 7:** Flexural strength of SCC with **30% GGBS** and with combination of admixtures (SP+VMA)

| Specimen identification | Failure Load (KN) | Flexural strength F=PL/BD$^2$ | Average tensile strength (MPa) |
|---|---|---|---|
| C1 | 11.4 | 5.70 | |
| C2 | 10.8 | 5.40 | 5.53 |
| C3 | 11 | 5.50 | |

**Table No.8:** Flexural strength of SCC with **40% GGBS** and with combination of admixtures (SP+VMA)

| Specimen identification | Failure Load (KN) | Flexural strength F=PL/BD$^2$ | Average tensile strength (MPa) |
|---|---|---|---|
| D1 | 9.80 | 4.90 | |
| D2 | 10.30 | 5.15 | 4.92 |
| D3 | 9.40 | 4.70 | |

**Overall Results of Flexural Strength**

The following table gives the overall results of flexural strength of self compacting concrete containing the combination of admixtures (SP+VMA) for various percentage addition of GGBS

**Table No.9:** Overall Result of flexural Strength

| *Percentage addition of GGBS* | *Flexural strength (MPa)* | *Percentage increase or decrease of tensile strength w.r.t. ref. mix* |
|---|---|---|
| 0(Ref.) | 5.12 | - |
| 20 | 5.19 | +1.367 |
| 30 | 5.53 | +8.01 |
| 40 | 4.93 | -3.85 |

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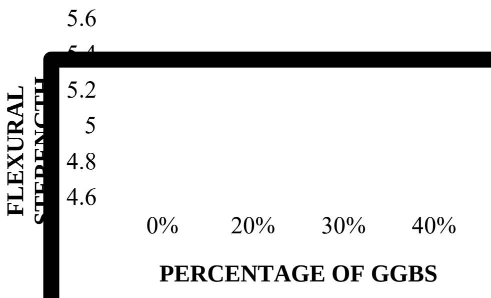


**Figure 6:** The variation of flexural strength of SCC containing GGBS

### 4.4 Flow Test Result Of GGBS

The following tables give the flow test results of effect of addition of red mud in various percentages on the properties of self compacting concrete containing an admixtures combination of (SP+VMA)

**Table 10:** Slump flow test results

| Percentage of GGBS | Slump flow (mm) | Time in sec $T_{50}$ |
|---|---|---|
| [illegible] | 690 | 4.70 |
| 20 | 710 | 4.60 |
| 30 | 730 | 4.67 |
| 40 | 720 | 4.62 |

**Table 11:** L box test result

| *Percentage of GGBS* | *Height H1* | *Height H2* | *H2/H1* | *Time taken to reach 200mm* | *Time taken to reach 400mm* |
|---|---|---|---|---|---|
| 0 | 85 | 75 | 0.88 | 9.24 | 15.8 |
| 20 | 75 | 62 | 0.83 | 6.30 | 10.2 |
| 30 | 80 | 77 | 0.96 | 3.80 | 6.5 |
| 40 | 70 | 63 | 0.60 | 4.60 | 8.8 |

## 4. Conclusion

It has been observed that the compressive strength of self compacting concrete produced with the combination of admixtures such as (SP+VMA) goes on increasing upto 30% addition of GGBS.

After 40% addition of GGBS, the compressive strength starts decreasing i.e. the compressive strength of self compacting concrete produced with (SP+VMA) is maximum i.e 41.30 Mpa when 30% GGBS is added.

The percentage increase in the compressive strength at 30% addition of GGBS is 1.74%. Thus, it can be concluded that maximum compressive strength of self compacting concrete with the combination of admixtures (SP+VMA) may be obtained by adding 30% GGBS which is a waste material of Iron industry.

From the above experimental results, it is proved that GGBS can be used as an alternative material for cement, reducing cement consumption and reducing the cost of construction. Use of industrial waste products saves the environment and conserves natural resources.

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