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# COMPARATIVE STUDY ON COMPRESSIVE STRENGTH OF SELF COMPACTING CONCRETE WITH HIGH VOLUME OF FLY ASH AND GGBS

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**Abstract**

The boon of industrial revolution is the great transformation of rural to urban due to the growth of industries. At the same time our earth has to face the threat to manage the industrial waste. To Ensure the 12th SDG goal, sustainable consumption and production patterns, the ingredients of SCC like fine aggregate and binding material can be replaced and reused by the industrial waste. The application of Self-compacting concrete (SCC) was improved widely in the construction industry to overcome the labour scarcity. Fly ash and GGBS the residue of the iron and steel plant waste can be replaced to cement in high volume to achieve the SCC workability properties. Nine mix designs with replacement of fly ash and GGBS were designed along with one control mix. In all mix design the weight of binding material is maintained the same whereas the water to cement ratio is adjusted with the by product weight ratio. The wet concrete tests were done for each batch and the results are compared to the EFNARC limiting values. [5]. The characteristic cube strength was found under universal testing machine at 28 days after proper curing. The target strength achieved by the SCC cubes with varying percentages, ranges from 26 to 48MPa. The strength and the cost based analysis can lead to produce self compacting concrete with fly ash & GGBS economically.

Keywords: Concrete, Self compacting, Fly ash and GGBS, Slump flow, Compressive strength.

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## 1. Introduction

Self-compacting concrete (SCC) is defined as the workability which is enhanced to flow, pass and level by its own self gravity on the formwork without any vibration equipments over wet concrete, along with high consistence. It ensures proper filling and avoid honey combing in structural members of restricted corners, beam column joints, in deep beams and heavily reinforced RCC members. In the 1980s, SCC was developed in Japan, in seismic regions where the seismic resistant structures with confinement reinforcement in columns and beams are to be designed to achieve the stability against earth quake forces.[9] The special benefits of using SCC, especially when economically produced using industrial by products are, Eliminating the usage of vibrating equipments to avoid honeycombing in concrete. Hence the noise pollution in the site is avoided Improving the filling and passing ability on corners and beam column joints and thin slender slabs Facilitating constructability and ensuring required compressive and flexural strength and good durable performance. Comparatively the number of masons was minimized and which finally bring down the overall cost of the concrete. The heat librated during hydration process of concrete can be minimized by the replacement of fly ash & GGBS, which enhance the concrete density, permeability and durable properties. The good workability and fluidity can be achieved by the addition of suitable percentage of super plasticizer to the mix design. The major admixtures like GGBS, VISCOSITY MODIFYING AGENTS and Super plasticizer like Fritz-Pak Super plasticizer PCE, help to remain cohesive under working conditions. All these activities increase the cost of concrete, hence by eliminating those chemical admixtures by the industrial by-products, the flowing properties of SCC can be achieved. The industrial waste is now renamed as industrial by products. Industrial by products which are dumped in yards which pollute the land in due course can be reused in concrete industry in free of cost. [10-13].

## 2. Properties of Self Compacted Concrete in Fresh State

### *2.1 Filling ability*

The powder type concrete very much having self weight flowing ability helps to catch the corners of the formwork and seep through into congested rebar cages without any external fore like needle vibrators. Super plasticizer is used in order to obtain high mobility. The limiting values for the filling ability test are based on the spread diameter of 500mm after the immediate lifting f the slump mould. And the time taken to spread must be between 2 to 10 seconds.

2.2 Passing *ability*

SCC overcomes the problem of normal concrete which has in placing perfectly without forming honey comp in hard concrete, in the reinforced cages like segmental RCC elements. Since SCC is rich in fine content and powder ratio enhance to pass in reinforcement cages even in the minimal spacing without vibrators. Test methods to determine the workability properties of SCC are listed in the table 1.

*2.3 Resistance to segregation*

The density of concrete is achieved by the homogenous mixture of coarse and fine aggregates. Since self compacting concrete is in flowing condition, which allows the aggregate to segregate from the wet concrete mixture. This can be fixed by adding fly ash and GGBS with the mixture. GTM screen stability test and V-funnel at T5minutes test are conducted to ensure homogeneity of the SCC mixture within the limiting values, for every batch of mix design.

**Table 1**

Test methods to determine the workability properties of SCC

| SI NO | METHOD | PROPERTY | LIMITING VALUES |
|---|---|---|---|
| 1. | Slump-flow by Abrams cone | Filling ability | 650-800mm |
| 2. | T50cmslumpflow | Filling ability | T 50cm |
| 3. | J-ring | Passing ability | 0 – 10 mm |
| 4. | V-funnel | Filling ability | 8 – 12 sec |
| 5. | V-funnel at T5minutes | Segregation resistance | + 3 sec |
| 6. | L-box | Passing ability | H2 / H1 = 0,8-1,0 |
| 7. | U-box | Passing ability | H2-H1 = 30 mm |
| 8. | Fill-box | Passing ability | 90–100% |
| 9. | GTM screen stability test | Segregation resistance | 0– 5 sec |
| 10. | Orimet | Filling ability | 0– 5 sec |

## 3. Experimental Methods

The experimental program is based on the powder type self-compacting concrete. One control concrete mix design and Nine SCC mixtures with different percentage replacement of fly ash & GGBS were designed by trial and error method to achieve the workability properties of SCC.[14-18]. From each concrete mixture, three numbers of stand size of 150 mm cubes specimens were casted and were tested under UTM to determine the compressive strength after 7-, 14-, and 28-days curing. The weight of the binding ingredient is kept constant as (400 $kg/m^3$), while the water/cement ratios are obtained by trial and error method and were fixed as 0.35, 0.4, and 0.45 along with super plasticizer. The proportions of self - compacting mixtures are defined as of 20%+20%, 30%+20%, and 40% +20% by Class F fly ash and GGBS to cement respectively. Every wet batch is tested for its workability before casting into cubes.

## 4. Replacement Material observation

The industrial by products used in this project is to be confirming with 3812-1981. The Class F Fly ash and GGBS are collected from the nearby the industrial yards, dumped in land and the following test are done to check the compatibility to blend with the binding material. Physical properties of fly ash and GGBS are tested and listed in table 2. Super plasticizer Glenium B233 PCE (Polycarboxylic ether) is used as an admixture for all SCC mix proportions except for control concrete. [19-22]. A synthetic resin-type Air-entraining admixture (AEA) was used in all the SCC concrete mixtures. The ingredients of the various mixes are tabulated in table 3.

**Table 2**

Physical properties of fly ash and GGBS

| Material observation | FLY ASH | GGBS |
|---|---|---|
| Appearance | Blackish | Mottled green |
| Specific Gravity | 2.14 | 2.9 |
| Fineness | 78% passing through sieve No 325 | Greater than 340m2kg |

**Table 3**
Self-Compacting Concrete Mix Design Proportions

| Mix. No | W/(C+FA) | Water | Cement | Fly ash and GGBS | | F.A. kg/m$^3$ | C.A kg/m$^3$ | AEA, mL/m$^3$ | SP, L/m$^3$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | kg/m$^3$ | % | kg/m$^3$ | | | | |
| 1 | 0.5 | 163 | 326 | - | - | 650 | 905 | 67 | 0 |
| 2 | 0.45 | 188 | 251 | 40 | 167 | 831 | 842 | 338 | 1.2 |
| 3 | 0.4 | 159 | 238 | | 159 | 844 | 844 | 355 | 2.9 |
| 4 | 0.35 | 136 | 232 | | 155 | 846 | 847 | 345 | 3.8 |
| 5 | 0.45 | 188 | 207 | 50 | 207 | 845 | 843 | 356 | 0.4 |
| 6 | 0.4 | 161 | 200 | | 200 | 842 | 843 | 372 | 1.7 |
| 7 | 0.35 | 138 | 197 | | 197 | 856 | 856 | 338 | 2.8 |
| 8 | 0.45 | 190 | 169 | 60 | 254 | 853 | 853 | 483 | 0 |
| 9 | 0.4 | 164 | 163 | | 245 | 851 | 851 | 394 | 2 |
| 10 | 0.35 | 141 | 161 | | 241 | 866 | 864 | 345 | 3 |

## 5. Results and Discussions

### *5.1 Free Flow Test*

The lab test is done with each batch of the mix. On lifting the slump cone, filled with concrete, the concrete flows and the diameter of the spread mix is measured in two opposite directions. A stop clock is started and the time taken is noted simultaneously. The mean diameter of the concrete mix shows the capability to flow freely in the moulds. The time taken is a secondary indication of flow. The time taken in seconds is noted upto the mix reaches the first concentric circle which is 500mm in the steel plate. (figure 1).

**Fig. 1** Slump Flow Test

**Fig. 2** V- Funnel Test

### *5.2 Funnel Test*

In the standard V-funnel test, 12 litres of SCC mix is required. This test measures the free flow in casting thin section of RCC elements in structures. The flow path is broad in initial stage and narrow at the end. The time taken is indirectly proportional to the flowing capacity of the mix. The lack of homogeneity in the mix causes segregation of the aggregates from the mix. The segregation behaviour is also extracted from this test. A waiting period of 5 minutes has to be adopted in each refill so as the shutter in the bottom end has to be closed. For various water and additive ratios the test were conducted and the results are shown in the figure 3. The tested values are presented in Table 4

The fresh concrete test, slump flow verses water cement ratio is shown in

*5.3 Compressive Strength*

All the cubes were cured in the curing tank for 28 days. To study the early strength the cubes were tested for seventh and fourteenth day after casting. From the UTM test results the early strength is also very appropriate to the target strength in the last two mix proportions.

The strength of the mixes inversely proportional to the addition of the flyash and ggbs. Hence for the higher end of replacements shows less target strength. Whereas the lower end replacement of materials achieved the target strength. The water-to-cement ratio is between 0.40 and 0.45. The universal testing machine results of all mixes are tabulated in figure 4.

**Table 4**

Properties of the Fresh Concrete

| Mixture no. | W/(C+FA) | % of fly ash and GGBS | Slump, mm | Slump flow, mm | Funnel test flow time , sec | Compressive strength MPa |
|---|---|---|---|---|---|---|
| 1 | 0.5 | . | 110 | . | - | 36.9 |
| 2 | 0.45 | | 240 | 625 | 3 | 36 |
| 3 | 0.4 | 20+20 | 240 | 625 | 4 | 36.5 |
| 4 | 0.35 | | 240 | 650 | 7 | 36 |
| 5 | 0.45 | | 230 | 520 | 3 | 35.3 |
| 6 | 0.4 | 30+20 | 240 | 570 | 5 | 33.2 |
| 7 | 0.35 | | 240 | 540 | 6 | 30.4 |
| 8 | 0.45 | | 230 | 450 | 3 | 28.3 |
| 9 | 0.4 | 40+20 | 240 | 600 | 3 | 26.2 |
| 10 | 0.35 | | 240 | 650 | 4 | 26.7 |

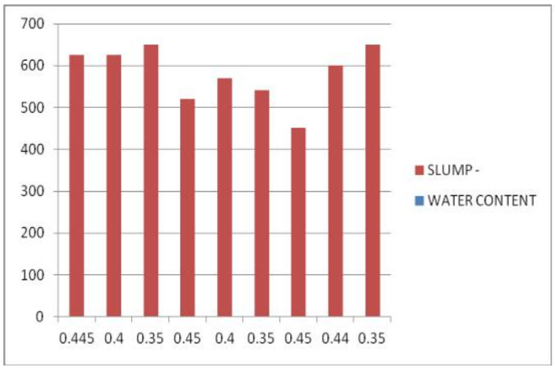


**Fig. 3** Slump flow verses water cement ratio

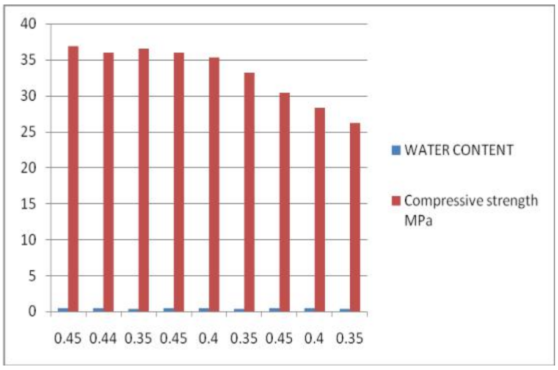


**Fig. 4** Compressive strength verses water cement ratio

*5.4 Cost Analysis*

The target mix design strength of the control concrete is fixed and designed for M35. The self-compacting concrete mix developed with a water-to-cement ratio of 0.45, and replaced with total volume of fly ash and GGBS about half of the cement volume without any chemical admixtures approximately achieved the above target strength. The costs analysis of the above two mixtures shown in the table 5. Hence the application of industrial waste products in self compacting concrete helps to reduce the labour in site and avoid the mounting of by products in industries, which directly helps to avoid the pollution to land.

**Table 5.**

Weightage of materials of control concrete & Self Compacting concrete

| W/(C+A) | Cement Kg / m3 | % of Fly ash and GGBS | Kg/m3 | Fine aggregate Kg/m3 | Coarse aggregate Kg/m3 | AEA ml/m3 | SP L/m3 |
|---|---|---|---|---|---|---|---|
| 0.5 | 326 | - | - | 650 | 905 | | 0 |
| 0.45 | 251 | | 167 | 845 | 846 | 0.34 | 1.2 |
| 0.4 | 238 | | 159 | 844 | 844 | 0.36 | 2.9 |
| 0.35 | 232 | 20+20 | 155 | 846 | 847 | 0.35 | 3.8 |
| 0.45 | 207 | | 207 | 845 | 843 | 0.36 | 0.4 |
| 0.4 | 200 | | 200 | 842 | 843 | 0.37 | 1.7 |
| 0.35 | 197 | 30+20 | 197 | 856 | 856 | 0.34 | 2.8 |
| 0.45 | 169 | | 254 | 853 | 853 | 0.48 | 0 |
| 0.4 | 163 | | 245 | 851 | 851 | 0.39 | 2 |
| 0.35 | 161 | 40+20 | 241 | 866 | 864 | 0.35 | 3 |

**Table 6.**

Cost analysis of Control Concrete & Self Compact Concrete

| Cement at Rs350/BAG | Fly ash and GGBS | F.A at Rs 900/TON | C.A at Rs625/TON | AEA at Rs 150/L | SP at Rs 120/L | Total Cost Rs / m3 |
|---|---|---|---|---|---|---|
| 2282 | - | 585 | 565.625 | - | - | 2282 |
| 1757 | 167 | 760.5 | 528.75 | 51 | 144 | 3408.25 |
| 1666 | 159 | 759.6 | 527.5 | 54 | 348 | 3514.1 |
| 1624 | 155 | 761.4 | 529.375 | 53 | 456 | 3578.775 |
| 1449 | 207 | 760.5 | 526.875 | 54 | 48 | 3045.375 |
| 1400 | 200 | 757.8 | 526.875 | 56 | 204 | 3144.675 |
| 1379 | 197 | 770.4 | 535 | 51 | 336 | 3268.4 |
| 1183 | 254 | 767.7 | 533.125 | 72 | - | **2809.825** |
| 1141 | 245 | 765.9 | 531.875 | 59 | 240 | **2982.775** |
| 1127 | 241 | 779.4 | 540 | 52 | 360 | 3099.4 |

## 6. Conclusions

The hardened test results obtained for SCC blended with industrial waste reaches the target strength for 30% flyash & 20%GGBS replacement. M35 is the target strength obtained by the control concrete without any admixture effect. The cost of production of control concrete of M35 is approximately matches the cost of production of SCC with cement replacement and addition of super plasticizer. The cost analysis includes the labour rate also.

Based on the study, the following conclusions can be drawn.

Economic SCC, for normal strength up to M30grade can be developed, by replacing cement with mineral additives without any chemical additives which is comparatively higher end in cost wise along with the main ingredients of concrete (cement, fine aggregate, and coarse aggregate).

In future, more other industrial waste has to be replaced and experimentally the suitability is tested in producing SCC in concrete industry which directly helps to bring the sustainability in construction industry.

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