# Research on Self Compacting Geopolymer Concrete

**Thavasumony. D, Nalanth. N**

***Abstract The construction sector is suited for economy progress due to urbanization, industrialization, profitable growth and improved quality of life. The building material most commonly used is cement and its demand is increasing everyday that urged the industry to focus towards its production using alternative materials obtained from industrial by-products which may reduce the carbon foot print owing to the current global issues. Geopolymer concrete (GPC) has gain significance in this respect by using industrial by-product waste to replace cement and reduced carbon emission during its production. By alkali reaction of materials like alumina and silica it is produced. Because of the lack of compaction due to viscosity nature of GPC, a Self Compacting Geopolymer Concrete (SCGC) is used that compresses by its self weight. Industrial by-products like fly ash, Ground Granulated Blast Furnace Slag (GGBFS) and Silica Fume is utilized for generating SCGC. In this paper investigation on mechanical properties of SCGC under hot air curing and ambient curing is done. A variety of trial mixes for the fresh and hardened properties were tested. It was evident that the overall specimen subjected to test showed enhanced strength by increasing the content of GGBFS and fly ash.***

***KEYWORDS: Self Compacting Geopolymer Concrete, Fly ash, GGBFS, and Hot air curing.***

## I. INTRODUCTION

Massive concrete production depletes major quantities of natural resources and as a consequence of limestone decarbonization and fossil fuel combustion, releases substantial quantities of greenhouse gasses into the ecosystem Next to aluminium and steel, cement is the most energy-intensive material used in construction (Hardjito and Rangan, 2005). Because of cement production, CO2 emissions are estimated to increase by about 50% from present levels by 2020 (Naik, 2005). Worldwide, enormous initiatives are being created to reduce cement use. An emerging technique, Self-compacting concrete (SCC), is yet another advancement that is gaining worldwide popularity. It’s potential to compact under self-weight and with no influenced vibration its transfer via reinforcement provides advantages compared to conventional concrete (CC). Benefits such as enhanced concrete standards, less construction time, easier positioning in crowded reinforcements, consistent and entire consolidation, enhanced bond strength, and reduces level of noise owing to lack of tremor, reduces general expenses, and secure functioning environment (Liu, 2010). The most frequently used component in SCC was fly ash (Khatib, 2008), GGBFS and silica fume (Fareed et al., 2013). It excludes the nature of viscosity-enhanced chemical admixtures by incorporating mineral admixtures. Reduced water content in the concrete results in increased durability and better mechanical integrity. It is recognized that certain admixtures may enhance rheological characteristics and decrease concrete cracking owing to reduced overall hydration heat and boost concrete's workability and long-term characteristics (Bouzoubaa and Lachemi, 2001).

An attempt was made to create an advanced concrete that incorporates the benefits of both SCC and GPC. . SCGC is a comparatively fresh idea in concrete technology and the recent development. The usage of Portland cement is completely avoided in the manufacturing process and there is no requirement for compaction in this form of concrete. An analysis was adopted to produce SCGC using generally accessible materials by investigating its characteristics. This paper documents the trials outcomes performed for evaluating the fundamental characteristics of SCGC curing under hot air and ambient curing. The observations of this research have been assumed to help predict SCGC's behaviour.

## II. LITERATURE REVIEW

In the geopolymerization process, alkaline solution plays a significant part. Alkali silicate is a strong binder chemical activator and plays a major role in GPC efficiency. Because of the low price alternative to K-silicate, Na-silicates are most commonly used activators. By mixing an activator with both alkali silicates and alkali hydroxides to suitable proportions, many investigators have created GPC (Shayan and Phaedonos, 2016). (Raijiwala et al., 2012) studied the strength and durability characteristics of alkaline activators. The compressive and split tensile strength was improved by enhancing the alkaline activator content. For 24 hours, the gain in strength stays very moderate because the polycondensation method has already been completed at a room temperature of 60°C and the particle interface is also reached. GPC's strength development is strongly affected by water content. (Shayan and Phaedonos, 2016) examined the geopolymer compressive strength by increasing the level of water. They discovered that the compressive strength declined exponentially with an increase in water level from 0.15-0.5 with respect to the solid ratio. Increasing the water composition enhanced the slump flow thereby reducing the compressive strength.

**Revised Version Manuscript Received on 10 September, 2019.**

**Thavasumony. D**, Noorul Islam Centre for Higher Education, Kumarakovil, Tamil Nadu, India.

**Nalanth. N**, Noorul Islam Centre for Higher Education, Kumarakovil, Tamil Nadu, India.

Admixtures are used to enhance concrete mix's fresh features to better fit the concrete for a particular use. The inclusion of superplasticizer shows an increase of 50% to 75% in the early strength of concrete and workability on the fresh concrete improved (ASTM-C494). While GPC's properties are strongly impacted by the kinds of activators and binder used, its proportions can also have a significant impact on a mix's characteristics. The impact on fresh characteristics of sodium hydroxide concentration and compressive strength of SCGC has been recorded (Fareed et al., 2013). Test results revealed that sodium hydroxide content variability had the least impact on SCGC's new characteristics. The workability of new concrete has been mildly decreased by enhancing the sodium hydroxide concentration; however, the associated compressive strength has been improved. Highest compressive strength was generated by concrete specimens with 12 M sodium hydroxide. At 70 degrees Celsius, the curing of SCGC is either through ambient curing or oven curing. The research indicates that the impact of curing the concrete and designated oven curing technique on mechanical characteristics is better than the ambient curing technique (Nipun and Anil, 2015).

## III. MIX PREPARATION

Mix design was proposed by Ferdous et al. (2013) for fly ash based SCGC taking into account the workability of concrete density variation, material-specific gravity, air consumption, and strength. The important problem in design phase may be the choice of the activator to fly ash proportion, as well as the determination of the precise content of the activator solution regarding the fly ash. In GPC, the alkaline is an expensive ingredient and concerning the economic design, it is necessary to minimize the use of alkaline content and to maintain the required workability and. strength Because of constrained studies on GPC's mix design; no particular procedure appears to have taken into consideration. Therefore, an effort has been created in this technique to suggest a mix design procedure taking into consideration the main disadvantages of the previous techniques proposed (Monita Olivia et al. 2012). The mix design proportion is shown in table 1.

**Table 1: Mixture proportion for SCGC**

| Binder (Fly ash) | Sand | Coarse aggregate | Alkaline liquid |
|---|---|---|---|
| 428.6 kg/m$^3$ | 540 kg/m$^3$ | 1260 kg/m$^3$ | 171.4 kg/m$^3$ |
| 1 | 1.26 | 2.94 | 0.4 |

SCGC mixtures were perfectly shaped to analyze the impact of various mixing elements, the number of admixtures in fly ash replacement, proportional to GGBFS, with an alkaline solution and aggregates. Davidovits (2002) proposed that, before adding the NaOH (Sodium Hydroxide) pellets, the combination of sodium silicate and sodium hydroxide solution should be prepared prior to one day.

**Table 2: Properties & Chemical composition of Fly ash**

| Color | Specific gravity | Loss on ignition | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | CaO | MgO | $SO_3$ | Insoluble Residue | Alkalies | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | $Na_2O$ | $K_2O$ |
| Dark Gray (Blackish) | 2.76 | 0.13 | 55.25 | 12.65 | 17.22 | 6.85 | 6.01 | 1.45 | - | 0.10 | 0.32 |

**Table 3: Properties & Chemical composition of GGBFS**

| Color | Specific gravity | Loss on ignition | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | CaO | MgO | $SO_3$ | Insoluble Residue | Alkalies | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | $Na_2O$ | $K_2O$ |
| Off white | 3.20 | 1.45 | 38.75 | 0.45 | 11.88 | 40.28 | 6.28 | 0.35 | - | 0.58 | 1.26 |

The main ingredients (fly ash and GGBFS) were mixed in a moisture-free vessel to prepare the mix. Next aggregates are mixed in a separate pan with the fly ash and GGBFS. Finally, the above combination is added with an appropriate quantity of the alkaline activator solution until homogeneity of the mix is achieved. Figures 1 show the method engaged in the production of SCGC. The characteristics and Chemical composition of GGBFS and fly ash used in this inquiry are shown in Table 2 and Table 3.

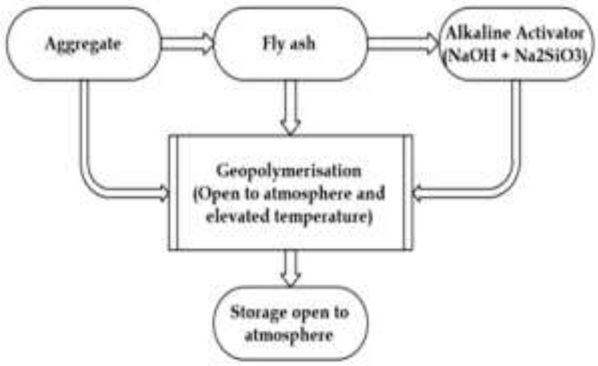


**Figure 1: Geopolymerization process**

The chemical reaction of the silicate sodium and hydroxide sodium solution resulted in the production of the alkaline solution. To form a solution, NaOH particles were dissolved in water. Molar (M) conveys the quantity of NaOH. In the trial mixes, molarity between 8 M to 16 M was used. In the experimental investigation, fine aggregate falling under area II of IS 383-1970 was used (river sand). Fine aggregate tests were performed as per IS: 2386 (Part III). For the investigation, the coarse aggregate size of 20 mm is used in accordance with IS: 383-1970 to determine the characteristics of its laboratory experiments. High range water-based on naphthalene sulphonic acid was used in this inquiry. The superplasticizer validates to class A and F admixture of ASTM C494-12 (ASTM standard, 2012). Superplasticizer helps to enhance the CC workability. Its use for SCGP, however, may not operate in the same system as CC. The concentration of water determines concrete strength. In this investigation, water satisfying the criteria as stated in IS 456-2000 was used. Water can lead to corrosion if not suited, or it can directly impact the structure's strength.

*Retrieval Number: B13150982S1119/2019©BEIESP*
*DOI: 10.35940/ijrte.B1315.0982S1119*



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## IV. HOT AIR CURING

In this research, two kinds of curing are used: curing at room temperature and hot air curing to a temperature of 60ºC. The concrete must be allowed to set for 30 minutes. The specimens were air cool after demoulding and tested respectively after 7, 14 and 28 days. Figure 2 shows the chamber of hot curing. During the curing process, polymerization phase is activated. Polymerization becomes faster at high temperatures and the concrete reaches 70% of its strength after 4 hours of curing (Kong & Sanjayan 2008). The hot curing chamber temperature was set to 60ºC in this investigation, and the hot curing duration was 24 hours. After that, the ambient curing was assigned to the specimens.

**Figure 2: Specimens after Curing**

## V. EXPERIMENTAL INVESTIGATION

### *5.1 FRESH STATE TESTS*

In accordance with the method described in IS 7320: 1974, testing for the fresh concrete's workability was made. For measuring the fresh concrete's slump, a mould with a height, top and bottom diameter of 300 mm, 100 mm and 200 mm are used. Initially slump mould, the base plate, and tamping rod were soaked. The mould was steadily set by positioning at the bottom of the two plates. The mix was then dumped into the mould with 25 tamping rod blows (600 mm in length and 15 mm in diameter) in three equal layers. On the application of the tamping rod blow it penetrates past the previous layer. After filling the top layer the surface was levelled to trim excess mix. Without lateral displacements, the mould was then lifted upright. From the top of the mould, the centre and edges vertical displacements at top surface of the concrete mixture were measured. The comparison of slump values for trial mixes is showed in figure 3.

**Table 4: Fresh and hardened state properties test results**

| Mix ID | Fresh state test | Hardened state test (MPa) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Slump flow (mm) | Compressive strength | | | Split tensile strength | | | Flexural strength | | |
| | | 7 day | 14 day | 28 day | 7 day | 14 day | 28 day | 7 day | 14 day | 28 day |
| CC | 81 | 32.7 | 39.88 | 47.51 | 2.46 | 3.07 | 3.99 | 2.61 | 3.51 | 4.21 |
| SCGP1 | 99 | 31.27 | 37.34 | 45.27 | 3.50 | 4.08 | 4.905 | 5.46 | 6.06 | 7.17 |
| SCGP 2 | 96 | 32.75 | 38.31 | 46.53 | 3.76 | 4.39 | 5.09 | 5.68 | 6.27 | 7.51 |
| SCGP 3 | 94 | 34.08 | 40.01 | 47.34 | 4.05 | 4.599 | 5.32 | 5.81 | 6.54 | 7.79 |
| SCGP 4 | 92 | 37.31 | 42.08 | 49.49 | 4.30 | 4.85 | 5.76 | 6.05 | 6.78 | 8.13 |
| SCGP 5 | 89 | 39.28 | 44.31 | 51.55 | 4.76 | 5.36 | 6.07 | 6.36 | 7.08 | 8.39 |
| SCGP 6 | 88 | 40.89 | 45.64 | 52.49 | 4.98 | 5.55 | 6.40 | 6.65 | 7.21 | 8.21 |
| SCGP 7 | 87 | 42.55 | 47.38 | 54.85 | 5.16 | 5.88 | 6.68 | 6.79 | 7.53 | 8.83 |
| SCGP 8 | 86 | 45.04 | 49.71 | 58.55 | 5.49 | 6.10 | 6.96 | 6.86 | 7.71 | 8.99 |
| SCGP 9 | 83 | 43.21 | 48.01 | 56.65 | 5.25 | 5.92 | 6.75 | 6.81 | 7.49 | 8.85 |
| SCGP 10 | 79 | 42.21 | 47.44 | 55.65 | 4.96 | 5.41 | 6.38 | 6.15 | 7.12 | 8.53 |
| SCGP 11 | 73 | 41.48 | 46.55 | 53.81 | 4.60 | 5.23 | 6.05 | 5.98 | 6.89 | 8.19 |

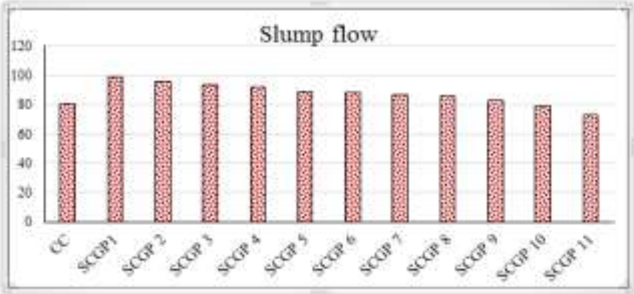


**Figure 3: Comparison of slump values for trial mixes**

### *5.2 HARDENED STATE TEST*

According to the guidelines provided by IS: 516 – 1959, the entire hardened state test on concrete was tested. The specimens comprising of 324 were casted, cured and tested which includes 108 cubes, 108 cylinders and 108 prisms.

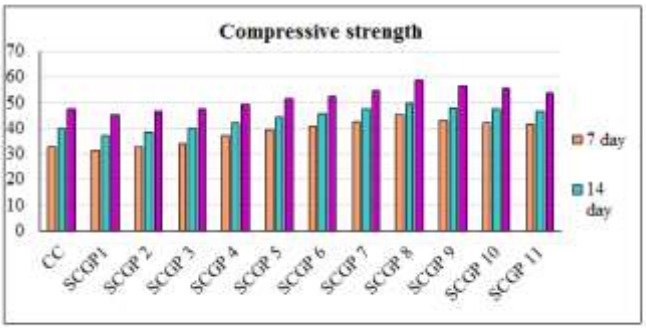


**Figure 4: Compressive strength on concrete cubes**

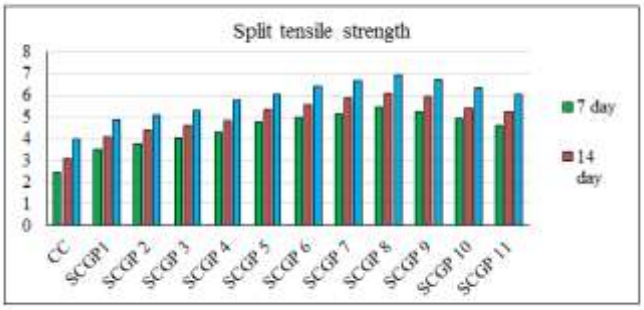


**Figure 5: Split tensile strength on concrete cylinders**

For casting cubical specimens, cube molds of size as per (IS 516: 1959) were used. Using the SCGP mix that cleared the fresh state tests, minimum of three samples per series was casted. For 24 hours, curing of SCGP specimens was performed in an oven at 600oC and was kept in the air for 7 days, 14 days and 28 days. Testing was made in a compression testing machine by forcing load gradually at the rate of 140 kg/cm2. A test was performed on prism sample of size 10 x 10 x 50 cm to obtain the flexural strength test. The tensile strength helps estimating the load at which concrete crack occurs, that in turn helps diagnose the tensile failure. The test was conducted on specimen of diameter 15cm and length 30cm as per (IS: 516 -1959) to determine the split tension. The specimens were subjected to compression testing machine. The results obtained are furnished in table 4 and the respective graphical representation is presented in figure 4, 5, and 6.

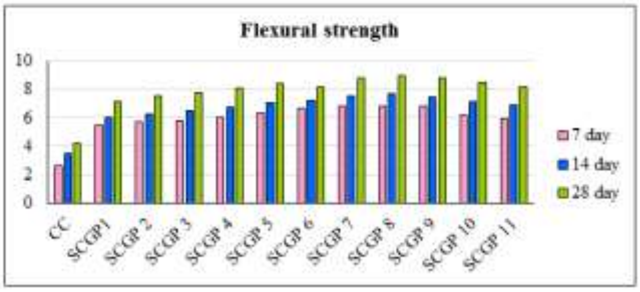


**Figure 6: Flexural strength on concrete prisms**

## VI. CONCLUSION

The tests of strength and durability were carried out in accordance with IS 516-1959. Molarity, fly ash, and GGBFS increase the strength of SCGP components. The fly ash and GGBFS contains majority of silica and alumina content and actually act with an alkaline solution as a good reactive powder. In 12 M, from the initial test results, the solution gets good concentration compared to other molarities. The specimens and structural elements of the SCGP resisted more strength, high deformation resistance and less deflection than the elements of the CC. It was discovered from the initial test outcomes that the compressive, split tensile and flexural strength of the SCGP specimen were 20%, 43% and 53% higher than CC specimens.

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*Retrieval Number: B13150982S1119/2019©BEIESP*
*DOI: 10.35940/ijrte.B1315.0982S1119*



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