Self-compacting geopolymer concrete-a review

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Abstract: In this construction world, Geopolymer concrete is a special concrete which doesn't require the Ordinary Portland Cement and also reduces the emission of carbon-dioxide. The Geopolymer Concrete is made up of industrial by-products (which contains more Silica and Alumina) and activated with the help of Alkaline solution (combination of sodium hydroxide & sodium silicate or potassium hydroxide & potassium silicate). The high viscosity nature of Geopolymer Concrete had the ability to fail due to lack of compaction. In improvising the issue, Self Compacting Geopolymer Concrete has been introduced. The SCGC doesn't require any additional compaction it will flow and compacted by its own weight. This concrete is made up of industrial by-products like Fly ash, GGBFS and Silica Fume and activated with alkaline solution. The earlier research was mostly on Fly ash based SCGC. In few research works Fly ash was partially replaced with GGBS and Silica Fume. They evaluated the compressive strength of concrete with varying molarities of NaOH; curing time and curing temperature. The flexural behaviour of the concrete also examined. The Fly ash based SCGC was got high compressive strength in heat curing as well as low compressive strength in ambient curing. The presence of GGBS improves the strength in ambient curing. For aiming the high strength in ambient curing Fly ash will be completely replace and examine with different mineral admixtures.

1. Introduction

Now-a-days common Portland Cement (OPC) is having a major role in the construction family. Concrete for a building has most likely been based on a usual Portland Cement (OPC) binder [1]. The increase in the progress of population results in growing in construction progress expense. Prof. Dr Joseph Davidovits mentioned that the creation of 1 ton cement releases approximately 0.85 - 1 ton of carbon dioxide [2], [3]. Presently, the cement manufacturer is responding speedily to the perceive societal need for diminished CO2 emissions, via setting up the production of blended Portland cement, utilizing supplementary cementitious factors which possibly traditionally derived from industrial by way of making use of products, similar to blast-furnace slag and coal combustion fly ashes [4]. Amongst all of the materials within the OPC concrete, cement is the primary ingredient which helps to bind the aggregates [5]. A big amount of industrial waste and demolition waste are produced every year [6]. Useful lands are occupied by these waste materials, re-utilizing the waste fabric grew to be the new discipline of research and plenty of experiments were carried out to make use of the commercial waste as substitution of typical Portland cement concrete. This effort helps to find out the alternative material with entire removing of Portland
cement. In view of sustainable development in the building industry, an alternative substitute to the Ordinary Portland cement concrete has been developed. By utilizing the industrial by-products with alkaline solution undergoes polymerization to form Geopolymer concrete, termed by French professor Davidovits in 1978 [3]. Geopolymer cement is manufactured in yet another process than that of Portland cement. They don’t require excessive-temperature kilns, with a massive expenditure of fuel, nor do they require this type of huge capital funding in plant and gear. Naturally, taking place alumino-silicates (geological assets readily available on all continents) are supplying compatible polymeric raw substances [3]. While manufacturing of one ton of Geopolymeric cement from the carbon fuel combustion, releases the 0.18 tons of CO2, comparatively less than the one ton of CO2 which is released from one ton Portland cement [2], [3]. Due to the high viscous nature of geopolymer concrete, it has the ability to fail due to lack of compaction [5]. Now, investigations were carried out on the workability of geopolymer concrete. Workability might be a significant concern for a fresh fly ash-based geopolymer because of its excessive viscosity. To care for this trouble, the feasible advantages of utilizing superplasticizers are investigated [7]. The workability depends on the type of activators and superplasticizers [8]. The workability and setting time was decreased with increasing of slag content and lowering of alkaline liquid [9]. The extra water improves the workability up to 200%, however reducing other properties through 27%. Admixture improves the workability as much as 115%, however reducing the other properties by means of 25% [10]. The significant increase in the strength leads to the reduction within the workability and that had been located in geopolymer concretes, with a huge quantity of GGBFS and less SS to SH ratio within the combinations [11]. Geopolymer Concrete is an alternative material to OPC, but due to its viscosity nature, the problem causes in compaction. To overcome the issue, Self Compacting Geopolymer Concrete has been introduced.

The Self Compacting Concrete is a special concrete, which does not require compaction. It will flow and compacted by its self-weight. It was firstly introduced by Japanese researchers. The requirement of SCC is designed under i) Filling ability, ii) Passing ability and, iii) Segregation resistance. The size of coarse aggregate shall not exceed 20mm. Experimental tests like (Slump-Flow by Abrams cone, T50cm Slump Flow, J-ring, V-funnel, U-box, L-box) and their limits are followed as per EFNARC guidelines in Table 1 [12].

| Tests                      | Units | Minimum Value | Maximum Value |
|----------------------------|-------|---------------|---------------|
| SLUMP FLOW                 | MM    | 650           | 800           |
| T50CM SLUMP FLOW           | SEC   | 2             | 5             |
| J-RING                     | MM    | 0             | 10            |
| V-FUNNEL                   | SEC   | 8             | 12            |
| L-BOX                      | H2/H1 | 0.8           | 1.0           |
| U-BOX                      | (H2-H1) MM | 0       | 30            |

2. Self Compacting Geopolymer Concrete

The SCGC is a distinctive concrete, which does not require any extra compaction, it will flow and compact by way of its self-weight, mainly at congested reinforcement. The SCGC is manufactured through utilizing industrial by means of-products like Fly ash, GGBS, waste glass powder, silica fume and
rice husk ash, materials containing extra alumina and silica can be used. These materials can be activated by adding an alkaline solution (Sodium Hydroxide and sodium silicate). By utilizing of superplasticizers like Viscosity modifying Agent (VMA), concrete can flow.

Metakoline is a supply material with three forms of fines like pumice, recycled glass; semi-crystalline feldspar sludge (nepheline syenite) with 2.5 to 7.5 wt%. Additionally, they've examined the version of the bi-axial flexural strength with the addition of fines. From the results, biaxial flexural strength improves from 5 Mpa to 8 Mpa, with the addition of pumice and recycled glass [13].

The mixture of fly ash, M-sand and average course aggregate (12.5mm) and superplasticizer poly carboxylic ether based (Master Glenium SKY 8233) is used. Within the two combine proportions M20; M30, replacing fly ash with typical Portland cement (0% to 20%) with 5 percent interval. The durability tests like acid attack, sulphate assault, and sorptivity had examined [14].

Fly ash is replaced with 50% GGBS. The work also carried with the version of molarities (8M to 12M). The contribution of GGBS helps the SCGC to obtain tremendous compressive strength at ambient room temperature. It is determined growing dosage of NaOH molarity, reduced in fresh properties, nevertheless, it elevated in compressive strength [15].

The varying of molarity from 8M to 12M was implemented. Only 6 percent of superplasticizer is required to drift the concrete. Changing of GGBS, 30% is Optimum [16]. Fly ash is replaced by 30% GGBS, sodium hydroxide of 12M and superplasticizer like Glenium B233 was used. For Glenium B233 has a limit of 500ml to 1500ml per kg. Flexural test was implemented; the result suggests that 100% M-sand with 0% R-sand offers more flexural strength [17].

The GGBS had given the excessive compressive strength rather than fly ash. The Compressive strength of GGBS and fly ash for 56 days are forty Mpa and 15.89 Mpa [18]. The specimens had cured at 70 C for 48 hours and examined in room temperature for 24 hours. By using 12M concentration, maximum compressive strength was obtained [19].

The superplasticizer dosages from 3% to 7% had taken and cured them at 70 C for 48 hours. The FESEM relieved that the strength was accelerated when the ITZ thickness was lowered by higher dosages of SP [20]. The Superplasticizer dosage varies from 3% to 7% and extra water varies from 10% to 20% by means of the mass of fly ash. Beyond 15% of water by mass of fly ash leads to bleeding and segregation. The compressive strength was tremendously lowered with the amount of water exceed 12% by mass of fly ash [21]. The long curing time raises the polymerization. The specimen cured at 70C, produced the high compressive strength [22].
Table 2. Summary of role of Binding materials in SCGC

| Authors         | P-binder         | S-binder | FA                      | Remarks                                                                 |
|-----------------|------------------|----------|-------------------------|-------------------------------------------------------------------------|
| Elie et al. [13]| Metakaolin       | -        | Pumice; Alumiosilicate   | Alumiosilicate based FA, densify the microstructure; reduced pore thresholds |
|                 |                  |          | waste glass             |                                                                         |
| Jeyaseela et al. [14]| Fly ash | OPC      | M-sand                   | Replacing Fly ash by OPC up to 20%; R-sand is completely replaced by M-sand |
| Sashidhar et al. [15]| Fly ash | GGBS     | M-sand                   | Replacing Fly ash by GGBS 50%; R-sand is completely replaced by M-sand   |
| Usha et al. [16]| Fly ash          | GGBS;SF  | R-sand                   | Fly ash is replaced by GGBS (0-30%); SF (0-15%)                          |
| Usha et al. [17]| Fly ash          | GGBS     | R; M-sand                | Replacement of Fly ash by GGBS of 30%; various replacements of R-sand by M-sand |
| Srishaila et al. [18]| Fly ash | GGBS     | R-sand                   | The strength properties had increased with high NaOH cons. of GGBS based SCGC |
| Fareed et al. [21]| Fly ash          | -        | R-sand                   | Water beyond 15% results in bleeding; strength decreased with extra water exceed 12% |

Table 3. Summary of role of chemical activators in SCGC

| Authors            | Molarity | SS/SH | AAS/Solid | SP. dosage |
|--------------------|----------|-------|-----------|------------|
| Sasidhar et al. [15]| 8M- 12M  | -     | 0.4       | 3%         |
| Usha et al. [16, 17]| 8M - 12M | 2.5   | 0.33      | 0-6%       |
| Samuel et al. [20]  | 12M      | 2.5   | -         | 3-7%       |
| Fareed et al. [21]  | 12M      | 2.5   | 0.5       | 3-7%       |
| Ahmed et al. [22]   | 12M      | 2.5   | 0.5       | 7%         |

3. Constituents of Geopolymer Concrete

3.1. Source of Materials

Fly Ash (FA): Fly ash is a by-product of the combustion of coal that wants to be disposed of in an environmentally friendly manner [23]. Thermal curing has a colossal outcome on transport properties of low calcium Fly ash based GPC, also Proper thermal curing reduces the porosity and sorptivity coefficient; increases the compressive strength and electrical resistivity of Fly ash based geopolymer
concrete [24]. The compressive strength was decreased by increasing fly ash content in OPC based SCC [25]. The Stress strain relation of geopolymer concrete is equal to Portland cement concrete and the tensile strength of geopolymer concrete is more than that of normal concrete [26]. The high risk of corrosion in high-calcium class F fly ash geopolymer concretes [27].

Ground Granulated Blast Furnace Slag (GGBFS) and Silica Fume (SF): GGBFS were used as a partial replacement material in GC [28]. Fly ash geopolymer combos had been designed including GGBFS as a lot as 30% of the entire binder. These specimens had been cured at ambient temperature (200°C to 230°C) instead of heat curing. GGBFS had extra fascinating early strength development in ambient situation. The workability and setting time had reduced with the increase of GGBFS and decrease of alkaline liquid solutions [9]. The presence of silica fume in geopolymer concrete, mechanical properties had been increased [29]. By partial replacement of Fly ash with GGBS, heat curing can be avoided. Increasing the GGBFS content, both flexural and tensile strength can be improved.

Palm Oil Fuel Ash (POFA): Palm waste as ash, which is known as Palm Oil fuel Ash [30]. A few released reports have famous POFA’s immense talents as a partial substitute for cement in concrete. Some of the primary findings are that concrete that involves 20% nice POFA by weight of cement confirmed higher sturdiness homes than OPC concrete. Furthermore, a hundred% cement-free geopolymer concrete may also be produced utilizing blended ash, such as POFA and fly ash [31]. POFA and FA are used to thoroughly change cement to provide geopolymer concrete [32]. High volume POFA (90%) was once used within the development of geopolymer concrete [33].

Glass powder: Increasing waste glass powder results in increase in results [34]. Using WGS improves the sturdiness of the concrete uncovered to the blended motion of freeze -and-thaw and deicing salt [35]. Dissolution of glass powder will make an extra dense structure of UHPC. Glass powder will further raise compressive strength greater than 30 Mpa. Glass powder is an amazing contender for silica fume. The pozzolanic response effectively simply is not a essential important property of glass powder [36].

Rice Husk Ash (RHA): Rice husk ash [37] is an agricultural waste that traditionally consists of amorphous silica depending on the combustion stipulations. It was determined that incorporating RHA increased the tensile and flexural modulus, however, reduces the tensile strength, elongation at smash, tear strength and toughness [38]. Calcite producing micro organism accelerated the capacity of RHA concrete. Water absorption, porosity and chloride permeability diminished with RHA and bacterial. Abrasion loss was minimum in RHA-bacterial concrete. SEM and XRD analysis indicated the formation of calcite in bacterial concrete [39]. Progress within the sturdiness of mortar is validated by way of addition of RHA. The permeability is decreased with develop inside the contents of RHA [40].

3.2. Alkaline Activator Solutions (AAS)

The pleasant mixture of Sodium Hydroxide and Sodium silicate is almost always used for the reason that they are more cost-effective than potassium solutions. The sodium hydroxide (NaOH) solution has been ready by means of dissolving either the flakes or the pellets in water [41], [42], [43] described a correct process would have been to take some range of water, say, about 500ml of water and mix slowly in very small steps 480 grams of Sodium Hydroxide solids. After complete dissolution of solids, the quantity of SHS is checked to peer whether or not it is one liter. If it is less than one liter, additional water is introduced to makeup to one liter exactly. If the SHS prepared was once greater than one liter then again, 480 grams of Sodium Hydroxide answer is delivered to a number of water lower than that used in the
previous preparation and the system stated above is continued. Accordingly, to get SHS of Molarity, M, it’s incorrect so as to add (M*40) grams of Sodium Hydroxide solids (SHF) either to one kg of water or to (1000 - M* 40) grams of water, due to the fact that in both instances, the final solution got just isn’t precisely one liter. After making SHS, mix both SHS and Sodium Silicate solution, at least 24 hours before adding the liquids to the dry materials [41], [42], [43].

4. Summary of Results and Discussions

4.1. Workable Properties of SCGC

The workability is one of the fundamental investigations for SCC. The workability tests are required to determine the filling, passing and segregation resistance of SCC. The tests like Slump Flow test, T50cm test, J-Ring, V-Funnel are carried as per EFNARC guidelines, 2002 [12]. The summary of earlier research work as shown in Table IV.

Table 4. Summary of workability properties of SCGC

| AUTHORS               | MIX   | SLUMP FLOW | T50CM SF | V-FUNNEL | V-T5MIN L-BOX (H2/H1) U-BOX | J-RING | COMP. STRENGTH |
|-----------------------|-------|------------|----------|----------|-----------------------------|--------|----------------|
|                       |       | MM         | SEC      | SEC      | RATIO | MM | MM | MPA |
| Sasidhar et al. [15]  | M3    | 670        | 4        | 11       | 0.9 | -  | -  | 51.177          |
| Usha et al. [16]      | M5    | 680        | 4.5      | 10.5     | 0.95 | 28 | -  | 38              |
| Srishaila et al. [18] | M3(12M) | 670      | 5        | 11       | 0.88 | -  | 9  | 36.5            |
| Fareed et al. [19]    | M3(12M) | 690     | 4.5      | 10       | 0.94 | -  | 7  | 51.52           |
| Samuel et al. [20]    | M1    | 710        | 4.0      | 7.0      | 0.96 | -  | 5  | 53.08           |
| Memon et al. [22]     | M1    | 710        | 4        | 7        | 0.96 | -  | 5  | 51.68           |
| Min. value            |       | 650        | 2        | 6        | 0.8  | 0  | 0  |                |
| Max. value            |       | 800        | 5        | 12       | 1.0  | 30 | 10 |                |

4.2. Microstructure characteristics of SCGC

In the following consequences of SP on Interfacial transition zone had been investigated. The different SP dosages are 3% to 7% are considered. From the result founded that SP dosage on microstructure properties played a main function in making geopolymer concrete self-compactable. The ITZ thickness was observed for 3% to 6% dosage of SP dosage. For the higher dosage of 7% SP dosage, there is ITZ thickness is not found. It is also noted that when the dosage of SP percentage increases, ITZ thickness decreases, but compressive strength of the concrete had increased. The FESEM micrographs of SCGC samples of 3%, 6% and 7% are shown in Figure 1, Figure 2 and Figure 3 [20].
5. Conclusion

From the earlier researcher’s investigations on Self Compacting Geopolymer Concrete, it is founded that, increasing the dosage of NaOH molarity leads to decrease in fresh properties, however it
increased the compressive strength. The contribution of GGBS helps the SCGC to attain high compressive strength at ambient room temperature [15]. GGBS at ambient curing condition had more compressive strength rather than Fly ash based SCGC. It is recommended that sodium hydroxide and sodium silicate should be done at least 24 hours before to use [18]. The usage of extra water more than 15% in SCGC, results in bleeding and segregation. The compressive strength was reduced with the quantity of extra water increase more than 12% by the mass of binder [44]. The specimens were cured at 70°C had produced higher compressive strength. Whereas the long term curing increases the geopolymerization [22]. The FESEM described that the concrete performance was improved, when ITZ thickness was decreased and the compressive strength was increased at higher SP dosage of 7% [20].

6. References

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