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Experimental study on Self Compacting Geopolymer Concrete

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Abstract – *Self Compacting Geopolymer Concrete (SCGC) is an innovative construction material in concrete technology. As the name replies, it does not need any compaction efforts, to achieve full compaction and utilizes supplementary cementitious materials (SCM) in addition with alkaline solutions like Sodium hydroxide and sodium silicate and super plasticizer as a binder for matrix formation and strength. In the present study, flyash based SCGC replaced with various percentages of GGBS. The concrete specimens were cured both oven curing and ambient curing. The results showed that the addition of GGBS to flyash based SCGC, the workability characteristics are decreased and strength was increased with increase in binder content. Hence the results showed that the SCGC was suitable for both oven & ambient temperature curing with GGBS as replacement to flyash based GPC.*

Key Words: Geopolymer concrete, self compacting concrete, SCM, alkaline activator, Ambient curing.

1. INTRODUCTION

Concrete is an vital ingredient in infrastructure development and with its versatile application, globally its usage is second to water. For several years, the use of cement as a binder in a concrete mixture has been often criticized by many parties concerned with environmental conservation. This is associated with global warming and depletion of significant amounts of natural resources in Portland cement production that became the main attention during the last decades. Global warming can be caused by greenhouse gas emission such as carbon dioxide, which occurs due to human activities in PC manufacture. So, to overcome this problem, the concrete use should be ecofriendly (or) environmental friendly. Geopolymer Concrete (GPC) is a new binder material that does not need the presence of Portland cement as a binder. Hence, instead of portland cement, we are using source of some source of Supplementary Cementitious Materials such as [Fly Ash, Ground Granulated Blast Furnace Slag (GGBFS), Rice Husk Ash (RHA), Silica Fume (SF), Metakaolin, etc., and these materials are rich in Silicon (Si) and aluminum (Al) are activated by Sodium Hydroxide (NaOH) and Sodium Silicate (Na_2SiO_3) alkaline liquids to produce the Geopolymer binder. Self Compacting Geopolymer Concrete (SCGC) is relatively a new concept and can be regarded as the most revolutionary development in the field of concrete technology. SCGC is an innovative type of concrete that does not require vibration for placing it and can be produced by complete elimination of Ordinary portland Cement (OPC).

B Vijaya Rangan [1] This study presents that the tests conducted to establish the effect of water-to- geopolymer solids ratio by mass on the compressive strength and the workability of GPC and concluded that compressive strength of GPC decreases and also that the water-geopolymer solids by mass increases and obviously as the water- geopolymer ratio increased, the workability increased as the mixture contained more water. Test results showed that the heat-cured low calcium fly-ash based GPC have an excellent resistance to compressive strength.

D B Raijiwala, H S Patil, I U Kundan [2] the influence of alkaline activators on the strength and durability properties has been studied. By increasing the alkaline activator content the compressive strength and split tensile strength was increased. It has been observed that at 12 molarity of KOH, the gain in strength remains very moderate and the reason is at an ambient temperature of 60°C for 24 hours the polycondensation process has already completed and particle interface is also achieved.

Pradip Nath , Prabir Kumar Sarker [3] This study aimed to achieve fly ash-based geopolymers with GGBFS suitable for curing without elevated heat. Slump of concrete and flow of mortar decreased with the increase of slag. However the workability and setting time increased when alkaline liquid content was increased, with reduced compressive strength. Concrete and mortar samples cured without heat developed strength gradually over the age, while samples cured in 60°C for 1 day achieved high early strength which increased negligibly over the age.

V. Eswaraiah, G. Nagesh Kumar [4] This paper aimed an experimental investigation on the mechanical properties of 16M and 14M concentrations of different binder composition of Ecopolymer concrete (EPC) and also we make study on analysis and design of Recorn-3s polypropylene fibers in 16M, 14M. EPC Possess less Shrinkage property than that ordinary Port land Concrete. Due to Fiber Content in Concrete and it expands chemical molecular Structure.

G. Nagesh Kumar, K. Surendra Babu, Ch. Sudharani [5] Presented the properties of SCC, mixed with quartzite as fine aggregate. This project aims to focus on the possibility of using industrial by-product like flyash, crushed quartzite. The usage of this crushed quartzite is proposed as partial replacement of fine aggregate and flyash to cement in the production of SCC. The strength properties are increased.

J.M. Khatib [6] The influence of including fly ash (FA) on the properties of self-compacting concrete (SCC) is investigated. The results indicate that high volume FA can be used in SCC to produce high strength and low shrinkage. Increasing the admixture content beyond a certain level leads to a reduction in strength and increase in absorption. The correlation between strength and absorption indicates that there is sharp decrease in strength as absorption increases from 1 to 2%. After 2% absorption, the strength reduces at a much slower rate.

M. Fareed Ahmed, M. Fadhil Nuruddin [7] This paper reports the effect of sodium hydroxide concentration on the fresh properties and compressive strength of self-compacting geopolymer concrete (SCGC). Test results indicate that concentration variation of sodium hydroxide had least effect on the fresh properties of SCGC. With the increase in sodium hydroxide concentration, the workability of fresh concrete was slightly reduced; however, the corresponding compressive strength was increased. Concrete samples with sodium hydroxide of 12 M produced maximum compressive strength.

R. Anuradha, R. Bala Thirumal [8] Study based on workability tests for various molarities, the results are within the limits of EFNARC Guidelines. The workability of 8M concentration is high compared to all the other molarity. It is mainly due to the concentration of NaOH. It was observed that concrete mixes containing higher concentration of NaOH were more Cohesive and results in reduction of workability of SCGC. If the replacement of GGBFS and Silica fume increases more than 30% and 15% respectively, it does not satisfy the workability requirements of SCGC. The Material achieves early strength when heat curing is adopted instead of ambient curing.

2. MATERIALS

2.1 Flyash: Flyash produced from Raichur thermal power plant, Karnataka was used. Flyash with specific gravity of 2.20 and surface area of 350 m^2/kg was used. The chemical compositions are given in table 1.

2.2 GGBS: Ground granulated blast furnace slag (GGBS) consists essential silicates and alumino silicates of calcium. GGBS obtained from JSW steel Ltd, Bellary. The specific gravity of 2.90 and surface area of 400 m^2/kg was used. The chemical compositions are given in table 1.

2.3 AGGREGATES: Well graded locally available fine aggregates passing of 4.75 mm and coarse aggregate of passing 12.5 mm are used in the present work.

2.4 ALKALINE ACTIVATOR SOLUTION: The alkaline activator solution (AAS) plays an important role in Geopolymer concrete. The AAS is the combination of sodium hydroxide and sodium silicate solutions. The concentration of NaOH solution can vary in the range between 8M to 16M; In this study, 12M is considered. The NaOH for 12M is 12x40 (Molecular weight) = 480gms should dissolve in 1 litre of water. After mixing the NaOH flakes in water its molecular weight reduces to 361gms for 12 Molarity. For 12M NaOH solution, for 1 litre of water we require 36.1% of NaOH flakes and 63.9% of water. The solution must be prepared at least 24 hours before to use.

Table -1: Chemical Compositions

Oxide	Flyash (%)	GGBS (%)
CaO	3.20	37.34
Al_2O_3	30.60	14.42
Fe_2O_3	1.50	1.11
SiO_3	61.12	37.73
MgO	0.75	8.71
Na_2O	1.35	----
LOI	0.79	1.41
MnO	----	0.02

2.5 SUPERPLASTICIZER: Super plasticizer (SP) is an essential ingredient of SCC to provide adequate workability. In the present study, the SP used is Conplast SP 430 supplied by Fosroc constructive solutions, INDIA. Conplast SP430 is used where a high degree of workability .It facilitates production of high quality concrete. It is appeared in brown colored liquid instantly dispersible in water. The optimum dosage is determined by trails with the concrete mix which enables the effects of workability and strength measured.

2.6 VMA: In the present study Master Matrix 2, which is bought from BASF, Hyderabad was used. The advantage of using VMA in SCC is it reduces the sensitivity of self compacting concrete with variation in water content. It is used to avoid bleeding and segregation.

3. EXPERIMENTAL DETAILS

3.1 A.OBJECTIVE: Develop the flyash based self compacting geopolymer concrete and replaced flyash in various percentages of GGBS which achieved both workability and mechanical properties. Finally studying the effect of curing time and curing temperature on the properties of SCGC.

3.2 **MIX PROPORTIONS:** Here, the mix design of SCGC is purely different to that of OPC concrete. The production of SCGC was carried out by using the trial and error method. In GPC, generally the mass of combined aggregates may be taken to be between 70% to 80%. With regard to alkaline liquid to fly ash ratio by mass of flyash, values in range of 0.35 to 0.5 are recommended. In the beginning, a total number of 17 trial mixes of SCGC were produced to assess the workability characteristics and study the influence of various parameters on the compressive strength. Finally the ratio of alkaline liquid to flyash was kept 0.5 as constant and the ration of the sodium silicate solution to sodium hydroxide solution was kept 1 as constant for all mix proportions. The addition of extra water improved the workability characteristics of SCGC mixtures, however the addition of water beyond the limit results bleeding and segregation of fresh concrete & decreased the compressive strength of SCGC. Here, 12% of extra water, SP%, VMA% by mass of flyash was taken. The mix proportions of SCGC were given in table 2.

3.3 MIXING, CASTING, CURING: The components of SCGC i.e., fine aggregate, coarse aggregate, flyash, GGBS, were dry mixed in the pan mixer about 2 min. Then the dry mix followed by the wet mix where by the liquid part of the mixture i.e., sodium hydroxide solution, sodium silicate solution, AAS solution, SP, extra water mixed with VMA for another 2 min. After mixing, the fresh concrete was then filled into steel moulds and allowed to fill all the spaces of the moulds by its own self weight without any compacting efforts.

After casting the specimens were put for curing. Here the curing methodology is purely different that to curing of OPC concrete. After casting the specimens with mould kept for drying in both oven curing at 70℃ and ambient curing temperature.

Table 2: Mix proportions

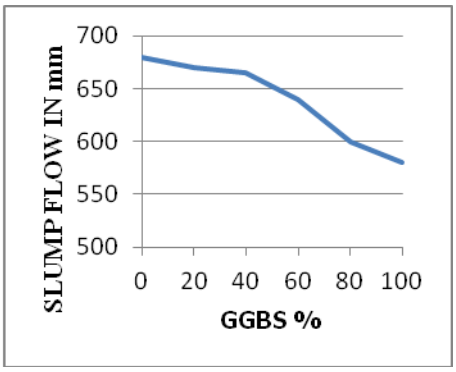
Parameters	Proportions
Coarse aggregate (kg/m³)	935
Fine Aggregate (kg/ m³)	829
Binder (kg/ m³)	424
NaOH Solution (kg/ m³)	106
Na_2SiO_3 Solution (kg/ m³)	106
AAS/Binder	0.5
NaOH / Na_2SiO_3	1:1
SP (%)	1
VMA (%)	0.05
Extra water (%)	12

4. RESULTS

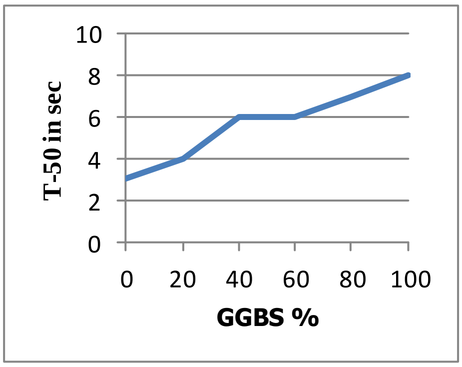
4.1 FRESH PROPERTIES: The essential fresh properties required by SCGC are flowability or filling ability, passing ability and resistance to segregation. The tests performed on SCGC are Slump flow, T-50cms flow, V-Funnel, L-Box satisfying the EFNARC guidelines. The values are tabulated in table 3 and shown in figures 1(a), 1(b), 1(c), 1(d).

Table 3: Fresh properties of SCGC

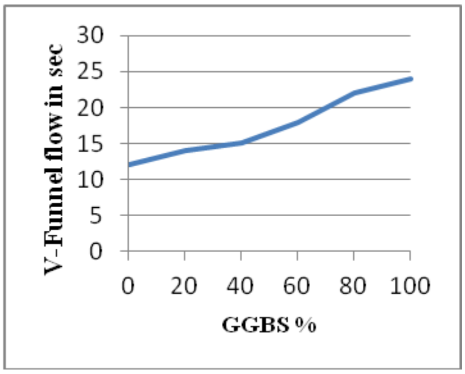
MIXES	Slump flow in mm	T-50cms in sec	V-Funnel in sec	L-Box
M1	680	3	12	0.92
M2	670	4	14	0.89
M3	665	6	15	0.86
M4	640	6	18	0.85
M5	600	7	22	0.77
M6	580	8	24	0.74



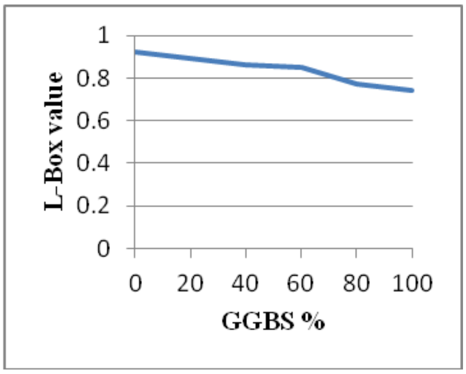
(a). Slump Flow



(b). T-50cms



(c). V-Funnel



(d). L-Box

1. Fresh properties of SCGC

4.2 HARDENED PROPERTIES: The hardened properties are assessed by compressive strength, split tensile strength, flexural strength. The values are tabulated in table 4 and shown in figures 2(a), 2(b), 2(c).

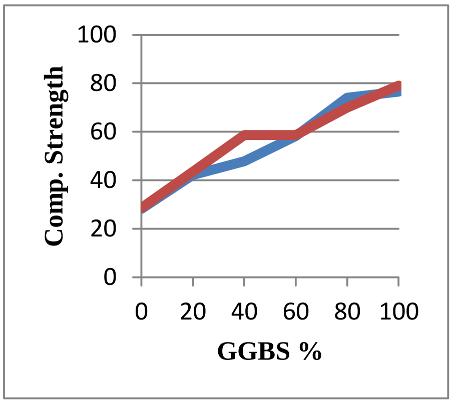
Table 4: Hardened properties of SCGC

(a). Oven Curing at 70°C

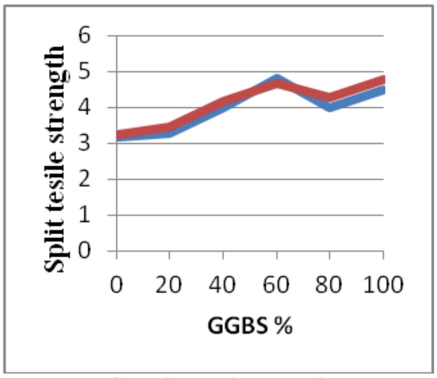
% of GGBS replaced with flyash	Comp. strength Mpa	Split tensile strength Mpa	Flexural strength Mpa
0	28.22	3.15	2.60
20	42.22	3.29	2.75
40	47.88	4.00	2.68
60	58.22	4.81	2.77
80	74.00	4.00	2.70
100	76.50	4.50	2.80

(b). Ambient temp. Curing

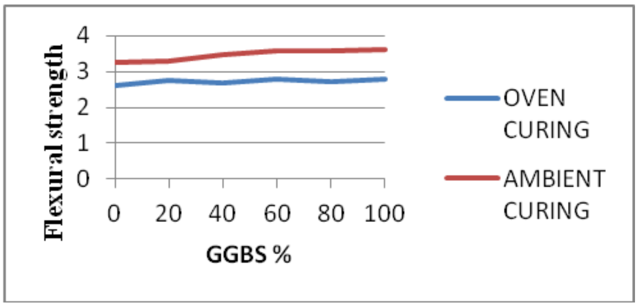
% of GGBS replaced with flyash	Comp. strength Mpa	Split tensile strength Mpa	Flexural strength Mpa
0	28.55	3.26	3.26
20	43.50	3.28	3.28
40	58.66	3.46	3.46
60	58.66	3.56	3.56
80	76.00	3.58	3.58
100	79.00	4.77	3.62



(a). Compressive Strength



(b). Split tensile Strength



(c). Flexural Strength

Figure 2: Hardened properties of SCGC

5. CONCLUSION

In this experimental study, the workability characteristics and strength properties of Low-calcium flyash based SCGC assessed with different replacements. From experimental results, the following conclusions are drawn:

- GPC offers environmental protection by means of recycling flyash, GGBS, wastes or by products from industries, into a high volume of construction material for infrastructure development.
- The increase of GGBS in the flyash based GPC reduces the workability characteristics.
- By adding GGBS to flyash based SCGC, the strength properties are increased. Ambient temperature curing for 28 days specimens has high strength compare to oven cured specimens at 70℃ for 7 days.
- Economic benefits are achieved by reducing cost curing and labour for compaction.
- The SCGC is suitably designed for both oven curing at 70℃ and ambient temperature curing.

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