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Sustainable Self-Compacting Geopolymer Concrete under Ambient Curing – Durability Properties

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Sustainable Self-Compacting Geopolymer Concrete under Ambient Curing – Durability Properties

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Abstract. In this study, industrial by-products like fly ash, Ground Granulated Blast Furnace Slag (GGBFS) and silica fume were used to develop the sustainable Self-Compacting Geopolymer Concrete (SCGC) under ambient curing. The combination of source materials is kept constant such as 50% fly ash, 30% Ground Granulated Blast Furnace Slag (GGBFS) and 20% silica fume, respectively. In the series of experiments, sodium silicate (Na2SiO3) solution of 1.75M is kept constant. The Solution/Binder (SB) ratio has been varied such as 0.65, 0.68 and 0.70. Rapid Chloride Permeability Test (RCPT), water absorption and Ultrasonic Pulse Velocity (UPV) of SCGC are measured at 28 days. The test results indicated that, the durability properties were inimically affected with increase in SB ratio and better properties observed with low content SB ratio. This because of increase in Silica (Si) content in the concrete undergoes slow polymerization process at ambient curing. The optimum mix with 0.65 SB ratio is identified with better results and considered for further studies.

Keywords: Self-Compacting Geopolymer Concrete, Ambient curing, Durability properties

1. Introduction

The Geopolymer blend attains a notable reduction in CO2 emission and intensive energy process as compared to the Ordinary Portland Cement [1]. An increase in attention towards Geopolymer source materials owing to their fresh and hardened properties, at minimal cost of production generates chemical and high temperature resistance [1-3]. Many earlier researcher's studies utilized the fly ash as a source material which is generated from the thermal power plants. The presence of Silica (Si) and Alumina (Al) in the fly ash reacts with alkali solution such as sodium silicate (Na2SiO3) solution and sodium hydroxide (NaOH) solution [4]. Most of the studies considered NaOH molarity is in the range of 8M to 14M [3,4]. The binders react with alkali solution and forms three-dimensional cross-linked aluminosilicate structure. The source materials like industrial by-products are required to produce as Geopolymer binders, reduces greenhouse gases emission significantly [5]. The industrial by-products utilization is economical, which are all available at low cost.

Nath and Sarker [6] examined a significant improvement in 3-days strength with GGBFS as partial replacement to fly ash. Adak et al. [7] stated that the development in hardened properties observed with 10% silica was added to Geopolymer concrete. Kusbiantoro et al. [8] attained maximum compressive strength of 74 .8 MPa with combination of fly ash/Rice husk ash based Geopolymer concrete. The earlier studies improved the strength and durability properties with addition of calcium content materials. The addition of silica content materials improved the hardened properties and matrix of the concrete were reported by many studies [9-12]. It was reported that the presence of silica content increase result in increase in compressive strength and denser matrix of geopolymer. Nevertheless, the action of silica content in matrix is based on way of manufacturing, uniformity of the mix and morphology [13, 14].

A number of literatures is available on Self-Compacting Geopolymer Concrete (SCGC) which is focused on workability and strength properties [15-20] and lots of research attention required to understand the durability properties of SCGC under ambient curing. This study paper, the strength and durability properties of SCGC is investigated under ambient curing. Durability properties such as Rapid Chloride Permeability Test (RCPT), water absorption and Ultrasonic Pulse Velocity studied by varying Solution/Binder (SB) ratio under ambient curing.

2. Materials and Experimental details

2.1. Materials
The fly ash is obtained from thermal power plant in Chennai. GGBFS and Silica fume obtained from Astra Chem. Pvt. Ltd. Chennai. Sodium silicate solution of modular ratio 2 (with 1.75M, Na_2O = 10.8%, SiO_2 = 21% and H_2O = 68.1%) is supplied by Kiran Global Chem. Pvt. Ltd. Chennai and Superplasticizer is added to improve the viscosity of the concrete.

2.2. Mix Proportions
The fly ash/GGBFS content of 80% and silica fume content of 20% is kept constant. SCGC mixes has varied the Solution/Binder (SB ratio) such as 0.65, 0.68 and 0.70. the superplasticizer of 1% is added to the mix to achieve the targeted flow properties.

2.3. Preparation of samples
The raw source materials are mixed using pan mixture for uniformity. Coarse and fine aggregate is added and mixed for 2 minutes. Later, solution is added and allowed to mix for another 5 minutes. The fresh concrete is tested for workability and casted in steel mould as per tests required. After demoulding, the specimens are placed under ambient curing.

3. Results and Discussion

3.1. Water absorption test
The amount of water absorption in the specimens has been determined and represented in the Fig. 1. The disc size of 100 mm*50 mm has been cut and were placed in oven at 110oC for 24 hours. The oven dry weight of the specimen is recorded (w1). Later, the specimens were placed in water tank for 24 hours and then weight of the saturated dry specimens were recorded (w2). The amount of water absorption by a specimen is determined by the following equation: Absorption of water content can be calculated from [(w2 - w1)/ w1] * 100 (Where, w2 = Saturated surface dry weight (g) of specimens in the room temperature and w1 = specimen weight by oven dry). It has been recorded that the water absorption values of the SCGC mixes are 5.1%, 5.31% and 5.7% respectively. The test results had been slightly influenced by Na_2SiO_3 solution being used. The low rate of water absorption is observed with lower SB ratio of Na_2SiO_3 solution and also, with GGBFS/silica fume has achieved through capillary suction. The water absorption rate is found to be improved with minimizing in the SB ratio. Neville had reported that the good quality concrete absorbs low water percentages (less than 10%) [21].

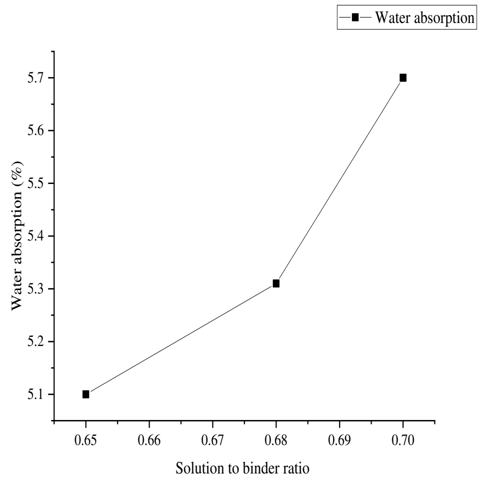

Figure 1: Water absorption

3.2. Rapid Chloride Permeability Test (RCPT)

The 28-days test results of the mix proportions were represented in Fig. 2 The amount current charge supplies in specimens are noted in terms of Coulombs as 1561, 2300 and 2891 respectively. From test results that indicates the charge passed for mix with SB ratio 0.70 is high when compared to the mix with SB ratio of 0.65. As per the code ASTM C 1202, the chloride penetration occurs in to the specimens, the penetrability of the concrete is estimated. The chloride permeability of the mix consisting of SB ratio of 0.70 and 0.68 had passed 2891 and 2300 coulombs which was moderate and the mix consisting of SB ratio of 0.65 had passed 1561 coulombs which is low. The influencing factor of the concrete permeability is the pore structure. The pore structure had been increased with increase in solution to binder ratio from 0.65 to 0.70 respectively. This was mainly due to an increase in the presence of water is increased with increase in solution content thus leading to an increase the porous structure.

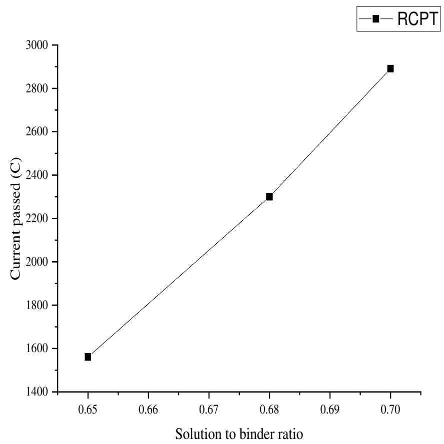

Figure 2: Chloride penetration resistance

3.3. Ultrasonic Pulse Velocity (UPV)

The UPV is carried out as per Indian code of IS: 13311 (1992) to estimate the behavior of consistency of concrete, voids and micro cracks which supports to understand concrete quality and strength. The 28-day UPV test results of the SCGC are as shown in Fig. 3. The poor quality of concrete occurs due to porous characteristics of the concrete and also the lack of aggregates effects creates voids and leads to lower pulse velocity rate. The mix SB ratio of 0.65 has achieved higher pulse velocity of 3.6 km/s as compared to the mixes SCGC0.68 and SCGC0.70 which have achieved 3.5 and 3.29 km/s, respectively. However, the UPV test results indicate that the mixes with SB ratio 0.65 and 0.68 can be graded as Good quality of concrete and mix with 0.70 was graded as Moderate concrete.

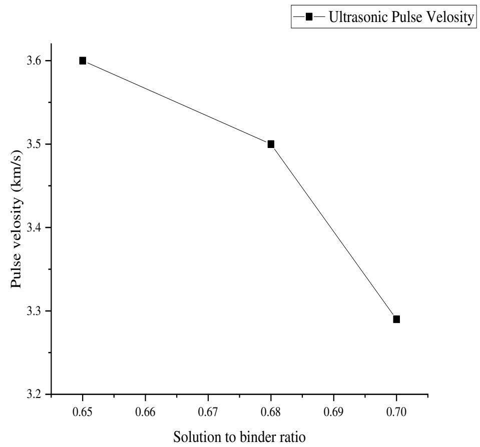

Figure 3: Pulse velosity

3.4. Drying Shrinkage

The drying shrinkage test had been carried out for SCGC mixes from the specimen age of 12 hours to 28 days respectively. The graph has been plotted for drying shrinkage strain verses time period as shown in Fig. 4.

It can be observed that the mixes SCGC0.65 and SCGC0.68 undergoes low drying shrinkage as compared to the mix SCGC0.7. The value of drying shrinkage strain of the mixes SCGC0.65, SCGC0.68 and SCGC0.70 after 28 days was around 1620, 2010 and 2280 microstrains respectively. In SCGC mixes, most of the water content released during the polymerization process may evaporate during the curing period. The lower drying shrinkage was observed with mix contain SB ration of 0.65, because the amount of water may contain in the micropores are small as compared to the mixes with SB ratio's 0.68 and 0.70 respectively.

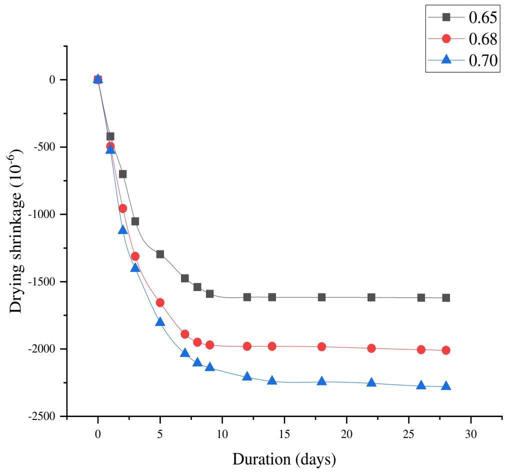

Figure 4: Drying Shrinkage

4. Conclusions

The list of following conclusions are drawn from this study:

- The lower water absorption value (5.1%) were obtained for mixture SB ratio of 0.65 as compared to the mixes with SB ratio of 0.68 and 0.70, respectively.
- The influencing factor of the concrete permeability is the pore structure. The pore structure had been increased with increase in SB ratio from 0.65 to 0.70.
- the mixes with SB ratio 0.65 and 0.68 can be graded as Good quality of concrete and mix with 0.70 was graded as Moderate concrete.

The above conclusions which provides the durability behavior of SCGC under ambient cured specimens and are considered for further studies.

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