Study on Mechanical Characterization of Geopolymer Cement Mortar with Single Solution and Combined Solution

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Abstract- Geopolymer mortar is a highly effective, innovative and environmentally friendly material that could replace conventional cement mortar. This paper aims to highlight the performance of a single solution in the mix. The strength of geopolymer mortar depends on the molarity, amount of sodium hydroxide, curing period etc. When the Molarity increases, the amount of sodium hydroxide increases and resulted increase in strength of mortar. In this context, few mortar cubes are cast with 1:3 proportion using single activator and combined solution (Mix of sodium hydroxide and sodium silicate solution of ratio 2.5 with 8 Molarity) and tested compressive strength after 1, 3, 7 and 28 days under ambient curing. Besides, UPV test is done for the specimens and compared. In this paper, fly ash and GGBS are utilized in various proportions and used as main source material as cement to develop a mortar with single and combined solution. The test results displayed that a single solution cube specimens produced better early strength properties compared to other specimens. It could be conclude that single activator has more benefits over alkaline activator in terms of early strength, cost effective, less skilled worker, etc.

Keywords – ***Geopolymer, Single Solution, Alkaline Activator, UPV, Compressive Strength***

I. INTRODUCTION

The Conventional mortar is prepared with cement, fine aggregate and water. Cement is used as second most utilized material on the planet after the water. Nevertheless, this fast creation of cement produce two major natural issues for which we need to discover structural building arrangements. The first ecological issue is the outflow of carbon dioxide emissions during the manufacturing process. Since the cement is most important material in construction which results in around 8% of carbon dioxide emissions [1] into atmosphere that leads to global warming and consume large number of natural resources. Along these lines, there is a need to conserve the utilization of concrete. One of the reasonable solutions for economize cement is to supplant with beneficial cementations materials like fly ash, slag, sludge, metakaolin etc. It is very evident to identify new type of cement to save earth and natural resources with landfill materials used in profitable manner. [2] Conducted experiments on the utilization of marble powder as

partial replacement of cement to minimize the cement production. The waste replaced with cement up to 30%, conducted tests to determine strength properties, and compared to conventional concrete and found better strength. [3] also conducted tests on utilization of ceramic powder up to 30% partial replacement of cement to minimize the cement production and resulted better properties compared to normal concrete However, there are wide researches available on geopolymer cement in which fly ash and GGBS are used as source materials and stated the optimum percentage of GGBS content in fly ash to develop geopolymer concrete is 30% with alkaline activator (SS/SH) ratio 2.5. Fly ash is one of the source materials formed with the burning of coal thermal plants. This ultrafine material will better fill voids between concrete particles and result in a thick concrete with higher compressive strength and amazingly low permeability. The use of different supplementary cementitious materials as partial/ fully replacement with cement in developing a concrete in current scenario is much appreciated and acceptable. [4] Fly ash concrete/ mortar undergo hydration process with available calcium hydroxide to form CSH gel when placed in ambient curing. GGBS is the industry by product obtained from steel industry acquired through fast cooling by water or extinguishing liquid slag. [5] Suggested the concrete that does not use cement as a binding material, and the materials used instead are fly ash, silica smoke, or GGBS, along with the alkali solution. [6] Suggested the utilization of geopolymer concrete assists with taking care of a high number of the issues that were making damage to the earth and human, including lessen the amount of waste obtained from industries. It likewise assumes a significant job in diminishing the carbon dioxide outflows from the concrete business. [7] Suggested binding materials produce polymerization with basic solutions for fly ash and rice husk ash. Geopolymer has a ton of advantages like accessibility of plentiful fly ash, little CO2 discharge, less vitality utilization, low creation cost, high early quality, quick setting. These properties make geopolymer discover extraordinary applications in numerous fields of the development business. However, there is lack of work identified in the same context when the alkaline activator ratio exceeds 2.5 with different molarities. One of the main disadvantage with geopolymer concrete is preparation of alkaline activator. During the mix of alkaline activators, sodium hydroxide plays a major role, which depends on molarity. The higher molarity leads to high quantity of NaOH solution with less amount of sodium silicate that creates more heat while preparing the solution. Skilled persons are required during the preparation of the solution. The ratio of alkaline activator completely depends on NaOH solution and sodium silicate and said to 2.5 form by the various researchers. It is very much important to understand the impact of molarity (1Molarity – 20 Molarity) during the preparation of NaOH solution where Na OH is used to dissolution of source materials and Na Sio2 used for developing bond strength between aggregates. To overcome this problem, different activators are required to replace alkaline activator. Due to the lack of studies on the current issue, the literature review is scarce and hence, stepped forward to attempt a study on the use of single activator to determine the compressive strength of mortar and compared with geopolymer mortar made up of combined solution.

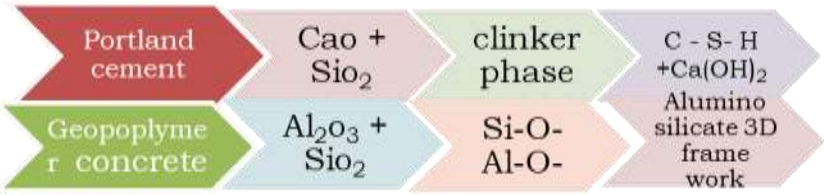

Figure 1. Schematic diagram of Reaction Mechanism in OPC and Geopolymer Concrete

The development of calcium-aluminate-hydrate observed in early stage with addition of huge amount of fly ash in the mix as shown in schematic diagram in Figure 1. This is due to calcium oxide present in flyash [8]. The molar proportion of SS/SH ratio influencing the properties of geopolymers. After a few examinations, [9] recommended the ratio of 2.5 is optimum. [10] Conveyed the trial examination on geopolymer mortars with class c fly ash. [11] Investigated the performance of fly ash based geopolymer, for example, fly ash to activator ratio, etc. It has been discovered that the ideal substance properties s is fly ash: activator as 60:40 with 12M. [12] Contemplated the properties of activator with fly ash and GGBS mortar with two super plasticizers. The Polycarboxylates-based and naphthalene-based super plasticizers were added to the blends at various measurements of 0%, 1%, 2%, 3%, and 4% by the mass of binder under outdoor curing. The results showed increase in the strength of mortar with increase of slag content. The increase in strength noticed as expanding with increment in age. [13] Considered fly ash and GGBS as source material of geopolymer mortar comprising of SS/SH of various molarities with ratio of 2.5. From the outcomes, it has been shown that the mix of fly ash and GGBS brings diminished final setting time and improved compressive strength. [14] Reported that fly ash based GPC under pre curing at room temperature for development in quality. Moreover, it has shown that the geopolymers authorized with NaOH had more strength than

those started by sodium silicate solution. The compressive strength of the geopolymer concrete has extended with a development in GGBS substance and solution as inspected by [15]. He talked about the effect of fly ash to GGBS proportion from 0-100% and the effect of the dissolvable substance by contrasting the sodium silicate to sodium hydroxide extent (1-1.5) keeping the blend of sodium hydroxide as 10M. [16] Considered the use of Palm oil ash by varying the extents with sodium silicate to sodium hydroxide extent from 0.5 to 2.5 and temperatures from 400C to 800C for 24 hours. From the XRD examination, it was seen that sodium alumna silicate hydrate gel responsible for the development of strength of geopolymer mortar. [17] Considered the strength of fly ash based geopolymer mortar by change in the molarities and sodium silicate to sodium hydroxide ratio. [18] Discussed the setting of fly ash based geopolymers for various properties of NaOH and alkaline mix for fly ash at room temperature and proportion of water to binding material. From the results, the expansion in the sodium hydroxide improved the compressive strength of geopolymer mortars. [19], analyzed the properties of low calcium fly ash based geopolymer concrete for different molarities and SS/SH ratio under 60°C for 24 hours curing. From the results, it is observed that strength of mortar increased with increment of sodium hydroxide and curing period. [20] Contemplated the mechanical properties of fly ash based geopolymer concrete of different binder content with fine aggregate in room temperature and ratio of sodium hydroxide/sodium silicate 1:2.5. The hydration framework known as C-S-H gel with proportion of low calcium and silica [21]. In addition to this, [22] detailed in their investigation on the hydration of alkaline mix. They observed silica gel formed in the underlying phases of hydration of slag enacted with water glass arrangement. The main objective of this attempt is to identify the effect of compressive strength of geopolymer mortar for different proportion of GGBS in fly ash and investigate the effect of sodium silicate solution (single activator) for geopolymer mortar.

II. METHODOLOGY

Mixing and Casting-The fly ash and GGBS blended in required quantities until homogeneity achieved and fine aggregate is added to the mix and allowed to blend. Later, the sodium silicate solution is added to the total mix and stir completely for 3-5 minutes and filled in the cube moulds of size 100mm × 100mm ×100mm by three layers with compaction and vibration to avoid air voids. These specimens are demoulded after 24 hours and place in the ambient curing for 7 and 28 days of testing. Few specimens were casted with single activator and alkaline activator for various percentages of (25% 50%, 75% and 100%) GGBS in fly ash with activator to binder ratio of 0.5

Single Solution (Sodium Silicate Solution)-During the mix of alkaline activator, adequate amount of sodium hydroxide and sodium silicate solution are used. It requires skilled workforce and have to wait for 24 hours to use in the mix before casting and this might lead to generate heat during preparation of solution. However, sodium silicate solution also called single activator has better advantages over alkaline activator without compromising the effect of strength properties of mortar and provide low work ability. This activator required no skilled workforce and produce less heat during mix. Moreover, this activator can use directly before casting the cubes. Besides, the cost of sodium hydroxide pellets and sodium silicate is higher compared to single activator.

III. RESULTS AND DISCUSSION

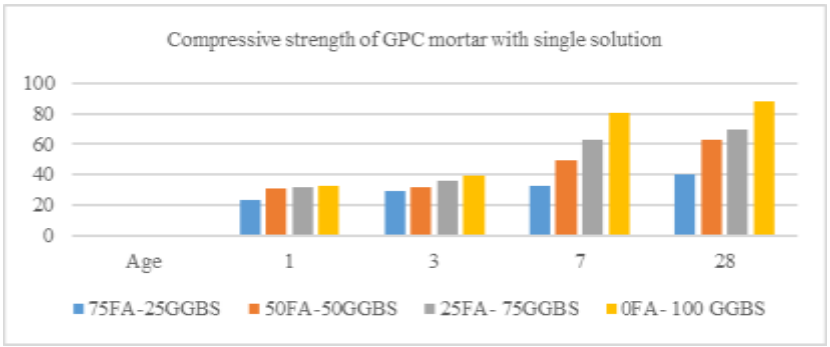

Figure 2: Compressive strength results of fly ash – GGBS based geopolymer mortars using single solution

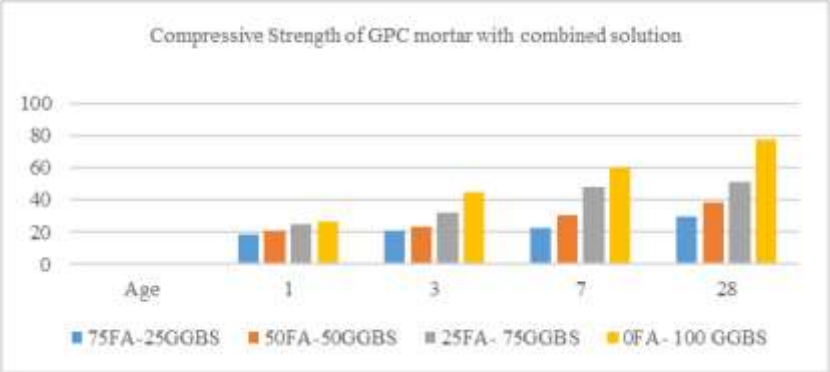

Figure 3: Compressive strength results of fly ash – GGBS based geopolymer mortars using combined solution.

Discussion on compressive strength results- The specimens of different proportion are casted and tested to determine compressive strength. It is observed that geopolymer mortar with single activator provide better strength compared to combined solution. Moreover, the increase of GGBS content increases strength properties of mortar compared to other mixes. The effect of GGBS in various proportions with single activator and combined solution on compressive strength of mortar for the age of 1, 3, 7 and 28 days shown in Figure 2 and Figure 3. From the result table, the 28-day compressive strength of geopolymer mortar prepared with single solution with 100 GGBS: 0 FA is high compared to combined solution of 100 GGBS: 0 FA. The development of strength depends on amount of GGBS content in the mix. It is evident that the increase in strength with 100 GGBS compared to other specimens in both solutions. The dissolution of calcium in combined solution is faster that resulted in good strength properties of geopolymer mortar. Similarly, it is noticed that the strength increment with the increase of age as shown in the table. This paper endeavor to determine the compressive strength of geopolymer mortar at 1, 3, 7 and 28 days. The strength of geopolymer mortar relies upon curing system and alkaline solution. It is clearly noticed the increase of strength with increase of curing period. The specimens are casted and placed for 1, 3, 7 and 28 days of curing for assessing its compressive strength. In outdoor curing, the increase in the strength is less because of moderate polymerization process. Compressive strength of the considerable number of blends expanded over the time and higher at 28 days. From the available studies and result, it is found that increase of GGBS content in flyash specimens shown better early strength properties compared to high fly ash and less GGBS specimens. For example, a mix with 40 percent of GGBS with 60 percent fly ash shown better strength properties over other percentages of fly ash: GGBS ratio

Ultrasonic pulse velocity test (UPV test) - The nature of geopolymer concrete evaluate before testing by utilizing UPV test. This testing strategy includes estimation of time for ultrasonic pulse to go through specimen. The quality of specimen measured on value obtained in the test. The higher value show better quality. Whitehurst specified a table with ranges as shown in Table 1. The pulse velocity calculated by

Pulse velocity = Path Length / travel time

S No	Pulse Velocity (Km/S)	Concrete quality (grading)
1	Above 4.5	Excellent
2	3.5 to 4.5	Good
3	3.0 to 3.5	Doubtful
4	2.0-3.0	Poor
5	< 2.0	Very Poor

Table 1: Interpretation of UPV results for Conventional concrete

The UPV test is a measure to percentage of voids and the consistency of mortar. The 28 days UPV for 100FA blend was discovered 2.58 km/s for ambient cured samples. From the obtained values, it is noticed that range of 100 Fly ash value id bit higher than 100 GGBS sample. The UPV values obtained for 1, 3, 7 and 28-days for all geopolymer mortar specimens shown in Figure 4. All these specimens tested under ambient curing and found in good and above range.

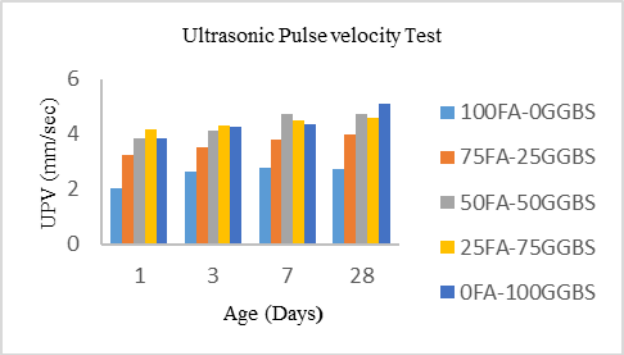

Figure 4: UPV results of fly ash – GGBS based geopolymer mortars (Km/s)

IV.CONCLUSION

1. The impact of GGBS in fly ash for advancement in concrete industry shown steep increase in strength properties
2. The compressive strength acquired at 28 days with single solution is higher compared to combined solution
3. The compressive strength of geopolymer mortar improved with increase of GGBS percentage in fly ash
4. The blend of fly ash and GGBS utilized for improvement of geopolymer mortar with single solution under ambient curing could be used in construction industry
5. The strength of geopolymer mortar increments with increment in the age of the mortar.
6. Single solution could be considered cost effective compared to combined solution and easy to access without skilled people

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