Effect of Molarity on Strength Properties of Flyash and GGBS Blended Geopolymer Concrete

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Abstract— The objective of this project is to study the effect of molarity (8M, 10M and 12M) on strength properties of class F fly ash (FA) and ground granulated blast furnace slag (GGBS) blended geopolymer concrete (GPC) at the 50% replacement level (FA50-GGBS50). Sodium silicate (Na2SiO3) and sodium hydroxide (NaOH) solution has been used as alkaline activator. In the present investigation it is proposed to study the mechanical properties viz. compressive strength, split tensile strength and ultrasonic pulse velocity after 7, 14, 28, 56 and 112 days of ambient room temperature curing.

Key words: Fly Ash, Ground Granulated Blast Furnace Slag (GGBS)

I. Introduction

It is widely known that concrete is the most widely used constructing material and Portland cement is one of the ingredient used in the concrete. Mainly the production of Portland cement takes considerable energy, due to that it releases large volume of carbon dioxide (CO_2) into the atmosphere. The climate change is mainly concerned with the global warming. Generally the various greenhouse gases, such as carbon dioxide (CO_2), methane, nitrous oxide are releasing into the atmosphere due to various human activities. These gases are mainly responsible for global warming. Many industries are releasing CO_2 into the atmosphere, in those cement industry also playing one of the role. Generally the one ton of CO_2 is approximately releasing due to the production of one ton of Portland cement. However in concrete construction, Portland cement is one of the main binders. So, we have to search for more environmental friendly materials. There are many attempts are under research for the replacement of Portland cement with other cementitious materials such as fly ash, ground granulated blast furnace slag (GGBS), rice-husk, in order to reduce global warming issues. Fly ash is the by-product of burning coal that is accessible at worldwide. It is being used for replacement of Portland cement in concrete. High calcium fly ash or ASTM class C ash possess the self-binding properties. Low calcium fly ash or class F fly ash possesses pozzolanic properties. Davidovits (1978), had developed alternative binder "geopolymer" that contains cementing properties. So, it can be used as replacement of cement. A geopolymer will be created by the combining of aluminosilicate material with high alkalic liquids. Usually geopolymer will be made up of the materials that contain Al (Al) and oxide (Si) content. Fly ash and ground granulated blast furnace slag (GGBS) are rich in Al and oxide content. So, these can be used for replacing the cement in concrete.

II. GPC Mix Design

Rangan and Hardjito (2005) have noted that unlike conventional cement concretes GPCs are a new class of construction materials and therefore no standard mix design approaches are yet available for GPCs. While GPC involves more constituents in its binder (viz., FA, GGBS, sodium silicate, sodium hydroxide and water), whose interactions and final structure and chemical composition are under intense research whereas the chemistry of Portland cement and its structure and chemical composition (before and after hydration) are well established due to extensive research carried out over more than century. While the strength of cement concrete is known to be well related to its water-cement ratio, such a simplistic formulation may not hold good for GPCs. Therefore, the formulation of the GPC has to be done by trial and error basis. The role and the influence of aggregates are considered to be the same as in the case of Portland cement concrete. The mass of combined aggregates may be taken to be between 75% and 80% of the mass of geopolymer concrete. The performance criteria of a geopolymer concrete mixture depend on the application. For simplicity, the compressive strength of hardened concrete and the workability of fresh concrete are selected as the performance criteria. In order to meet these performance criteria, the alkaline liquid-to-fly ash ratio by mass, water-to-geopolymer solids ratio by mass, the wet-mixing time, the heat-curing temperature, and the heat-curing time are selected as parameters. With regard to alkaline liquid-to-fly ash ratio by mass, values in the range of 0.30 and 0.45 are recommended. Sodium silicate solution is cheaper than sodium hydroxide solids. Commercially available sodium silicate solution A53 with SiO_2-to-Na_2O ratio by mass of approximately 2, i.e., Na_2O = 14.7%, SiO_2 = 29.4%, and water = 55.9% by mass, and sodium hydroxide solids (NaOH) with 97-98% purity are recommended. Laboratory experience suggests that the ratio of sodium silicate solution-to-sodium hydroxide solution by mass may be taken approximately as 2.5 (Hardjito and Rangan, 2005).

Mixture proportion of heat-cured low-calcium fly ash-based geopolymer concrete with design compressive strength of 45 MPa is needed for precast concrete products as follows: Assume that normal-density aggregates in SSD condition are to be used and the unit-weight of concrete is 2400 kg/m^3. Take the mass of combined aggregates as 77% of the mass of concrete, i.e. 0.77x2400 = 1848 kg/m^3. The combined aggregates may be selected to match the standard grading curves used in the design of Portland cement concrete mixtures. For instance, the aggregates may comprise 277 kg/m^3 (15%) of 20 mm aggregates, 370 kg/m^3 (20%) of 14 mm aggregates, 647 kg/m^3 (35%) of 7 mm aggregates, and 554 kg/m^3 (30%) of fine sand to meet the requirements of standard grading curves. The fineness modulus of the combined aggregates is approximately 5.0.The mass of low-calcium fly ash and the alkaline liquid = 2400 – 1848 = 552 kg/m^3. Take the alkaline liquid-to-fly ash ratio by mass as 0.35; the mass of fly ash = 552/ (1+0.35) = 408 kg/m^3 and the mass of alkaline liquid = 552 – 408 = 144 kg/m^3. Take the ratio of sodium silicate solution-to-sodium hydroxide solution by mass as 2.5; the mass of sodium hydroxide solution = 144/ (1+2.5) = 41 kg/m^3; the mass of sodium silicate solution = 144 – 41 =103 kg/m^3.Therefore, the trial mixture proportion is as follow: combined aggregates = 1848 kg/m^3, low-calcium fly ash = 408 kg/m^3, sodium silicate solution = 103 kg /m^3, and sodium hydroxide solution = 41 kg/m^3.

The sodium hydroxide solids (NaOH) with 97-98% purity is purchased from commercial sources, and mixed with water to make a solution with a concentration of 8 Molar. This solution comprises 26.2% of NaOH solids and 73.8% water, by mass. For the trial mixture, water-to-geopolymer solids ratio by mass is calculated as follows: In sodium silicate solution, water = 0.559x103 = 58 kg, and solids = 103 – 58 = 45 kg. In sodium hydroxide solution, solids = 0.262x41 = 11 kg, and water = 41 – 11 = 30 kg. Therefore, total mass of water =58+30 = 88 kg, and the mass of geopolymer solids = 408 (i.e. mass of fly ash) +45+11 = 464 kg. Hence, the water-to-geopolymer solids ratio by mass = 88/464 = 0.19. For water-to-geopolymer solids ratio by mass of 0.19, the design compressive strength is approximately 45 MPa, as needed. The geopolymer concrete mixture proportion is therefore as follows: 20 mm aggregates = 277 kg/m^3, 14 mm aggregates = 370 kg/m^3, 7 mm aggregates = 647 kg/m^3, fine sand = 554 kg/m3, low-calcium fly ash (ASTM Class F) = 408 kg/m^3, sodium silicate solution (Na2O = 14.7%, SiO2 = 29.4%, and water = 55.9% by mass) = 103 kg/m^3, and sodium hydroxide solution (8 Molar) = 41 kg/m^3 (Note that the 8 Molar sodium hydroxide solution is made by mixing 11 kg of sodium hydroxide solids with 97-98% purity in 30 kg of water).

Geopolymer concrete can be manufactured by adopting the conventional techniques used in the manufacture of Portland cement concrete. It is recommended that the alkaline liquid is prepared by mixing both the solutions together at least 24 hours prior to use. In the laboratory, the fly ash and the aggregates were first mixed together dry in 80-litre capacity pan mixer for about three minutes. The aggregates were prepared in saturated-surface-dry (SSD) condition. The alkaline liquid was mixed with the superplasticiser (SP) and the extra water, if any. The liquid component of the mixture was then added to the dry materials and the mixing continued usually for another four minutes. The fresh concrete could be handled up to 120 minutes without any sign of setting and without any degradation in the compressive strength. The fresh concrete was cast and compacted by the usual methods used in the case of Portland cement concrete (Hardjito and Rangan, 2005). Fresh fly ash-based geopolymer concrete was usually cohesive. The workability of the fresh concrete was measured by means of the conventional slump test.

III. RESULTS AND DISCUSSIONS

Mechanical Property	Age (Days)	Mix Type: FA50-GGBS50		
		8 Molarity	10 Molarity	12 Molarity
	7	36	40	44
Compressive Strength, f'_c (MPa)	14	37.88	38.7	48.2
	28	41.52	45.34	54.86
	56	44.28	48.66	68.33
	112	50.69	55.03	77

Table 1: Compressive strength test results

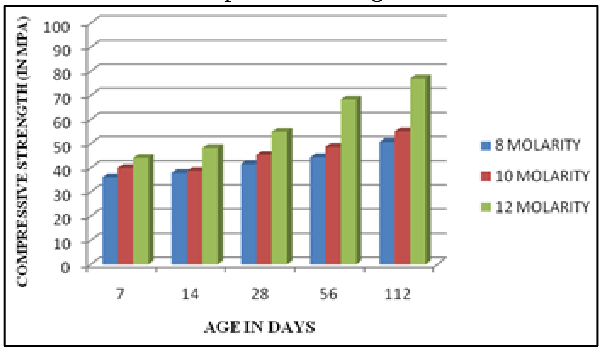

Fig. 1: Compressive strength versus age

Mechanical Property	AGE (days)	Mix Type: FA50-GGBS50		
		8 Molarity	**10 Molarity**	**12 Molarity**
Split tensile strength, f_{ct} (MPa)	7	1.64	2.82	2.98
	14	1.86	3.08	3.28
	28	2.83	3.64	5.67
	56	3.20	3.83	6.87
	112	3.89	4.56	7.65

Table 2: Split Tensile strength test results

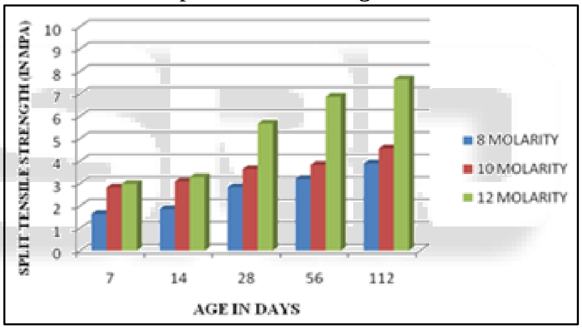

Fig. 2: Split tensile strength versus age

Property	Age (days)	Mix Type: FA50-GGBS50		
		8 Molarity	10 Molarity	12 Molarity
Ultrasonic pulse velocity (m/s)	7	2123	2947	3102
	14	2186	3005	3287
	28	2376	3378	3687
	56	2684	3874	4002
	112	2956	4364	4384

Table 3: Ultrasonic pulse velocity test results

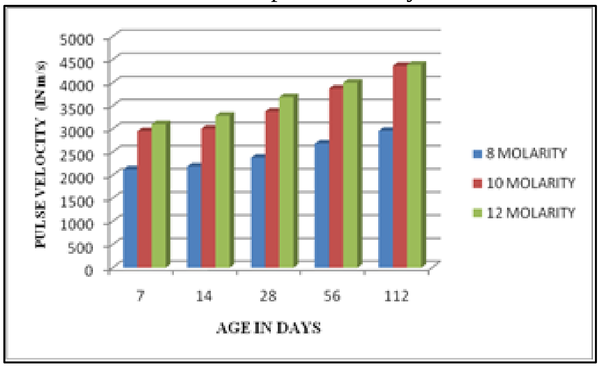

Fig. 3: Pulse velocity versus age

IV. CONCLUSIONS

Based on the test results, the following conclusions are drawn:

1) The increased level of NaOH molarity increased the mechanical properties of GGBS blended FA based GPC mixes at ambient room temperature curing itself without the need of heat curing as in the case of only FA based GPC mixes.
2) GGBS blended FA based GPC mixes attained enhanced mechanical properties at ambient room temperature curing at all ages.
3) Keeping in view of savings in natural resources, sustainability, environment, production cost, maintenance cost and all other GPC properties, it can be recommended as an innovative construction material for the use of constructions.

REFERENCES

[1] Davidovits J. Geopolymers: Man-Made Geosynthesis and the Resulting Development of Very Early High Strength Cement, Journal of Materials Education, 16 (1994) 91-139.
[2] Nath P, Sarker PK. Effect of GGBS on setting, workability and early strength properties of fly ash geopolymer concrete cured in ambient condition, Construction BuildingMaterials, 66 (2014) 163-171.
[3] Deb P, Nath P, Sarker PK. The effects of ground granulated blast-furnace slag blending with fly ash and activator content on the workability and strength properties of geopolymer concrete cured at ambient temperature, Materials and Design, 62 (2014) 32-39.
[4] Davidovits J. Geopolymers: Inorganic Polymeric New Materials, Journal of Thermal Analysis, 37 (1991) 1633-1656.
[5] Davidovits J. Global Warming Impact on the Cement and Aggregate Industries, World Resource review, 6 (1994) 263-278.