A Study on Factors Influencing Strength of Geopolymer Concrete

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Abstract
It is well known that a massive pollution has been created in the atmosphere because of the release of carbodioxide during the cement manufacturing process. To swap such hazard, so many efforts have been made to enlarge the employment of fly ash in construction. On the other hand, Flyash makes a great menace on its disposal. To resolve all these problems, Geopolymer concrete (GPC) paves a new path. The making of GPC follows the same mix design of OPC, but a different mixing procedure. This paper details the development of making process of GPC which mainly has fly ash as a base.
Keywords: Flyash, Geopolymer concrete, Mixing Procedure, OPC

1.Introduction

Geopolymer concrete (GPC) is a combination of flyash and GGBS which is activated by the reaction of aluminate and silicate materials to convert itself into a binder which is a substitute of conventional concrete. The industrial byproducts have been involved to reduce the carbon paw marks of cement production, and at the sametime GPC proves its vast challenging to the conventional concrete durability issues(1-20). GPC is used for construction purpose and also for radioactive waste encapsulation. It is notable that Flyash is rich in silica and alumina producing aluminosilicate gel when mixed with alkaline fluid to contribute itself to the construction society as an excellent material to replace cement. It is well known OPC is a vital substance in the structural creation activities. Conventional cement is produced by the flaming of bulky amount of heating source and disintegration of limestone which ends up with considerable air pollution. Geopolymer concrete has been fashioned to lessen this environmental pollution. Davidovits (1988) invented Geopolymer around 1978 to portray the alkali activated substance from by-product materials. Scientific observations have been accessible only from 1990s. Utilization of byproducts can only surrogate cement portion until certain entitlement. Geopolymer is formed by combining Polymers and geological origin products and therefore named as Geopolymer. Alkaline liquid which contains two chemical solutions namely sodium hydroxide and sodium silicate mixed to a specified ratio is necessary to supplement the reaction rate.

A lot of efforts have been taken since 1990 to launch the practice of this new material in the construction field. In this approach, Pavithra et al., (2016) have developed a mixing methodology.By using different alkaline fluid to the binder ratio, compressive strength of the

GPC mix have been elevated reasonably. Subhash(2015) has proposed a mix design procedure and illustrated with an experimental validation depending on the properties of GPC. The expected workability and strength have been renowned. Vignesh and Vivek (2015) have studied different strength aspects of GPC by means of adding five different percentages with low calcium fly ash . Aniket Shobha Diliprao Hadole (2021) have observed GGBS makes GPC more workable at ambient temperature. Different percentages of RHA also have been added and the strength variation has been checked.It has been observed that the increasing the GGBS content decreased the workability. Djwantoro Hardjito(2005) has found few properties like young's modulus, stress versus strain relationship and Poisson's ratio of toughened GPC imitating OPC. This paper briefs about the constituents of GPC along with a mix design proposed for M25 grade GPC which has been verified by conducting experiments.

2.Materials

Fly ash (Class F) has been supplied by Mettur Plant ,Salem . Ground Grandnulated Blast furnace Slag(GGBS) is added to Flyash to increase the strength. Sodium hydroxide (NaOH) flakes are (purchased from Pondicherry chemical supplier) dissolved in water and then Sodium silicate solution is mixed with a ratio of 2.5. Water from the Structural Engineering Laboratory is used to mix the chemicals. Preparation of alkaline fluid should be advanced by atleast 24 hours to acquire the target strength. Crushed 20mm aggregates and M sand are used as coarse and fine aggregates. A superplasticizer named FOSROC is also used in all of the geopolymer mixes. Table.1 depicts the Chemical Composition of Fly ash and GGBS.

Table.1.Chemical Composition of Fly ash and GGBS

GGBS		Fly Ash	
Oxides	**(Wt in %)**	**Oxides**	**(Wt in %)**
FeO	0.8	CaO	0.88
SiO2	35.5	SiO2	62
CaO	32.1	Fe2O3	4.2
MgO	2.00	MgO	0.4
Al2O	13	Al2O3	29
Mn	3.4	SO3	1.5
S	1.5	LOI	0.3
Na2o	1.2	Na2O	0.2
K2O	0.5	K2O	0.82
EaO	6.5		

3.Mix Design of GPC:

Prelimnary data:

1. Required compressive strength (fck) = 25 MPa
2. Fineness of Flyash in terms of specific surface=430m^2/kg
3. Type of curing = Ambient curing
4. Concentration of NaOH=10M
5. Max size of coarse aggregate = 20 mm
6. Specific gravity of GGBS = 3.1
7. Specific gravity of Fly ash = 2.1

1. As per IS10262-2005,the mix proportion of M25 grade of concrete has been determined as 1:1.88:2.95 and W/Binder-0.49

2. Then Binder material content has been calculated = 2400/(1+1.88+2.95)=411.64 kg/m^3

3.Calaculation of AAS:

NaOH=(128.54 x0.49)/3.5=57.63 kg/m^3 ; Na2Sio3=2.5 x57.63=144.01 kg/m^3

4.Calculation of Water content:

[10M=400grams of NaOH]

Mass of water content=57.63 x (1000-400)/1000=32.178 kg/m^3

5.Calculation of mass of all other materials:

1.Flyash+10% GGBS=411.66 kg/m^3: 2.Fine aggregate=1.88 x 411.66=773.92 kg/m^3;3.Coarse aggregate=2.95 x 411.66=1214.40 kg/m^3;4.Water=32.178 kg/m^3;5.NaOH=57.63 kg/m^3 : 6.Na_2Sio_3=144.1 kg/m^3

The various proportions adopted in the current study are given in Table.3

Table.3.Mix Proportions used in this Study

Ingredients	**OPC**	**GPC Mixes**		
	M1	**M1**	**M2**	**M3**
Cement	360			
Flyash		370.494	540	380.29
GGBS		41.17	60	42.25
NaOH		57.63	82.29	54.33
Na2Sio3		144.1	205.73	135.8

Fine Agg	682	773.92	600	709.87
Coarse agg	1221	1214.40	1200	1267.62
Water	180	32.178	49.374	32.60
SP		4.12	6	4.23
AAS/Binder	0.5	0.49	0.48	0.45
Mix Ratio	**1:1.89:3.39**	**1:1.88:2.95**	**1:1:2**	**1:1.68:3**

4.Casting Procedure of cubes

The mixing of GPC is done in the same way as the mixing of conventional concrete. At room temperature mixing of materials has been carried out. Materials to be mixed are weighed with the help of electronic weighing machine. First of all, Flyash and GGBS along with aggregates are mixed thoroughly. After a thorough mixing for atleast 5 minutes, the alkaline solution that has been ready 1 day in advance is also added. Once again the paste is thoroughly mixed for another 5 minutes till it gets its workability. The workability has been checked by conducting slump test. Slump value has been assumed as 85 mm. The paste is then immediately transferred to the cube moulds in 3 layers. After each layer the concrete is packed down by dropping 25 labour's intensive strokes using a thick steel rod which measures its diameter more than 16 mm.

5. Curing of concrete specimens

The concrete specimens are casted in the cube moulds and allowed to set for more than twenty four hours which makes easy to remove the specimens without any damages. After the removal the specimens are kept at ambient temperature for 28 days. Three different mixes of GPC have been used to make the same grade of concrete as given in the Table.3. Polymerization stages a central role to improvise the compressive strength of GPC at different curing times. Table.4 shows the compressive strength of various mixes and workability (slump value) of each mix.

Table.4. Work Ability and Compressive strength of CC and GPC

Mixes	**Slump in mm**	**Compressive strength(N/mm^2)**			
		7 days	**14 days**	**21days**	**28days**
Conventional concrete	81	17.3	31.8	34.25	37.37
		16.3	29.35	32.64	34.53
		15.32	27.4	31.65	32.23

		15.5	27.5	31.60	32.23
		17	29.8	30.95	35.00
GPC-TRIAL I	85	3.86	20.96	29	32.24
		2.56	20.3	27.89	30.26
		2.5	20.6	27.8	30.5
		2.6	19.15	27.52	29.5
		2.56	19.5	27.5	29
GPC-TRIAL II	81	3.43	15.2	20.56	22.85
		2.36	16.3	20.34	23.6
		4.05	18.9	18.5	24.5
		3.75	18.6	21.5	25.3
		3.2	17.89	21.35	25.3
GPC-TRIAL III	82	6.3	26	36.2	39.67
		5.9	25.4	35.06	37.6
		5.3	25	35.03	37.65
		6.2	24.82	34.95	36.2
		6.3	27	37.23	39

6.Influence of various factors on Compressive strength of cubes:

Three different Geopolymer concrete mix design have been used to prepare the mixes. Therefore the factors that are influencing the compressive strength of GPC have been analyzed and the results have been discussed.

1.Alkaline fluid to flyash Ratio: It has been observed that the ratio of alkaline liquid to fly ash, by mass shows invaluable change in the compressive strength of the geopolymer concrete but from the test results it has been noted that if the ratio decreases the compressive strength increases.

2. Curing Period: The curing time also plays an important role in improvising the polymerization process resulting in growth of compressive strength. The compressive strength is 15 % of target strength at 7th day whereas the strength gradually increases by 60% and 90% of the target strength at 4th and 21st days respectively. Fig.1 Shows the compressive

strength variation for different curing period for conventional concrete M25 mix, GPC Mix (Trial I), GPC Mix (Trial II), GPC Mix (Trial III).

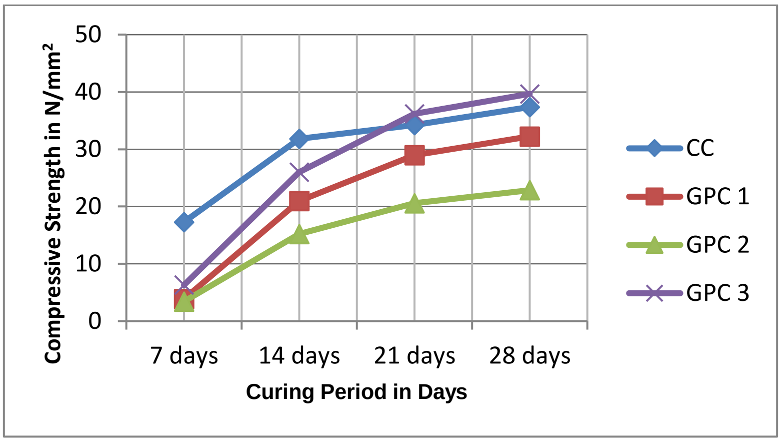

Fig.1.Compressive strength versus Curing Period

3. Super plasticizer: Superplasticizer also plays an imperative position in increasing the workability and strength characteristics. But more addition beyond the prescribed limits will not help to get better workability or strength of the GPC.

4. Water content of mix: The test results show that amplification of water to geopolymer solids ratio have an agreement with the increase of the workability of mixes. However adding more water decreases the strength.

7. Conclusions

From the work the following conclusions have been derived:

1. AAS/Flyash ratio does not affect much the compressive strength of GPC.
2. The ratio of sodium siliate and sodium hydroxide has been taken as 2.5 and the Molarity of NaOH has been fixed as 10M.
3. The compressive strength of GPC increases with the escalating curing period.
4. Workability of the GPC also increases within 3% accumulation of superplasticizer.
5. Compressive strength of GPC falls down with the rise of water / geopolymer solids ratio.

Therefore various parameters which affect the strength aspects of GPC is forcefully recommended at the primary stage before stepping into any kind of investigations related to flexural properties durability properties and Bond properties of the GPC in order to get the enviable benefits .

References

[1] Aniket Shobha Diliprao Hadole,(2021) Properties of Fly Ash based Geopolymer Concrete with GGBS & RHA , International Journal of Engineering Research & Technology (IJERT) , ISSN: 2278-0181,10(5) ,377-380.

[2] Davidovits J (1988) Geopolymer chemistry and properties. In: Proceedings of 1st Europeanconference on soft mineralurgy. Geopolymere, vol 88, France, pp 25–48

[3] Davidovits J (1991) Geopolymers: inorganic polymeric new materials. J Therm Anal37:1633–1656

[4] Davidovits J (1994) Geopolymers: man-made geosynthesis and the resulting development ofvery early high strength cement. J Mater Edu 16(2, 3):91–139

[5] Davidovits J (1995) Global warming impact on the cement and aggregate industries. World Res Rev 6(2):263–278

[6] Djwantoro Hardjito (2005),Studies on Fly Ash-Based Geopolymer Concrete,M.E Thesis, Curtin University of Technology

[7] Hardjito D, Wallah SE, Sumjouw DMJ, Rangan BV (2004) On the development of fly ash based geopolymer concrete. ACI Mater J 101:467–472

[8] Kumar V, Mathur M, Sinha SS, Dhatrak S (2005) Fly Ash: an environmental savior. Fly AshUtilisation Programme (FAUP), TIFAC, DST, Fly Ash India, New Delhi, IV, pp 1.1–1.4

[9] Malhotra V. M., 2000. Introduction: Sustainable Development and Concrete technology, ACI Concrete Journal, pp.1147-1165.

[10] Malhotra VM (1999) Making concrete greener with fly ash. ACI Conc Int 21(5):61–66

[11] Malhotra VM, Ramezanianpour AA (1994) Fly Ash in concrete. Canada Centre for Mineraland Energy Technology (CANMET), Canada

[12] Mehta P.K., 2001. Reducing the Environmental Impact of Concrete, Concrete International, pp. 61-66, 077-3085

[13] Mullick AK (2005) Use of fly ash in structural concrete: part I—why? Indian Conc J 79:13–22

[14] P. Pavithra , M. Srinivasula Reddy , Pasla Dinakar, B. Hanumantha Rao,B.K. Satpathy, A.N. Mohanty (2016), A mix design procedure for geopolymer concrete with fly ash, Journal of Cleaner Production 133,pp 117-125.

[15] Rangan BV (2008) Mix design and production of fly ash based geopolymer concrete. IndianConcr J 82:7–15

[16] Serag Farieda, W. H. Sofib, Al-Zahraa Tahac, Magdy A. El-Yamania and Taher A. Tawfik (2020),Mix design proposed for geopolymer concert mixtures based on ground granulated blast furnace slag, Australian Journal Of Civil Engineering, https://doi.org/10.1080/14488353.2020.1761513

[17] Subhash V. Patankar, Yuwaraj M. Ghugal and Sanjay S. Jamkar(2015) Mix Design of Fly Ash Based Geopolymer Concrete, Advances in Structural Engineering ,pp-1619-1634

[18] Sumajouw D.M., Hardjito D Wallah S.E., Rangan B.V., 2006. Fly ash based Geopolymer Concrete: Study of Slender Reinforced Columns, Advances in geopolymer science and technology, pp. 3124-3130

[19] Vijaya Rangan, Low-Calcium Fly Ash-Based Geopolymer Concrete; 2010.

[20] Vignesh, Vivek , (2015)An Experimental Investigation On Strength Parameters Of Flyash Based Geopolymer Concrete With GGBS, International Research Journal of Engineering and Technology (IRJET) ,ISSN: 2395-0056,2(2) ,135-142.