Comparative Studies of Fly Ash Based Geopolymer Concrete under Ambient Condition

Arpit Soni[1], Chetali Shrivastava Gangwal[2]

[1]Civil Engineering Department, Sanghvi institute of management and Science, India

[2]Asst. Professor Civil Engineering Department, Malwa institute of Science and Technology, India

Abstract: ***Concrete is the premier construction material across the world and the most widely used in all types of Civil engineering works, including infrastructure, low and high-rise buildings, defense installations, environment protection and local/domestic developments. Concrete is a manufactured product, essentially consisting of cement, aggregates, water and admixtures. Among these, cement, i.e. binder materials and major part of concrete increase the green house effect. However, in recent years the use of concrete increased day by day due to various advantages such as good strength, long life, low maintenance etc. Due to increase in uses the environment of earth is effected. The main effect of increase is temperature that melts the glaciers and increases the water level. One of the efforts to produce more environmentally friendly concrete is to reduce the use of ordinary Portland cement (O.P.C) by replacing the cement in concrete with geo-polymers. In geo-polymer concrete cement is replaced by fly ash and alkaline solutions such as sodium hydroxide (Na OH) and sodium silicate (Na_2O, SiO_2) to make the binder necessary to manufacture the concrete.***

Keywords: Geo-polymers concrete, ordinary Portland cement (O.P.C), sodium hydroxide (Na OH) and sodium silicate (Na_2O, SiO_2), compressive strength

1. Introduction

The global warming is caused by the emission of greenhouse gases, such as CO_2, CO to the atmosphere by human activities. Among the green house gases, CO_2 contributes about 65% of global warming. The cement industry is responsible for about 7% of all CO_2 emissions, because the production of one ton of Portland cement emits approximately one tone of CO_2 into the atmosphere. In this respect, the geo-polymer technology proposed by David shows considerable promise for the concrete industry as an alternative binder to OPC .In terms of reducing the global warming, the geo-polymer technology could reduce the CO_2 emission to the atmosphere caused by cement and aggregates industries by about 80%. One of the efforts to produce more environmentally friendly concrete is to reduce the use of OPC by replacing the cement in concrete with geo-polymers (i.e. 100% fly ash in place of OPC). Concrete usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacture of OPC due to the calcinations of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced. In addition, the extent of energy required to produce, OPC is only next to steel and aluminum. On the other hand, the abundant availability of fly ash worldwide creates opportunity to utilize this by-product of burning coal, as a substitute for OPC to manufacture concrete. When used as a partial replacement of OPC, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate. This research was therefore dedicated to the development, the manufacture, and the engineering properties of the fresh and hardened low-calcium (ASTM Class F) fly ash-based geo-polymer concrete.

2. Fly Ash-Based Geo-Polymer Concrete

Geo-polymer is a type of amorphous alumina-silicate cementations material. Geo-polymer can be synthesized by poly condensation reaction of geo-polymeric precursor, and alkali poly silicates. Comparing to Portland cement, the production of geo-polymers has a relative higher strength, excellent volume stability, better durability. Geo-polymer concrete based on pozzolana is a new material that does not need the presence of Portland cement as a binder. Fly ash based concrete has excellent compressive strength, suffers very little drying shrinkage low creep, excellent resistant to sulphate attack and good acid resistance. Given the fact that the fly ash is considered as a waste material, the fly ash based geo-polymer is therefore somehow cheaper than the OPC concrete. Moreover reduction of one tone of CO_2 yields one tone of carbon credit. This carbon credits significantly adds to the economy offered by the Geo-polymer. "Fly ash", Low-calcium (ASTM Class F) fly ash is preferred as a source material than high calcium (ASTM Class C) fly ash because the presence of calcium in high amount may interfere with the polymerization process and alter the microstructure.

3. Literature Review

Frantisek Skvara
Investigated the synthesis of geopolymer their microstructure and properties of concrete. The results showed that the mixtures containing higher percentage of fly ash exibit a different rheological behaviour. Both the static and dynamics viscosity of the gopolymer concrete are substantially higher. The strength values of pastes, mortar and concrete of the geopolymer on the basis of fly ashes increased from is to 70 Mpa after 28 days .The compressive strength measured after 28 days ranged from 100 to 160 Mpa.

James Aldred

Concluded that the term geopolymer was used to described the inorganic aluminosilicate polymer gel resulting from reaction of amorphous aluminosilicates with alkali hydroxide and silicate solution. The some others names was also identified in the literature , such as alkali- activated cement , inorganic polymer concrete and geocement was has been used to describe materials synthesised. Geopolymer binders was covered a wide range of possible source materials and activators. The low shrinkage, heat of hydration and high tensile strength means that the materials has been technical advantages over traditional concrete. The most common concrete grades was used and the compressive strength 32 and 40 Mpa and the cylinder strength is measured up to 70 Mpa.

H. J. H. Brouwers

Described that the dissolution of pulverised powder coal fly ash. This fly ash was modeled as hollow spheres and a shrinking core model was derived for these hollow spheres that contain two regions first one is outer hull and the other is inner region). The following thermodynamics properties of the studied fly ashes was derived such as the free energy, enthalpy and entropy of reaction. The equilibrium constant and the experimental data at various temperatures and also the free energy, enthalpy and entropy of reaction are compacted of EFA and LM phase. The data are used to compute the free energy of formation of both glass. It said that the free energy of formation is mainly governed by the molar ratio of the major constituents. The results suggested that the outer layer is poorer in silica and aluminium oxide was concentrated in the exterior hull.

4. Methodology

The Geopolymer concrete is mixture of Fly ash, Alkali solution, Aggregate, Sand and Water. The various test is done on Fly ash, Alkaline solution, Aggregate, Sand. The method used to find the compressive and flexural strength of Geopolymer concrete by same as the method used to find the strength of cement concrete. But in cement concrete the curing is done with water and the geopolymer concrete the curing is done under ambient condition. The main aim of this work is to compare the compressive and flexural strength of geopolymer and ordinary concrete and to find that the geopolymer concrete can be replaced by cement concrete.

Test procedure:

Casting of cubes and beams:

1) A total nine concrete cubes of 150mm X 150mm X 150mm of 12M, 14M and 16M morality and nine concrete beams of 150mm X 150mm X700mm of 12M, 14M and 16M morality of geopolymer are being casted.
2) Geopolymer concrete Cubes and Beams of following proportion are casted :
   12M - 9 no.s
   14M - 9 no.s
   16M - 9 no.s

Abstract Of Quantities

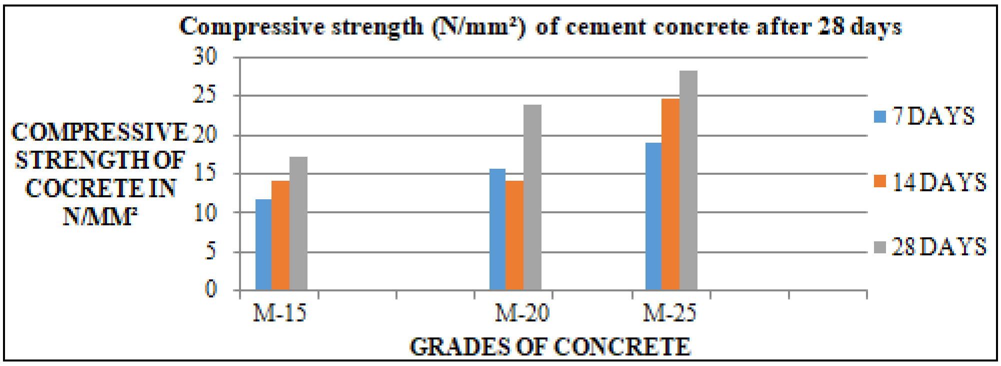
Combined aggregate = 1848 kg/m^3
Sodium silicate = 102.22 kg/m^3
Na OH (22.73 kg water + 18.15 kg Na OH flakes)=40.88 kg
Fly ash 408.88 kg
Commercial available super plasticizer is adopted is 1.5% of fly ash by wt

5. Results and Discussions

To estimate the compressive strength of cement concrete and geopolymer concrete mixture cubes are prepared. The test procedure for cement and geopolymer concrete cubes is same. For the cement concrete mixture and geopolymer concrete cubes, compressive strength test has given following results.

Table 1: Compressive strength (N/mm²) of cement concrete after 28 days

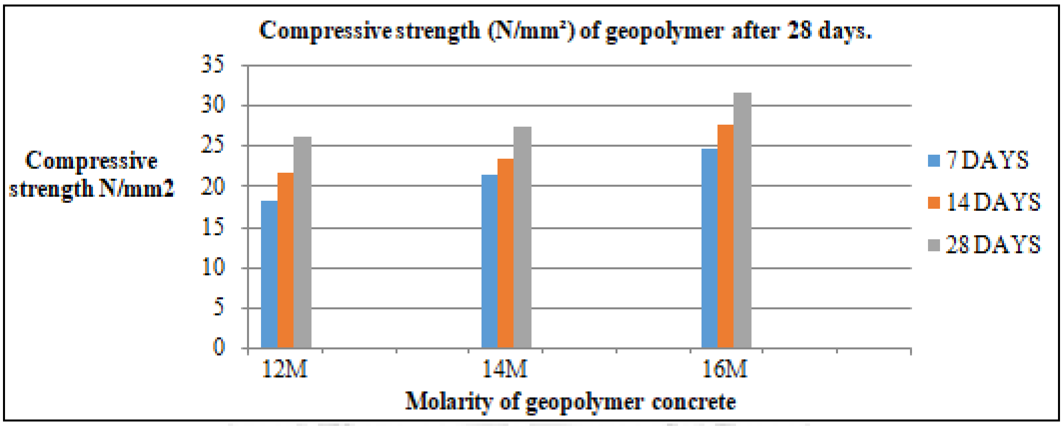
GRADE CURING	M-15			M-20			M-25		
7 DAYS	11.33	12.00	12.09	15.33	15.38	15.91	18.29	19.64	19.33
MEAN STRENGTH		11.80			15.54			19.08	
14 DAYS	13.78	14.56	14.22	19.08	18.97	18.55	24.49	24.34	24.77
MEAN STRENGTH		14.18			18.86			24.53	
28 DAYS	17.33	16.93	17.16	24.44	23.64	23.76	28.18	27.33	28.76
MEAN STRENGTH		17.14			23.94			28.09	



Graph 1: Compressive strength (N/mm²) of cement concrete after 28 days

Table 2: Compressive strength (N/mm²) of geopolymer after 28 days

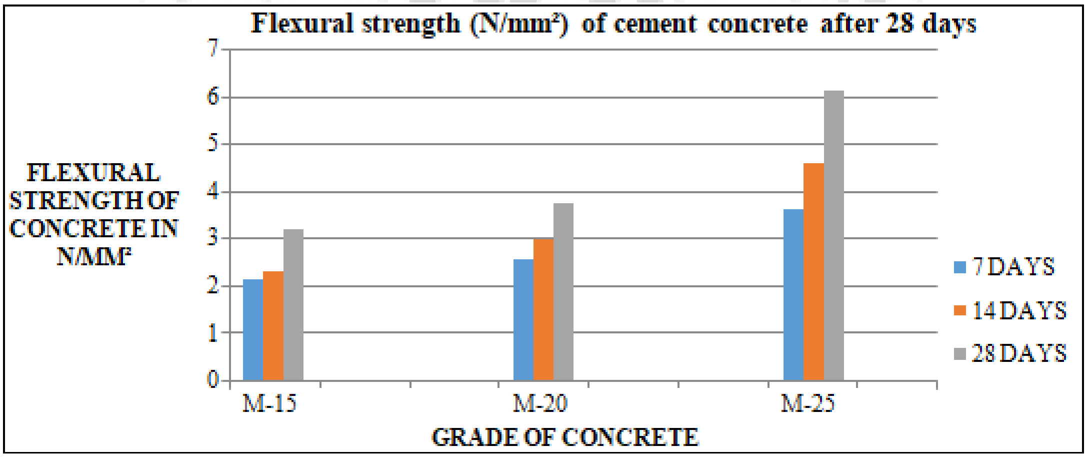
Grade Curing	12M			14M			16M		
7 Days	19.33	17.33	17.91	21.23	21.00	21.59	24.34	24.52	24.56
Mean Strength		18.19			21.27			24.47	
14 Days	21.22	21.59	22.00	23.43	23.76	23.00	27.32	27.98	27.12
Mean Strength		21.60			23.39			27.47	
28 Days	25.90	26.12	26.43	27.23	27.12	27.34	31.33	31.57	32.00
Mean Strength		26.15			27.23			31.63	



Graph 2: Compressive strength (N/mm²) of geopolymer after 28 days

Table 3: Flexural strength (N/mm²) of cement concrete after 28 days

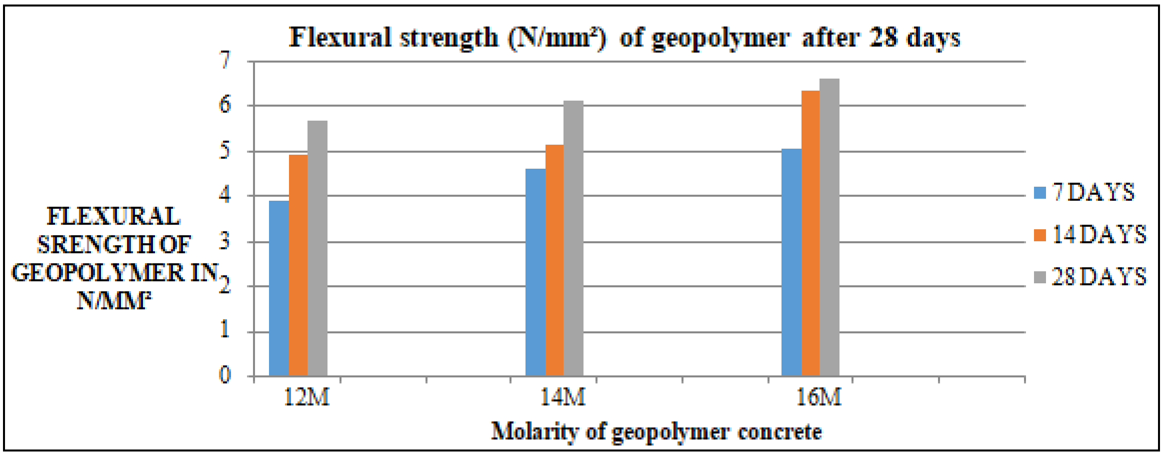
Grade Curing	**M-15**			**M-20**			**M-25**		
7 Days	2.15	2.19	2.10	2.34	2.53	2.77	3.36	3.80	3.62
Mean Strength		2.14			2.54			3.59	
14 Days	2.43	2.32	2.19	2.89	2.96	3.07	4.15	4.76	4.88
Mean Strength		2.31			2.97			4.59	
28 Days	3.07	3.32	3.17	3.77	3.82	3.66	6.13	6.22	6.00
Mean Strength		3.18			3.75			6.11	



Graph 3: Flexural strength (N/mm²) of cement concrete after 28 days

Table 4: Flexural strength (N/mm²) of geopolymer after 28 days

Grade Curing	12M			14M			16M		
7 Days	3.89	3.90	3.91	4.62	4.52	4.60	5.00	5.00	5.19
Mean Strength		3.90			4.58			5.06	
14 Days	5.00	4.88	4.89	5.10	5.12	5.19	6.22	6.29	6.55
Mean Strength		4.92			5.13			6.35	
28 Days	5.60	5.62	5.80	6.02	6.23	6.02	6.60	6.56	6.70
Mean Strength		5.67			6.09			6.62	



Graph 4: Flexural strength (N/mm²) of geopolymer after 28 days

6. Conclusion

1) After comparing compressive strength of cement concrete (M-15) and geopolymer concrete (12M) at 7, 14 and 28 days . It is concluded that Strength of gopolymer concrete is higher as compared to cement concrete. The compressive strength of geopolymer concrete in 28 days is 26.15 N/mm^{2}and the compressive strength of cement concrete in 28 days is 17.14 N/mm$^{2.}$
2) After comparing compressive strength of cement concrete (M-20) and geopolymer concrete (14M) at 7, 14 and 28 days . It is concluded that Strength of gopolymer concrete is higher as compared to cement concrete. The compressive strength of geopolymer concrete in 28 days is 27.23 N/mm^{2}and the compressive strength of cement concrete in 28 days is 23.94 N/mm$^{2.}$
3) After comparing compressive strength of cement concrete (M-25) and geopolymer concrete (16M) at 7, 14 and 28 days. It is concluded that Strength of gopolymer concrete is higher as compared to cement concrete. The compressive strength of geopolymer concrete in 28 days is 31.63 N/mm^{2}and the compressive strength of cement concrete in 28 days is 28.09 N/mm$^{2.}$
4) After comparing flexural strength of cement concrete (M-20) and geopolymer concrete (12M) at 7,14 and 28 days . It is concluded that Strength of gopolymer concrete is higher as compared to cement concrete. The flexural strength of geopolymer concrete in 28 days is 5.67 N/mm^{2}and the flexural strength of cement concrete in 28 days is 3.18 N/mm$^{2.}$
5) After comparing flexural strength of cement concrete (M-25) and geopolymer concrete (14M) at 7, 14 and 28 days. It is concluded that Strength of gopolymer concrete is higher as compared to cement concrete. The flexural strength of geopolymer concrete in 28 days is 6.09 N/mm^{2}and the flexural strength of cement concrete in 28 days is 3.75 N/mm$^{2.}$
6) After comparing flexural strength of cement concrete (M-40) and geopolymer concrete (16M) at 7, 14 and 28 days. It is concluded that Strength of gopolymer concrete is higher as compared to cement concrete. The flexural strength of geopolymer concrete in 28 days is 6.62 N/mm^{2}and the flexural strength of cement concrete in 28 d9ays is 6.11 N/mm^2.
7) The higher the ratio of alkaline solution to fly ash, i.e., chemical ratio, higher is the compressive and flexural strength of the geopolymer concrete.

References

[1] Kolli Ramujee and M.Potharaju. "Development Of Low Calcium Flyash Based Geopolymer Concrete " IACSIT International Journal for Engineering and Technology. Vol.6.No. 1, February 2014
[2] Frantisek Skvara, Josef Dolezal, Pavel Svoboda, Lubomir Kopecky, Simona Pawlasova, Martin Lucuk, Kamil Dvoracek, Martin Beksa, Lenka Myskova, Rostislav Sulc. " Concrete Based On Fly Ash Geopolymers" [1]ICT Prague, Faculty of Chemical Technology, Dept. of Glass and Cermics, Technicka 5, 166 28 Praha 6, [2] Czech Technical University, Faculty of Civil Engineering, Dept. of Building Technology , Thakurova 7, 166 29 Praha 6 [3] Betonconsult , BELOHORSKA 54 , 169 00 Praha 6
[3] James Aldred and John Day " Is Geopolymer Concrete A Suitable Alternative To Traditional Concrete " 37th Conference on our World in Concrete and Structure 29-31 August 2012, Singapore
[4] H.J.H. Brouwers and R.J. Van Eijk " Chemical Reaction Of Fly Ash " Proceedings of the 11th International Congress on the Chemistry of Cement (ICCC) 'Cement's Contribution to the Development in the 21st Century'
[5] .V.Bhikshma , M.koti Reddy and T. Srinivas Rao " An Experimental Investigation On Properties Of Geopolymer Concrete (No Cement Concrete) " Asia journal Of Civil Engineering (Building and Housing) Vol.13,No. 6 (2012)
[6] N.A.Lloyd and B.V. Rangan " Geopolymer Concrete : A Review Of Development And Oppoetunities ". 35th Conference on OUR WORLD IN CONCRETE AND STRUCTURES:25-27 August 2010,Singapore
[7] M.Kalaivani " Experimental Investigation For Flexural Strength Of Fly Ash Concrete With Addition Of Alkaline Activator " ARPN Journal Of Engineering And Applied Sciences Vol. 10, No. 11 , June 2015.
[8] ABHIJITSINH PARMAR[1] , DHAVAL M PATEL[2] "Effect On Flexural Strength Of Geopolymer Concrete By Using Fly Ash And Alkaline Solution As A 100%

Replacement Of Cement" Abhijitsinh Parmar, IJPRET , 2014; Volume 3 (4) : 100-106

[9] D.B.Raijiwala , H.S. Patil , I.U.Kundan " Effect Of Alkaline Activator On The Strength And Durability Of Geopolymer Concrete " Journal Of Engineering Research And Studies. Studies/Vol.III/IssueI/January-March, 2012/18-21

[10] L.Krishnan , S.Karthikeyan , S.Nathiya , K.Suganya " Geopolymer Concrete An EcoFriendlyConstructionMaterial International Journal of Research in Engineering and Technology Volume: 03 Special Issue: 11|NCAMESHE-2014 | Jun-2014

[11] Pradip Nath[a], Prabir Kumar Sarker[a] ,*, Vijaya B Rangan[a] "Early age properties of low calcium fly ash geopolymer concrete suitable for ambient curing" The 5th International Conference of Euro Asia Civil Engineering Forum (EACEF-5)

[12] Mrs. P. Priya Rachel and Dr. P. Partheeban "Durability Study of Low Calcium Fly ash Based Geopolymer Concrete" Indian Journal Of Applied Research Vol.3|Issue:6|June 2013|ISSN-2249-555X.

[13] Prabir Sarker "Bond Strength of Geopolymer and Cement Concretes" Madheswaran C.K[1], Gnanasundar G[2], Gopalkrishnan.N[3] "Effect of molarity in geopolymer concrete" International Journal of Civil And Structural Engineering Vol.4, No.2, 2013.

[14] Martynkova R. And Mavroulidou M.* "Properties of Alkali-Activated Concrete Based On Industrial Wastes Or By Products" Proceedings of the 14th International conference on Environmental Science and Technology Athens, Greece,3-5 September 2015.

[15] Muhammad Salman , Ozlem Cizer , Yiannis Pontikes , Luice Vandewalle , Bart Blanpain and Koen Van Balen "Effect of Temperature On The Alkali Activation of Continuous Casting Stainless Steel Slag" Central Europe Towards Sustainable Building 2013.