THOMSON REUTERS ENDNOTE

[*P.SANTOSH* et al.*, 5 (12): December, 2016]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

FLEXURAL RESPONSE OF HYBRID FIBRE REINFORCED GEO POLYMER CONCRETE

P.Santosh*, AVS Sai Kumar, Dr. VVRLS Gangadhar
PG Student (Structural Engg)*, HOD & Assistant Professor, Principal & Professor
Princeton College of Engineering & Technology, JNTUH, Hyderabad, India

DOI: 10.5281/zenodo.221005

ABSTRACT
Concrete is the most common material for construction. Concrete is known as a significant contributor to the emission of greenhouse gases. The cement industry is the second largest producer of the greenhouse gas. The environmental problems caused by cement production can be reduced by finding an alternate material. One of potential material to substitute for conventional concrete is geo-polymer concrete. Geo-polymer concrete is an inorganic alumino-silicate polymer synthesized from predominantly silicon, aluminium and by product materials such as fly ash, GGBS (ground granulated blast furnace slag). Geo-polymer concrete does not contain cement. Hybrid fibres were used in this study. Hybrid fibre is the combination of steel fibre and basalt fibre with different volume fractions. When these fibres are added to this special concrete it improves the ductile behaviour and energy absorption capacity. The main objective of the study is to look into the shear behaviour of hybrid fibre reinforced geo-polymer concrete beams. Test specimens of 1200×150×100 mm size were used for the study. 20-30% of Fly ash by the mass was replaced by GGBS. The variable used were percentage of steel fibre volume fraction viz. 0.0%, 0.5%, and 1%, and basalt fibre volume fraction viz. 0.0%, 0.15%,and 0.3. The geo-polymer specimens were cured by using steam curing chamber. The specimens were tested after the age of 7 days. The obtained results of Fly ash and GGBS -based hybrid fibre geo-polymer concrete (F&GHGPC) specimens were compared with the only Fly ash-based hybrid.

Keywords: Concrete, GGBS, Special concrete, Geo-polymer, Shear behaviour.

INTRODUCTION
The global use of concrete is second only to water. As the demand for concrete as a construction material leads to the increase of demand for Portland cement. Concrete is a mixture of Portland cement, aggregate, and water. Concrete is the most commonly used material in the world because of its outstanding strength, durability and availability. The worldwide consumption of concrete was estimated to be about 8.8 billion tons per year. Due to increase in infrastructure developments, the demand for concrete would increase in the future.

On the other hand, the climate change due to global warming has become a major concern. The global warming is caused by the emission of greenhouse gases, such as carbon dioxide (CO_2), to the atmosphere by human activities. Among the greenhouse gases, CO_2 contributes about 65% of global warming. The cement industry is held responsible for some of the CO_2 emissions, because the production of one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere (Davidovits, 1994). Several efforts are in progress to supplement the use of Portland cement in concrete in order to address the global warming issues. These include the utilization of supplementary cementing materials such as fly ash, granulated blast furnace slag, and alkaline solution to development of alternative binders to Portland cement.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

In this respect, the geo-polymer technology shows considerable promise for application in concrete industry as an alternative binder to the Portland cement. In terms of global warming, the geo-polymer technology could significantly reduce the CO_2 emission to the atmosphere caused by the cement industries.

LITERATURE REVIEW

Narayanan et al. (1988) Investigation carried out the Shear resistance of rectangular mortar beams reinforced with three combinations of steel fibers and conventional stirrups**.** The tests have also been designed to study the effect of partial replacement of cement by pulverized fuel ash (PFA). The experiments have demonstrated the advantages of combining steel fibers and stirrups for shear reinforcement. The partial replacement of cement by PFA results in improved workability and higher long term strengths. Based on the test observations, a rapid method of assessing the ultimate shear strength of reinforced concrete beams containing both stirrups and fibers as shear reinforcement is suggested. Good correlation has been obtained between observed test values and the predictions using the method suggested in this paper.

Davidovits et al. (1994) reported that in the production of geo-polymer about less than 3/5 of energy is required and 80–90% less CO2 is generated than in the production of OPC. Thus, it is of great significance in environmental protection for the development and application of geo-polymer cement.

Malhotra (1999) The trading of carbon dioxide (CO_2) emissions is a critical factor for the industries, including the cement industries, as the greenhouse effect created by the emissions is considered to produce an increase in the global temperature that may result in climate changes. The 'tradeable emissions' refers to the economic mechanisms that are expected to help the countries worldwide to meet the emission reduction targets established by the 1997 Kyoto Protocol.

Gengying et al. (2002) Study conducted on the influence of combination of fly ash (FA) and ground granulated blast-furnace slag (GGBS) on the properties of high-strength concrete. These included compressive strength and resistance to H_2SO_4 attack, the results shown that the Combination of Fly ash and GGBS can improve both short- and long-term properties of concrete, while HFAC requires a relatively longer time to get its beneficial effect.

Gourley et al. (2003) Investigation was carried out the usage of class F Fly ash. Stated that the use of class F fly ash was more preferable than class C fly ash as source material to make geo-polymers. The alkaline activators could be prepared by soluble alkali metals that are usually sodium (Na) or potassium (K) based.

Steenie et al (2004) Investigation was done on the reduce green house gas emissions. Reported that the geo-polymer concrete, a by-product material rich in silicon and aluminum, such as low-calcium (ASTMC Class F) fly ash, is chemically activated by a high-alkaline solution to form a paste that binds the loose coarse and fine aggregates, and other un reacted materials in the mixture. The test results shown that the usage of geo-polymer concrete is eco-friendly to the nature. and reduces the green house gas emission.

Djwantoro et al (2008) Experimental investigation carried out the short term engineering properties of Geopolymer concrete. In Geopolymer mortar, Portland cement is not utilized at all. In this research, the influence of various parameters on the short term engineering properties of fresh and hardened low-calcium fly ash-based Geopolymer mortar were studied.

According to **Yang et al. (2008)** much higher compressive strength is developed in GGBFS-based alkali-activated mortars than in Fly ash-based mortars. The rate of compressive strength development of GGBS-based alkali-activated mortars was more notable at early age on the other hand, compressive strength of fly ash-based alkali-activated mortar sharply increased with increase in age.

Bakri et al. (2010) In order to produce the high strength geopolymer concrete suggested the Fly ash and GGBS based geopolymer concrete. Study indicated that fly ash and GGBS based geopolymer concrete which is having a high setting and compressive strength. Compressive strength increases with fly ash fineness and thus the reduction in porosity obtained. The use of GGBS is significantly increases the setting time and compressive strength.

Fadhil et al. (2011) Investigation on the influence of the superplasticizer and NaOH concentration on the geopolymer concrete. Found out that low superplasticizers content had poor filling and passing ability. Superplasticizers dosage upto 6% contributed to passing ability and workability further increase in dosage does not contribute any change. . As the NaOH solution concentration increases from 8M to 14M compressive strength of geopolymer concrete increases but further increase in concentration of NaOH solution decreased compressive strength on geopolymer concrete.

Abdul et al (2012) Experimental work was conducted to find the for the geopolymer concrete. Reported that Geopolymer concrete utilizes an alternate material including fly ash as binding material in place of cement. This fly ash reacts with alkaline solution (NaOH) and Sodium Silicate (Na_2SiO_3) to form a gel which binds the fine and coarse aggregates. . An attempt has been made to find out an optimum mix for the Geopolymer concrete. Concrete cubes of size 150 x 150 x 150 mm were prepared and cured under steam curing for 24 hours. The compressive strength was found out at 7 days and 28 days. The results are compared.

Parda et al. (2014). The combination of Ground granulated blast-furnace slag (GGBS) with class F fly-ash can have a significant effect on the setting and compressive strength development of geopolymer concrete. The effect of different proportions of GGBS and activator content on the workability and strength properties of fly ash based geopolymer concrete. The test result shown that 28-day compressive strength reached up to 51 MPa in geopolymer concrete containing 20% slag and 80% fly ash in the binder and 40% activator liquid with SS/SH ratio of 1.5 when cured at 20 C

Pradip et al (2014) Study was conducted on the geopolymer concrete cured under ambient condition**.** Fly ash and GGBS base geopolymer concrete for curing by ambient condition can be proportioned for desirable workability, setting time, and compressive strength using ground granulated blast-furnace slag (GGBS) as a small part of the binder. Inclusion of GGBS with Class F fly ash helped achieve setting time and compressive strength comparable to those of ordinary Portland cement (OPC).

Eswari, et al. (2008) did an experimental investigation on the the ductility performance of hybrid fibre reinforce concrete. The influence of fibre content on the ductility performance of hybrid fibre reinforced concrete specimens having different fibre volume fractions was investigated. The hybrid fibre reinforced concrete specimen's exhibit enhanced strength in flexure. The hybrid fibre reinforced concrete specimens exhibit increase in deflection comparison with plain concrete. The hybrid fibre reinforced concrete specimens exhibit reduced crack width at all load levels.

Ganesan et al.(2014) The effect of hybrid fibres on the strength and behaviour of High performance concrete beam column joints subjected to reverse cyclic loads was studied. Addition of fibres in hybrid form improved many of the engineering properties such as the first crack load, ultimate load and ductility factor of the composite. The combination of 1% volume fraction of steel fibres and 0.15% volume fraction of polypropylene fibres gave better performance with respect to energy dissipation capacity and stiffness degradation than the other combinations.

MATERIALS AND ITS PROPERTIES

Coarse aggregate: The locally supplied granite type coarse aggregate of maximum size of 20mm are used in this study. The coarse aggregate have to be clean from organic material and dust, and it has to be in saturated and surface dry condition at the stage of usage. The samples were tested as per IS 383-1970 (reaffirmed 2002).

Table.1 Properties of coarse aggregates

S.NO	**Property**	**Test Result**
1	Specific gravity	2.78
2	Bulk density	1.63 g/cc
3	Loose density	1.46 g/cc
4	Percentage voids	49.23 %
5	Water absorption	1.67
6	Fineness modulus	6.89

Fine aggregate: Naturally occur river sand passing through 4.75mm sieve conforming to grading zone II is used in this project. It is to be used at the saturated and surface dried (SSD) condition. The samples were tested as per IS 383-1970 (reaffirmed 2002).

Table.2 Properties of fine aggregate

S.NO	**Property**	**Test Result**
1	Specific gravity	2.3
2	Bulk density	1.85 g/cc
3	Loose density	1.72 g/cc
4	Percentage voids	30.30 %
5	Water absorption	6.60 %
6	Fineness modulus	2.92
7	Zone	II

Fly-ash: In the present experimental work, low calcium, class F, (ASTM) dry fly ash obtained from the silos of thermal power plant is to be used the base material. The Scanning Electron Microscope (SEM) shown in Fig.1 reveals the chemical composition of fly ash and it shown in the Table.3

Fig. 1 SEM image of Fly ash

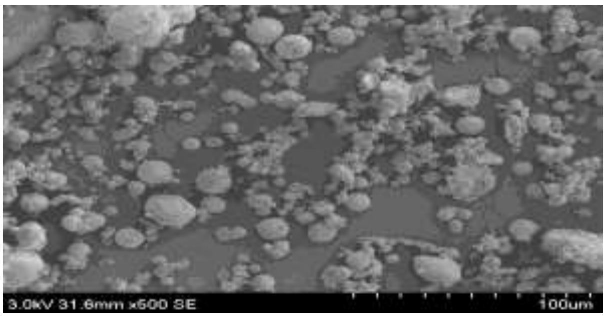


Table.3 Properties of Fly ash

S.NO	**Properties**	**Test results**
1	Specificgravity	2.36
2	Fineness	224 m^2/kg
3	Consistency	45%
4	Silica (SiO_2)	52%
5	Calcium (CaO)	4%
6	Ash	68-76%
7	Grade	F
8	Colour	Dark grey

GGBS (ground granulated blast-furnace slag):

Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces used to make iron. GGBS used in this study shown in Fig.2.

Fig.2 SEM image of GGBS

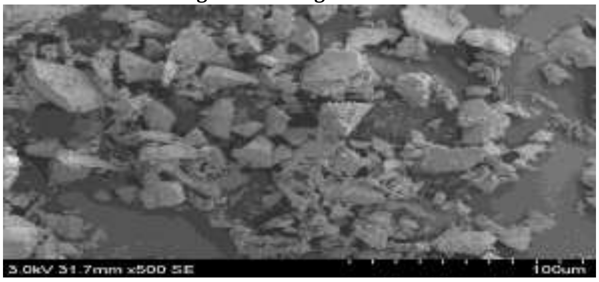


Table.4 Properties of GGBS

S.NO	Properties	Value
1	Colour	Off- white
2	Specific gravity	2.9
3	Fineness	>350m^2/kg
4	Bulk density	1200 kg/m^3
5	Calcium oxide	40%
6	Silica	35%
7	Alumina	13%
8	Magnesia	8%

Alkaline solution: A combination of the sodium hydroxide and sodium silicate solutions was used as the alkaline liquid to activate Fly ash and GGBS. Sodium hydroxide pellets and sodium silicate solution used in this study are shown in Fig.3.5 and Fig.3. A sodium hydroxide solution was prepared by dissolving the sodium hydroxide pellets in water.

Fig.3 Sodium hydroxide pellets

Table.5 Properties of sodium hydroxide (supplied by the manufacture)

S.NO	Properties	Value
1	Molecular formula	NaOH
2	Density	2.13 g/cm^3
3	Specific gravity	1.53
4	Sodium hydroxide	26.2%
5	Water	73.8%

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Table.6 Properties of sodium silicate (supplied by the manufacture)

S.NO	Properties	Values
1	Molecular formula	Na_2O SiO_2
2	Molecular weight	184.04
3	Specific gravity	1.3-1.5
4	Na_2O	14.7%
5	SiO_2	29.4%
6	H_2O	55.9%

Super plasticizer: Naphthalene based superplasticizer was used as the water reducer. Previous studies shown that the workability of fresh geo-polymer concrete mixture can be increased by adding superplaticizers. Conplast SP 430, a naphthalene based super plasticizer of specific gravity 1.22 obtained from local market was used as the chemical admixture in the study to obtain the required workability.

Table.7 Properties of Conplast SP-430

S.NO	Properties	Valve
1	Specific gravity	1.220
2	Chloride content	Nill as per IS 456
3	Air entrainment	1 to 2% air is entrained
4	Alkali content	<55g

Reinforcement:

High yield strength deformed bars (HYSD) bars of diameter 10 mm and 12 mm were used as main reinforcement in beams and 8mm bars as lateral reinforcement.

Table.8 Mechanical Properties of Reinforcement

Nominal diameter of bar	Actual diameter of bar	Yield strength	Ultimate strength	Modulus of elasticity
12	12.06	419	580	$2.28\text{x}10^5$
10	9.97	426	570	$2.32\text{x}10^5$

RESULT & DISCURSION

Compressive strength test were carried out with each mix proportion with cube of 150 mm size as per IS: 516-959 (reaffirmed 2004).

Table.9 Compressive strength of cubes

Mix	Compressive strength (MPa) 7^{th} day
I	55
II	43
III	**56**
IV	55
V	48
VI	44
VII	49
VIII	48

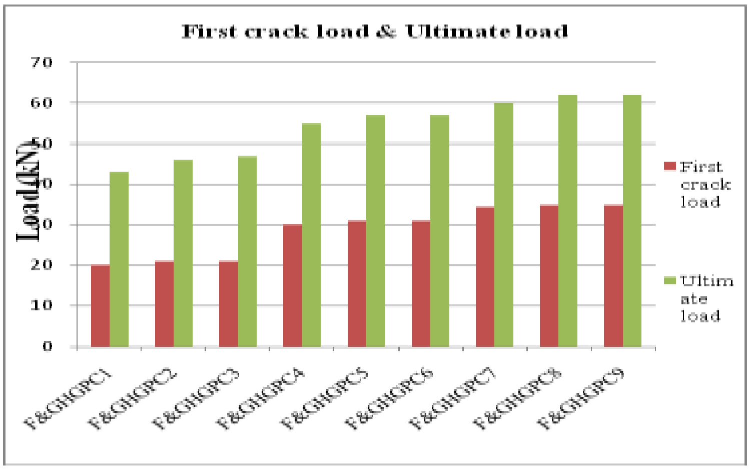
ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Table.10 Details of specimens

S. N o	Beam designation	Steel fibre volume(%)	Basat fibre	No. of beams
1	F&GHG	0	0	2
2	F&GHG	0	0.15	2
3	F&GHG	0	0.3	2
4	F&GHG	0.5	0	2
5	F&GHG	0.5	0.15	2
6	F&GHG	0.5	0.3	2
7	F&GHG	1	0	2
8	F&GHG	1	0.15	2
9	F&GHG	1	0.3	2
			Total	18

Table.11 Test results of shear specimens

Beam Designation	First crack Load (kN)	Ultimate Load (kN)	Deflection at ultimate load (mm)
F&GHGPC1	20	43	4.25
F&GHGPC2	21	46	4.50
F&GHGPC3	22	47	4.65
F&GHGPC4	30	55	5.00
F&GHGPC5	31	57	5.20
F&GHGPC6	31	57	5.22
F&GHGPC7	35	60	5.25
F&GHGPC8	35	62	5.40
F&GHGPC9	35	62	5.60



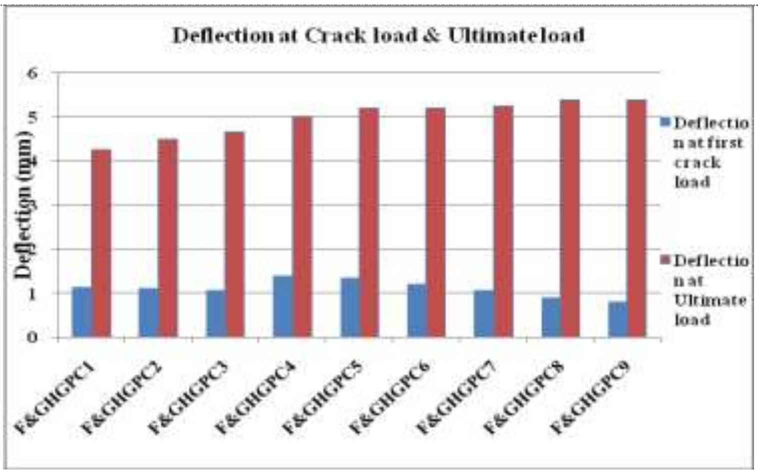


Table.12 Comparison of first crack load and ultimate load of F&GHGPC beams with FHGPC beams.

SI.No	Volume fraction (%)	First crack load (kN)		Ultimate load (kN)	
		F&GHGPC	FHGPC	F&GSHGPC	FHGPC
1	S0B0	20	10	43	23
2	S0B0.15	21	10	46	25
3	S0B0.3	22	12	47	28
4	S0.5B0	30	15	55	34
5	S0.5B0.15	31	15	57	37
6	S0.5B0.3	31	16	57	39
7	S1B0	35	20	60	41
8	S1B0.15	35	23	62	44
9	S1B0.3	35	23	62	46

CONCLUSIONS

The research reported herein comparised experinemtal study on the shear behaviour and strength of hybrid fibre reinforced fly ash and GGBS- based geopolymer concrete beams. Low calcium (ASTM Class F) dry fly ash obtained from the thermal power plant Mettur, Tamil nadu was used as the source material to make geopolymer concrete. 30% of the Fly Ash by mass is replaced by the GGBS (ground granulated blast slagfernce). Addition of GGBS increases the strength of the geopolymer concrete. Hybrid fibre (combination of Steel fibre and basalt fibres) are used in this study. Sodium silicate solution and sodium hyroxide solution were mixed to form alkaline solution. This alkaline solution have to be prepared one day before mixing with dry materials. The silicon and aluminium in fly ash reacted with alkaline solution to the form geopolymer paste that bound the loose aggregate and un-reacted materials to produce the geopolymer concrete. The aggregate consisted of coarse aggregate of maximum size 20 mm and fine aggregate confirming to zone II. The mix proportion and manifacturing process used to make the geopolymer concrete were based on the earlier studies available on geopolymer concrete.

Total 36 reinforced geopolymer concrete beams were made and tested. In this 18 beams are made with Fly ash and GGBS-based hybrid fibre geopolymer concrete (F&GHGPC) and 18 more beams are made with fly ash-based geopolymer concrete (FHGPC). These beam tested for shear behaviour of geopolymer concrete. Test results of F&GHGPC beams are compared with the test results of FHGPC beams.

i. Geopolymer concrete in structural applications has led to the total elimination of cement from concrete, which ultimately becomes "Green Concrete"
ii. The fly ash, once considered as waste material, has found usefulness through Geopolymer concrete in construction industries and become a valuable material
iii. The crack partten observed for hybrid fibre reinforced geopolymer concrete beams were similar to those reported in the literature for steel fibre reinforced portland concrete. All beams failed in ductile manner accompained by crushing of the concrete in the compression zone.
iv. While the addition of fibres improved the first crack load significantly, the improment was marginal for ulttimate load. The first crack load was found to have increased by about 75% at Steel 1% and Basalt 0.3% of fibre volume, when campared to the specimens without fibres. However the increase in ultimate load was found to be only 44%.
v. Energy absorbtion capacity increases for the beams with fibres compared to beams without fibres.
vi. Ultimate shear strength increased up to 47% for the F&GHGPC9 with 1% steel fibre and 0.3% basalt fibe.
vii. Ultimate load for the specimenS F&GHGPC5 and F&GHGPC6 is same. And ultimate load for the specimens F&GHGPC8, F&GHGPC9 is same. This may be balling effect of steel and basalt fibres.
viii. The first cracck load and ultimate load, Energy obsorption capacity and ductility behaviour of fly ash and GGBS- based beams (F&GHGPC) is higher than only fly ash- based beams (FHGPC) with same volume fraction of steel and basalt fibre.

REFERENCES

1. Abdul Aleem and Arumairaj P.D., (2012), "Optimum mix for the geopolymer concrete", Indian Journal of Science and Technology, Vol.5, No.3, pp.65-71.
2. Ambily, Madheswaran, Sharmila, Muthiah, (2011), "Experimental and analytical investigations on shear behaviour of reinforced geopolymer concrete beams", International journals of civil and structural engineering, Volume 2,No:2, pp.122-128
3. Andi Arham Adam, Horianto, (2014),"The effect of temperature and duration of curing on the strength of fly ash based geopolymer mortar", Procedia engineering 95, pp.410-414.
4. Antonio Greco A, Alfonso Maffezzoli A, Giovanni Casciaro B, Flavio Caretto B, (2014), "Mechanical properties of basalt fibers and their adhesion to polypropylene matrices",Composites: Part B 67, pp. 233–238.
5. AVS Sai Kumar, K.Anantha lakshmi Strength characteristics of concrete with partial replacement of cement with fly-ash & metakaolin"IJISRT,Vol 1, Issue 7
6. Chaohua Jiang, Ke Fan, Fei Wu, Da Chen, (2014), "Experimental study on the mechanical properties and microstructure of chopped basalt fibre reinforced concrete", Materials and Design 58, pp.187–193.
7. Davidovits.J (1994), "Properties Of Geopolymer Cements", Proceedings of 1st International Conference on Alkaline Cements and Concretes, KIEV Ukraine, pp.131-149.
8. Djwantoro Hardjito, Chua Chung Cheak , Carrie Ho Lee Ing, (2008), "Strength and Setting Times of Low Calcium Fly Ash-based Geopolymer Mortar", Curtin University of Technology, Volume 2,no.4, pp. 357-362.
9. Fadhil Nuruddin.M, Samuel Demie, Fareed Ahmed.M and Nasir Shafiq, (2011), "Effect of 0Superplasticizer and NaOH Molarity on Workability, Compressive Strength and Microstructure Properties of Self-Compacting Geopolymer Concrete", World Academy of Science, Engineering and Technology, pp.163-171.