International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 04, April-2019

Interface Shear of Fly ash and GGBS Based Geopolymer Concrete

B.Laxman Raju[1], L.Sudheer Reddy[2], Sumanth Kumar B[3]

[1]*PG Scholar, Department of Civil Engineering, KITS Warangal, India*
[2] *Professor, Department of Civil Engineering, KITS Warangal, India*
[3]*Asst. Professor, Department of Civil Engineering, KITS Warangal, India*

Abstract-This article presents an experimental study conducted to find the shear strength of geopolymer concrete. In addition, it was proposed to check the suitability existing equations like Birkeland and Birkeland, Mattock and Design code ACI 318, which are developed for ordinary Portland cement concrete for estimating the shear capacity of geopolymer concrete. Push off Samples were used to study the shear strength at the interface. Both reinforced concrete and non-reinforced concrete samples were used for investigation. It was observed that the shear strength of geopolymer concrete is superior to OPC concrete. The existence of reinforcement transversely shear plane produced a rise of about 29% of the shear resistance against slip.

Keywords: Interfacial shear, Fly ash. GGBS, ACI 318, Shear Friction, Geopolymer concrete

I. INTRODUCTION

Cement production processing is done at very high temperatures (from 1400 to 1500°C) and leads to uncontrolled mining natural resources and CO_2 emissions (greenhouse gas). Many efforts are being made to reduce the use of Portland cement in construction. These efforts include the use of supplementary cement materials against the replacement of Portland cement. Geopolymer concrete (GPC) is one such alternative for replacing Portland cement in concrete.

Geopolymers are formed by alkaline activation of alumino-silicate material. Formation The three-dimensional structure of geopolymer includes the main chemical reactions, such as dissolution, hydrolysis, and condensation. Depending on the ratio of silicon dioxide and alumina, there may be a geopolymer with a Si-O-Al or Si-O-Si bond [5, 6]. A literature review shows that fly ash, metakaolin, rice husk ash, red mud, etc. are commonly used alumino-silicate material and alkaline solutions include sodium hydroxide, potassium hydroxide, sodium silicate, calcium silicate, etc. [11]. GPC may require heat to facilitate the polymerization process. However, a small portion of the calcium-rich material, such as crushed granulated blast furnace slag, can be added to the mixture to ensure curing at room temperature.

GPC is best for precast concrete. However, connective distress is found in the prefabricated structure is centered around the shear boundary type of failure along a well-defined plane associated with brackets, support shoes, main book beam bearing, connected shear wall, wall to the foundation, deep beams, etc. [10, 12]. Shear-interface study of such monolithic and prefabricated structures is very important.

Studies have been done in the past to understand the shear strength of an interface in a typical Portland cement (OPC) concrete. Birkeland et al. [2] proposed the concept of friction shear to assess the shear resistance of the surface of a concrete block. Their hypothesis suggests that the external load shift tends to cause slippage along the interface plane, and it resists shear friction connection. They also suggested that the reinforcement across the interface is tensioned and that the dowel action is negligible. Accordingly, the shear capacity through the interface monolithic concrete with transverse shear plane reinforcement was calculated

$$v_u = \rho f_y \tan \varphi$$

Where v_u is the ultimate longitudinal shear stress at the interface;

ρ is the reinforcement ratio;

f_y is the yield strength of the reinforcement

φ is the internal friction angle.

The tangent of the internal friction angle is also designated as the coefficient of friction, represented by μ. This expression was proposed for smooth concrete surfaces, artificially roughened concrete surfaces, and concrete to steel interfaces.

The coefficient of friction was defined for several situations as:

μ = 1.7 for monolithic concrete (59.5°)

μ = 1.4 for artificially roughened joints (54.5°)

μ = 0.8-1.0 for ordinary construction joints (38.7° – 45°)

Mattock [8] reported shear strength research on reinforced concrete with and without a crack existing along the shear plane of repulsion samples and came to the conclusion that the shear stress depends on the initial state of the crack, the product of the gain and yield strength of shear reinforcement. It is assumed that the action of the rebar pin intersecting the shear plane is insignificant in the raw concrete, but significant with an already existing crack along the shear plane.

The friction shear design proposed by ACI assumes the value of the friction coefficient (μ or tan φ) for monolithically placed concrete as 1.4λ, where the λ value for normal-weight concrete is one. The value of λ depends on the type of concrete; namely, normal weight (λ = 1), sand light (λ = 0.85) and all light (λ = 0.75). Based on experimental studies using push-off specimens, Mattock [9] proposed an alternative equation to predict the final interface shear capacity, defined as

$$v_u = 400A_c + 0.8\left(A_s f_y + \sigma_n\right) \text{ (PSI)}$$

$$v_u = 2.76A_c + 0.8\left(A_s f_y + \sigma_n\right) \text{ (MPa)}$$

Researchers conducted experimental studies and the proposed modification of the ACI 318 – 2014 equation [1] to predict the interface shear strength of high strength concrete. It can be concluded that the shear strength of the interface concrete depends on various parameters such as the type of concrete, type of aggregate, cohesion concrete strength, the percentage ratio of reinforcement across the shear plane, etc. However, the study Shear strength of geopolymer concrete was not reported in the literature. Therefore, it has It was proposed to conduct an experimental study to study the behaviour of the interface shear geopolymer concrete.

II. EXPERIMENTAL PROGRAM

Fly Ash: Fly Ash was used as one of binder material and confirmed to IS: 3812 [4]. The Specific gravity was 2.17.

Ground Granulated Blast Furnace Slag (GGBS): Along with Fly ash, GGBS is used in the experiment which is confirmed to IS: 12089[3]. The Specific gravity was 2.90.

Alkaline Solution: Alkaline Solution with NaOH having a concentration of equal 8 moles/L was used. The ratio of sodium silicate solution to sodium hydroxide solution was 2.5 and the mixed solution was kept for 24 hours at room temperature (25±2°C) before it was used for casting.

Water: Potable water was used.

Super plasticizer: Sulphonate Naphthalene polymers (Complast SP430 Fosroc Make) was used as Super plasticizer.

Aggregates: Crushed and angular aggregate of nominal size 20 mm was used as coarse aggregate. For fine aggregate natural River sand had been used with grading zone as Zone II of IS: 383[7] and fineness modulus has been reported as 3.35. The water absorption was 2 % and the specific gravity was 2.61.

A. *Mix Proportions*

Mix proportion for GPC push off specimens was adopted from the procedure given by G Mallikarjuna Rao et al [13] and mix quantity shown in Table.1 after making different trials having different strengths.

TABLE I
Materials used in GPC (per Cu.m)

S. No	Grade of GPC	***Materials***						
		Coarse Agg. (kg)	Fine Agg. (kg)	Fly Ash (kg)	GGBS (kg)	NaOH Sol. 8 Molarity (kg)	Sodium Silicate (kg)	SP* (kg)
1	A20	965	812	294	126	66	165	4.2
2	B30	965	812	252	168	66	165	4.2
3	C40	965	812	210	210	66	150	4.2
*SP: Super plasticizer (SP 430, Make: Fosroc Chemicals).								

B. *Casting of GPC Push-off Specimens*

Dimensions of the push-off specimens considered for the study are presented in Figure 2. The samples were cast with and without reinforcement through the shear interface. 3 No's of 2L-6mm diameter i.e. 0.77% of steel with a yield strength of 250MPa are considered as closed links across the interface. 10 mm and 6mm (for links) diameter bars were considered to resist the flexural failure at the loading point. The details of the reinforcements are shown in Figure 3. After 24 hours, Samples were de-moulded and air cured for 28 days. The room temperature and relative humidity are 35±2^0 C and 75% are respectively. Before testing V-Groves of 4mm deep were made on either side of the push off specimen along shear plane for ensuring the failure at the interface.

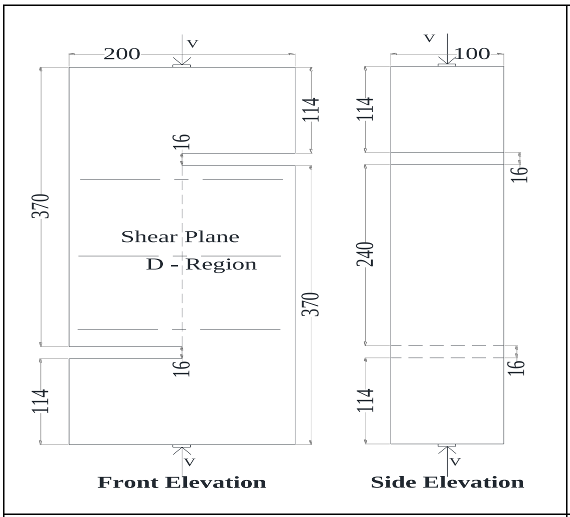

Figure 2. Push off Specimen

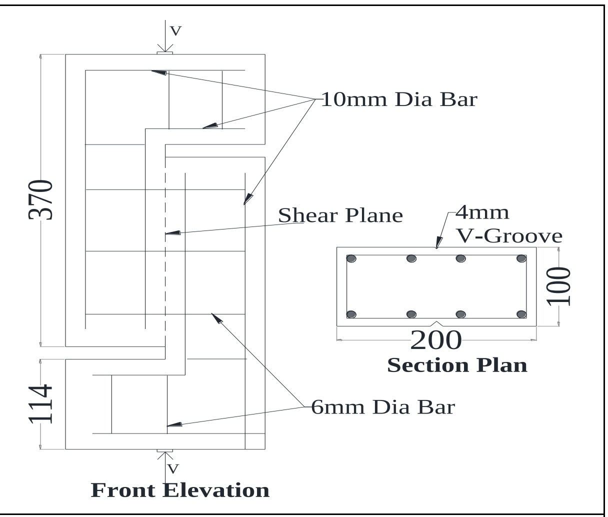

Figure 3. Reinforcement Details for Push -Off specimen

C. *Testing of GPC Push-off Specimens*

Figure 4, shows the test setup for push-off specimens. The samples were loaded axially till failure. The Push-off models with and without reinforcement across the slip plane, tested and failed by developing a crack along the interface. Figure 5, shows the typical failure in the push-off specimens. From the axial loads at failure (Ultimate load) the shear strength was calculated by dividing the ultimate load with the cross-sectional area of the interface. The failure loads and the shear strength values are given in Table.2.

Figure 4. Test Setup

Figure 5. Failure Pattern for unreinforced and reinforced across shear plane

III. RESULTS AND DISCUSSIONS

Cracking along the slip plane was virtually sudden in case of push off specimens with no reinforcement across the interface during testing, however, in event of push off specimens having reinforcement transverse the shear interface the visible cracking along the shear plane was noticed at about 70 to 80 percent of the ultimate loads. Due to the provision of suitable reinforcement in both halves of push of specimen, none of the specimens have failed prematurely due to flexure in horizontal or vertical arms of the push off specimen.

TABLE II
Ultimate loads, Shear strength of GPC Push off specimens

f_{ck}	With No Transverse Reinforcement across the shear interface			With Transverse Reinforcement across the shear interface			$(V_{ur}- V_{up}) / V_{up}$
	Spec.ID	P_u	V_{up}	Spec.ID	P_u	V_{ur}	
24.56	ANRS1	56.87	2.58	AWRS1	127.85	5.79	1.25
28.84	ANRS2	61.50	2.79	AWRS2	139.50	6.32	1.27
32.39	ANRS3	71.98	3.26	AWRS3	169.05	7.66	1.35
33.55	BNRS1	79.44	3.60	BWRS1	187.45	8.49	1.36
33.99	BNRS2	83.99	3.80	BWRS2	190.32	8.62	1.27
34.71	BNRS3	87.12	3.95	BWRS3	201.45	9.12	1.31
36.99	CNRS1	92.24	4.18	CWRS1	203.25	9.21	1.20
43.30	CNRS2	95.12	4.31	CWRS2	216.45	9.80	1.28
47.57	CNRS3	99.45	4.50	CWRS3	234.45	10.62	1.36
Notations						**Avg**	**1.29**

f_{ck}	Concrete Compressive Strength of 150mm Cube (MPa)	bh	Cross sectional area of the interface = 92 x 240 mm^2
P_u	Average Experimental Peak Load (kN)	V_{up}	Shear Stress at the unreinforced interface (MPa) = Pu/bh
V_{ur}	Shear Stress at the reinforced interface (MPa) = P_u/bh		

TABLE III
Comparison of Shear capacity using the empirical formula

Specimen ID	Ultimate Load Experimental Value $P_{U\,EXP}$ (kN)	Ultimate load Theoretical value P_{Uthe} (kN)			$P_{U\,EXP}$ / P_{Uthe}		
		Birkeland and Birkeland [2]	Mattock [9]	ACI 318 2014 [1]	Birkeland and Birkeland [2]	Mattock [9]	ACI 318 2014 [1]
GANRS1	56.87	0.00	60.94	0.00	0.00	0.93	0.00
GANRS2	61.50	0.00	60.94	0.00	0.00	1.01	0.00
GANRS3	71.98	0.00	60.94	0.00	0.00	1.18	0.00
GBNRS1	79.44	0.00	60.94	0.00	0.00	1.30	0.00
GBNRS2	83.99	0.00	60.94	0.00	0.00	1.38	0.00
GBNRS3	87.12	0.00	60.94	0.00	0.00	1.43	0.00
GCNRS1	92.24	0.00	60.94	0.00	0.00	1.51	0.00
GCNRS2	95.12	0.00	60.94	0.00	0.00	1.56	0.00
GCNRS3	99.45	0.00	60.94	0.00	0.00	1.63	0.00
GAWRS1	127.85	59.38	94.87	59.38	2.15	1.35	2.15
GAWRS2	139.50	59.38	94.87	59.38	2.35	1.47	2.35
GAWRS3	169.05	59.38	94.87	59.38	2.85	1.78	2.85
GBWRS1	187.45	59.38	94.87	59.38	3.16	1.98	3.16
GBWRS2	190.32	59.38	94.87	59.38	3.21	2.01	3.21
GBWRS3	201.45	59.38	94.87	59.38	3.39	2.12	3.39
GCWRS1	203.25	59.38	94.87	59.38	3.42	2.14	3.42
GCWRS2	216.45	59.38	94.87	59.38	3.65	2.28	3.65
GCWRS3	234.45	59.38	94.87	59.38	3.95	2.47	3.95
				Average	**3.12**	**1.96**	**3.12**

In the un-cracked stage, the shear across the interface in Push-off specimen is expected to be resisted mainly by the cohesion due to aggregate interlock of the concrete. After the beginning of cracking laterally the shear plane, the cohesion of concrete reduces and the other actions such as friction and dowel action of reinforcement across the interface come into action. Table 2 shows the shear strength for unreinforced and reinforced push-off specimens. In the event of reinforced shear interfaces, the shear strength has enhanced about 29%.

Table 3 relates the investigational shear capacity of reinforced specimen with the empirical formula available in the literature [1, 2, and 9]. From this table, it may be witnessed that the empirical formula proposed for OPC concrete, when used for GPC underestimates the shear capacity. Since no equation is presented for the prediction of shear strength of GPC it is suggested that, same empirical equations can be used for estimating shear strength. However, further study has to be carried out to propose a more developed estimate of shear strength of geopolymer concrete.

IV. CONCLUSIONS

The following are the conclusions arrived at after the comparative study of Shear strength of monolithic GPC interface.

1. The shear strength of GPC interface has improved with increase in compressive strength of GPC.
2. The existence of reinforcement transversely shear plane produced a rise of about 29% of the shear resistance against slip
3. The available normal concrete shear strength prediction models are highly conservative in estimating the shear strength of unreinforced and reinforced monolithic shear interfaces in GPC.
4. The models by Mattock (1974) seems to give better prediction of shear strength of GPC.

REFERENCES

[1] ACI (American Concrete Institute), 2014. Building code requirements for reinforced concrete. ACI 318-14.

[2] Birkeland, P. W., and Birkeland, H. W. "Connections in Precast Concrete construction," ACI journal, Proceedings, (1966), 63, (3), Mar. 1966, pp. 345-368.

[3] BIS (Bureau of Indian Standards), 1999. IS 12089: Indian standard specifications for granulated slag for the manufacture of Portland slag cement.

[4] BIS, 2003. IS 3812: Specification for fly ash for use as pozzolanic and admixture.

[5] Davidovits, J., Chemistry of Geopolymeric Systems, Terminology, Geopolymer'99, International Conference, France (1999).

[6] Divya Khale and Rubina chudhary "Mechanism of Geopolymerisation and factures influencing it development: Review", J. of Mater. Sci, (2007). 42, pp.729-746.

[7] IS: 383, 2016. Specification for coarse and fine aggregates from natural sources for concrete.

[8] Mattock, A.H. and Hawkins, N.M., 1972. Shear transfer in reinforced concrete-recent research. PRECAST/PRESTRESSED CONCRETE INSTITUTE. JOURNAL, 17(2).

[9] Mattock, A.H. - Shear transfer in concrete having reinforcement at an angle to the shear plane, American Concrete Institute, Special Publication 42-2, pp. 17-42, January 1974.

[10] Nicolas Saenz1and Chris P. Pantelides, M., "Shear Friction Capacity of Concrete with External Carbon FRP Strips", Journal of Structural Engineering, (2005), 131(12), pp.1911-1919.

[11] Pan Zhihua, Li Dongxu, Yu Jian, Yang Nanry. "Properties and microstructure of the hardened alkali activated red mud-slag cementitious material", Cem and Concr Res., (2003), 33(9), pp.1437–41.

[12] Park, R. and Pauley, T. Reinforced Concrete Structures, Wiley Inter-Science Publication, John Wiley& Sons, New York, 1975.

[13] Rao, G.M., Rao, T.D., Seshu, R.D. and Venkatesh, A., 2016. Mix proportioning of geopolymer concrete. Cement Wapno Beton, 21(4), pp.274-285.