International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.8, No.3, pp 1359-1364, 2015

Bond Behaviour of Fly Ash Based Concrete Reinforced with GFRP and Steel Bars

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Abstract: Fly ash based concrete is a developing construction material in which fly ash is partially substituted for cement. The use of GFRP as reinforcement in concrete structures is also considered to be a possible substitute to steel in those situations, where corrosion is possible. This paper evaluates the comparison of bond strength (BS) of fly ash replaced concrete (FAC) with sand coated GFRP bars and that of ribbed steel bars. Pull-out test is performed in accordance with IS: 2770 (Part I) – 1967. Tests were carried out on cube specimens and the BS of the various mixes of FAC was compared. The compressive and tensile strength of FAC is compared with that of ordinary cement concrete. The test parameters were Fly Ash replacing cement at 0%, 15%, 20% and 25% and also various diameters of reinforcement bars of GFRP and steel bars used during the test. The diameter of the bars were kept as 16mm and 20 mm diameter. The fly ash replacement is of the order 0%, 15%, 20% and 25%. The embedment length was kept as a constant of 140mm. The conclusive results of the tests indicate that if the diameter of the bar increases, the bond strength also increases. For 25% replacement of cement using fly ash, yields equal bond strength of the Ordinary Portland Cement.
Key words - Bond strength, fly ash replaced concrete, sand coated GFRP bars, Pull out test.

Introduction

The BS depends mainly on diameter of bars, bar surface, embedded length, concrete compressive strength, mechanical properties of bar and concrete cover. In the design of reinforced concrete members, it is necessary to ensure whether suitable bond is attained between steel bars and the surrounding concrete. As the use of steel bars as reinforcement embedded in concrete faced corrosion problems in structures exposed to highly aggressive environments, such as sea water , fiber reinforced polymer (FRP) reinforcing bars have been developed .They have high mechanical performances, low weight, satisfactory durability in an aggressive environment and Flexibility. As cement is not cost effective, and emits large amount of carbon dioxide during its production causes environmental problems, alternatives should be used to overcome such hindrances. Fly ash is one such alternative which is found in abundance that can be substituted for cement to a certain required percentage. It is also more cost effective and eco-friendly than other possibilities.

Bond in the concrete is defined as the transfer of shear force from bars to the surrounding concrete. The force is transferred by reinforcing bars and the bearing of the ribs of deformed bars against the concrete surface by adhesion and friction between concrete[1]. The study shows that, for low modulus and high modulus GFRP bars bond strength varies with different test parameters. Both GFRP bars show similar trend line for average bond strength[2]. Bond is depends on the different parameter like diameter of bar, surface condition of bar and embedment length[3]. The failure of GFRP bars in normal and self-compacting concrete is by splitting of concrete than pullout is same for steel bars but more cracks in GFRP bars than steel bars[4]. The test parameters of GFRP bars is rib diameter, rib height, rib spacing. From the results optimal rib spacing and rib height are the parameters which gives high strength[5]. In this study the bond strength increases with increase in concrete compressive strength. Steel bars failed in concrete crushing but GFRP bars failure occurs by binding of concrete and bar[6]. GFRP bars higher bond strength than MS bars. In this study two types of concrete failure occurred 1.splitting with longitudinal crack 2.concrete splitting. Embedment length decreases and increases in bond strength[7]. Concrete with high compressive strength the GFRP bars failed in pullout manner so the bond of FRP bars is not depends on the compressive strength of concrete. For low strength concrete, bond failure depends on concrete strength[8].

From the literatures, it has been observed that not much attempts have been made so as to compare bond behaviour of sand coated GFRP and steel bars with partial replacement of cement with fly ash. So it is very essential to study and investigate the bond behaviour of FAC concrete. The bond behaviour of FAC concrete is investigated with reinforcing steel and sand coated GFRP bars using pullout test. For comparison, control pullout specimens are made with steel and sand coated GFRP bars.

Materials & Methods

Cement

Ordinary Portland cement of 43 grade conforming to IS: 8122-1989 was used.

Table 1. Properties of ordinary Portland cement (OPC)

Description	Composition
Specific gravity	3.05
Initial setting time	30 minutes
Final setting time	600 minutes

Fly Ash

Fly ash of class C type was used as a cementitious material which was obtained from Neyveli Lignite Corporation, with a specific gravity of 2.2.

Table 2. Chemical properties of fly ash (mass %)

SiO_2	AL_2O_3	Fe_2O_3	CaO	LOI
31	22	7	35	5

Aggregates

Coarse aggregate (Granite) of maximum size 20 mm were used. River sand was used as fine aggregate.

Table 3. Properties of coarse and fine aggregates.

Properties	Coarse aggregate	Fine aggregate
Specific gravity	2.68	2.39
water absorption	1.56	0.8

Reinforcing Bars

In this study ribbed steel bars and sand coated low modulus GFRP bars are used. Diameter of bar used is 16 and 20 mm.

Table 4. Properties of steel and sand coated GFRP bars

Bar type	Bar diameter (mm)	Young's Modulus (GPa)	Tensile strength (MPa)	Yield load (kN)
Steel	16	200	653	83
Steel	20	200	662	98
GFRP	16	26	247	50
GFRP	20	26	363	92

Fig 1. Steel and GFRP bars

Experimental Investigation

Specimens were cast for a replacement of fly ash by 0%, 15%, 20% and 25% with cement. The cube specimens of size 150 × 150 × 150 mm were cast for compressive strength and cylindrical specimens of diameter 150 mm and height of 300 mm for split tensile strength. For pullout test, the specimens were cast as per IS code specifications for 16 mm and 20 mm diameter bars. The bars were embedded for a length of 140 mm. The compressive and split tensile strength test are done in compression testing machine as shown in fig 2 (a) and fig 2 (b). Pullout test is conducted in universal testing machine as shown in fig 2(c). The specimens were tested until it reaches peak load.

Fig. 2(a) Test setup of compressive strength

Fig. 2(b) Test setup of tensile strength

Fig. 2(c) Test setup of pullout test

Results and Discussion

Effect of Reinforcing Bar

From the results, the BS varies for different parameters. All the test parameters are compared to the control specimens. The pullout specimens with steel bars failed by splitting of concrete, whereas the specimens used for GFRP bars showed bond failure before concrete cracks. The crack pattern of specimens is present in fig (3) for steel bars and fig (4) for GFRP bars.

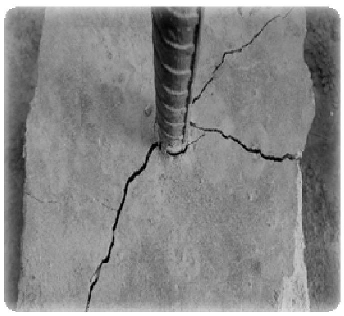

Fig 3.Faiure specimen of steel bar

Fig 4.Failure specimen of GFRP bar

All the test results shows that 25% FAC gave optimum values compared to other replacements. The average BS is taken from 2.5mm slip load and peak load.

Table 6. Bond strength of steel and GFRP bars in fly ash replaced concrete.

Description	Diameter of bar (mm)	Load @2.5mm slip (kN)	Bond strength (MPa)	Peak load (KN)
Fly ash replacement				
Steel bars				
control specimen				
15%	16	12	1.7	85
20%	16	8.35	1.18	72
25%	16	8.5	1.2	75
control specimen	16	11.5	1.64	83
15%	20	20	2.3	115
20%	20	15	1.73	100
25%	20	15.6	1.79	108
Sand coated GFRP bars	20	19	2.2	112
control specimen				
15%	16	10	1.42	75
20%	16	7	0.99	62
25%	16	7.2	1.02	63
control specimen	16	10.5	1.49	76
15%	20	15	1.73	100
20%	20	12	1.38	95
25%	20	13	1.5	97

Effect of Fly Ash Content

From the pullout test results of steel and sand coated GFRP bars specimen indicates, when the diameter of bar increases the bond strength also increases for both type of bars. Normally the bond strength increases for larger diameter, which was due to larger surface contact area of bars with concrete. The effect of bar diameter on bond strength for 16mm and 20mm diameter bars are shown in Fig (5), from which it can be seen that 16mm to 20mm steel and GFRP bars showed an increase in BS by 10% and 8.5% respectively.

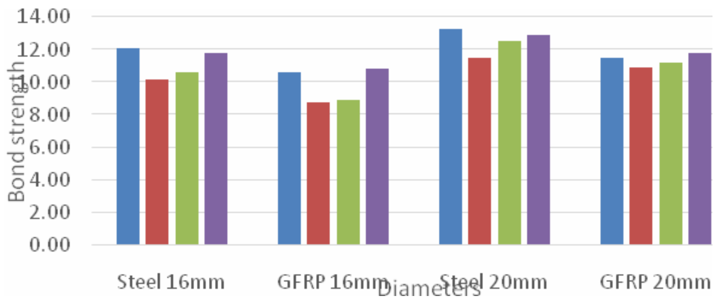

Fig 5. Bond strength of steel and GFRP bars with different diameters

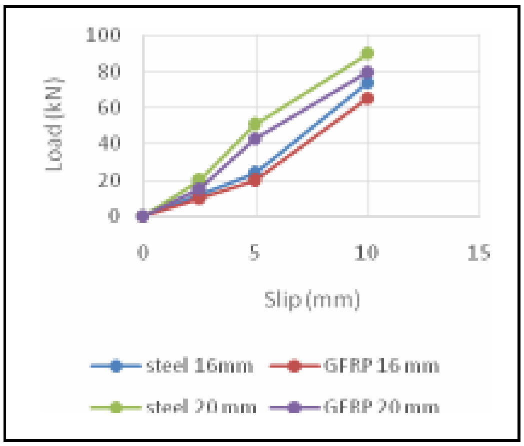

Fig 6.Comparision of Steel and GFRP bars for 0% replacement of fly ash

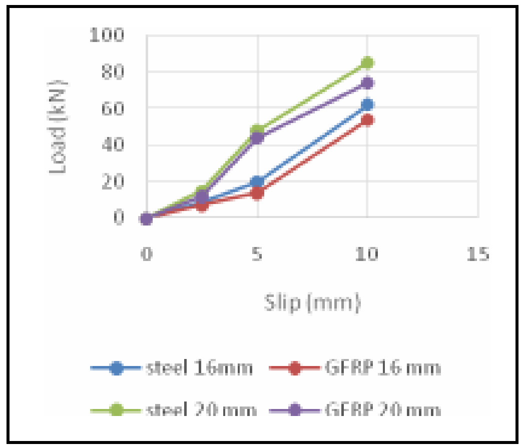

Fig 7.Comparision of Steel and GFRP bars for 15% replacement of fly ash

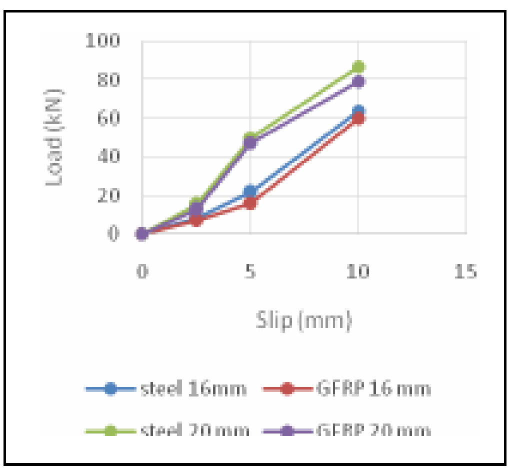

Fig 8.Comparision of Steel and GFRP bars for 20% replacement of flyash

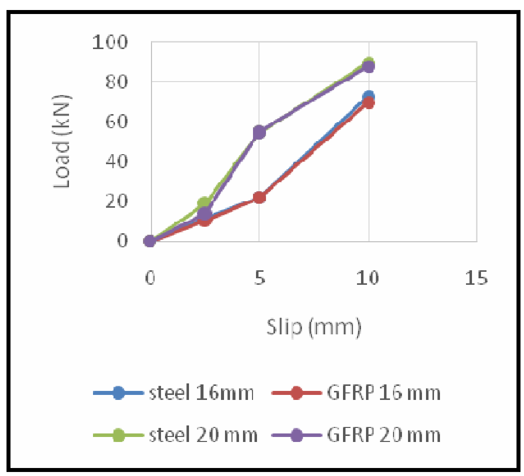

Fig 9. Comparision of steel and GFRP bars for 25% replacement of fly ash

From the graph, the 25% FAC has similar bond strength of OPC concrete. Fly ash contains less cementitious property when compared with OPC, but fly ash reduces water-cement ratio and increases the workability of concrete due to the size of particle. So the BS of 25% FAC gives similar results when compared to OPC concrete. The bond strength of steel control specimen increases by 2.3% and 3% compared to 25% FAC for 16mm and 20mm diameters respectively. For sand coated GFRP bars the 25% FAC gives higher bond strength of 1.5% and 2.5% for 16mm and 20mm diameter respectively. The BS between steel and sand coated GFRP, steel bars provides more bond than that of GFRP bars. The sand coated GFRP bars gives less bond strength than steel bars but provides sufficient bond strength. The failure of sand coated GFRP bar is due to low adhesion capacity between concrete and the bar. The bond strength of steel bar is more than 10% of sand coated GFRP bars in control specimens.

Conculsions

This study has been performed to find the BS of steel and sand coated GFRP bars in OPC concrete and FAC. From the test results the following conclusions were arrived,

- Fly ash concrete shows similar BS as that of OPC concrete.
- The pullout specimens with steel bars failed by splitting of concrete whereas Specimens with sand coated GFRP bars failed by bond failure.
- As the diameter of bar increases, the bond strength increases proportionally.
- For steel and sand coated GFRP bars 25% FAC gives similar results in pull out test.
- For 2.5mm slip of the bar the BS obtained for steel and sand coated GFRP bars are similar.
- The BS of sand coated GFRP bars is comparatively less than steel bars as there is less adhesion between the sand coated GFRP bar and surrounding concrete.

References

1. Qingduo Hao., Yanlei Wang., Zheng He and Jinping Ou., Bond strength of glass fiber reinforced polymer ribbed rebars in normal strength concrete, Construction and Building Materials, 2009, 23, 865–871.
2. Hossain, K. M. A., Ametrano, D., Lachemi, D., Bond Strength of Standard and High -Modulus GFRP Bars in High-Strength Concrete, Journal of materials in civil engineering, 2014, 3, 449-456.
3. Prabir Kumar Sarker., Bond strength of reinforcing steel embedded in fly ash-based geopolymer concrete, Materials and Structures, 2011, 44, 1021–1030.
4. Emadaldin Mohammadi Golafshani., Alireza Rahai., Mohammad Hassan Sebt., Bond behavior of steel and GFRP bars in self-compacting concrete, Construction and Building Materials, 2014, 61, 230–240.
5. Reza Esfahani. M., Mehrollah Rakhshanimehr., Roohollah Mousavi.S., Bond Strength of Lap-Spliced GFRP Bars in Concrete Beams, Journal of Composites for Construction, 2013, 3 , 314-323.
6. Lee, J.Y., Kim, T.Y., Kim, T.J., Yi, C.K., Park, J.S., You, Y.C., Park, Y.H., Interfacial bond strength of glass fiber reinforced polymer bars in high-strength concrete, Composites: Part B, 2008, 39, 258–270.
7. Malvar, L. J., Cox J.V and Bergeron Cochran, k., Bond between Carbon Fiber Reinforced Polymer Bars and Concrete. I: Experimental Study, Journal of Composites for Construction, 2003, 2, 154-163.
8. Julio, F., Davalos., Yi Chen. , Indrajit Ray., Effect of FRP bar degradation on interface bond with high strength concrete, Cement & Concrete Composites, 2008, 30, 722–730.
9. Yining Ding., Xiliang Ning., Yulin Zhang., Pacheco-Torgal, F., Aguiar, J.B., Fibres for enhancing of the bond capacity between GFRP rebar and concrete, Construction and Building Materials, 2014, 51, 303–312.
10. IS 2770 (Part 1)-1961, Indian Standard for Methods Of Testing Bond In Reinforced Concrete– Guidelines, Bureau of Indian Standard, Manak Bhavan, 9 Bahadur Shah ZaFAC Marg, New Delhi 110002.
11. IS 10262- 2009, Indian Standard for Concrete Mix Proportioning – Guidelines, Bureau of Indian Standard, Manak Bhavan, 9 Bahadur Shah ZaFAC Marg, New Delhi 110002.
12. IS:516 – 1959, Indian Standard Methods of Tests for Strength of Concrete, Bureau of Indian Standard, Manak Bhavan, 9 Bahadur Shah ZaFAC Marg, New Delhi 110002.
13. IS 1727 - 1967, Indian Standard for Methods Of Test For Pozzolanic Materials Guidelines, Bureau of Indian Standard, Manak Bhavan, 9 Bahadur Shah ZaFAC Marg, New Delhi 110002.

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