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BEHAVIOR OF HIGH STRENGTH CONCRETE COLUMN REINFORCED WITH HYBRID REINFORCEMENT POLYMERS SUBJECTED TO AXIAL LOAD

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ABSTRACT: Behavior of High Strength Concrete (HSC) column reinforced with steel, basalt fiber and hybrid reinforcement bars were investigated in this paper. Four Columns with 300*150 mm cross section and height of 1000 mm and reinforced with various type of reinforcement. Two of the specimens were reference. The specimens were casted and tested under axial loading. Type of failure, shape of cracks and strain of concrete and reinforcement were investigated. The results were satisfied and logic. In addition, show that the failure of HSC column reinforced with basalt reinforcement were brittle failure.

Key Words: High strength concrete (HSC), Fiber Reinforcement Polymers (FRP), Basalt fiber, Hybrid reinforcement, Axial loading, brittle failure, compression failure.

1. INTRODUCTION

A lot of research is always trying to find advanced, economical, and new material to manufacture new products with more workability, strength, etc. Using steel reinforcement in structural elements has many disadvantages like corrosion resistance, durability, and heavyweight compared with (FRP) reinforcement. As a result of the disadvantages of using steel in the structural elements, FRP is being used. FRP has been used in retrofitting/ strengthening columns and other elements of structures. FRP are composite materials composed of fibers embedded in a plyometric resin which types are Steel fibers, glass

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fibers, aramid fibers, carbon fibers, and basalt fibers as shown in figure 1.1.

Figure 1.1: various types of FRP.

Using composite materials in civil engineering spread during the last decades, because of their advantages like high strength-to-weight ratio, ease of handling, speed of installation, low thickness, visual impact and low weight, reversibility.

Residual strength of basalt fibers and glass fibers after thermal load at high temperatures have been compared [1]. The advantages of basalt fiber are having good resistance to chemical attack and fire with less poisonous fumes, also higher impact load [2]. Dias introduced basalt fibers in order to enhance the fracture toughness into concrete composites [3]. It was founded that using continuous basalt fibers improved the tensile strength of concrete more than E-glass fibers and gave a greater failure strain than the carbon fibers [4]. The influence of the volumetric fraction of chopped basalt fiber on the fracture toughness of geopolymetric cement concrete reinforced with basalt were investigated by Dias and Thaumaturgo. Also, they compared it with ordinary Portland cement concrete that reinforced with basalt fiber also [5].

A concrete cylinder which confined with basalt fiber reinforced polymer has been tested and examined its tensile strength has. The results show that the strength enhancement of the concrete cylinders consists of more ductile behavior [6]. High strength fiber reinforced concrete has been carried out and tested. Result shows that the flexural strength and toughness have been improved by Metallic fibers, but the formation of cracks delay by Non-metallic fiber [7].

The behavior of high-strength fiber concrete columns reinforced with glass fiber-reinforced polymer bars and strengthened by carbon-fiber-reinforced polymer wrap has been studied, The results show that steel-reinforced columns have a 13% higher ultimate load than corresponding GFRP reinforced columns, Also the first crack and failure load had an approximately linear increase with the presence of steel fiber in concrete from 20% to 42% for 1% fiber content and from 21% to 26 % for the first crack and ultimate load respectively [8]. An experimental and analytical study on 21 high-strength concrete tied columns under axial compression has been presented [9].

Most of the research studies undertaken in strengthening columns are based on concentrically loaded columns. In effect, the behavior of FRP wrapped columns under the influence of eccentric loading is less known compared to concentrically loaded columns [10].

2. Experimental Program

a. Test Specimens

Four HSC columns with 150 mm ×300 mm cross-section and 1000 mm in overall height were casted and tested. The columns are short columns as they have an aspect ratio of 3.33. Two of the columns were reference column and one of them reinforced with 6Ø12 steel, Also, the other control column reinforced with 6Ø12 basalt reinforcement. Also, two specimens were reinforced with hybrid reinforcement as shown in figure 1.2.

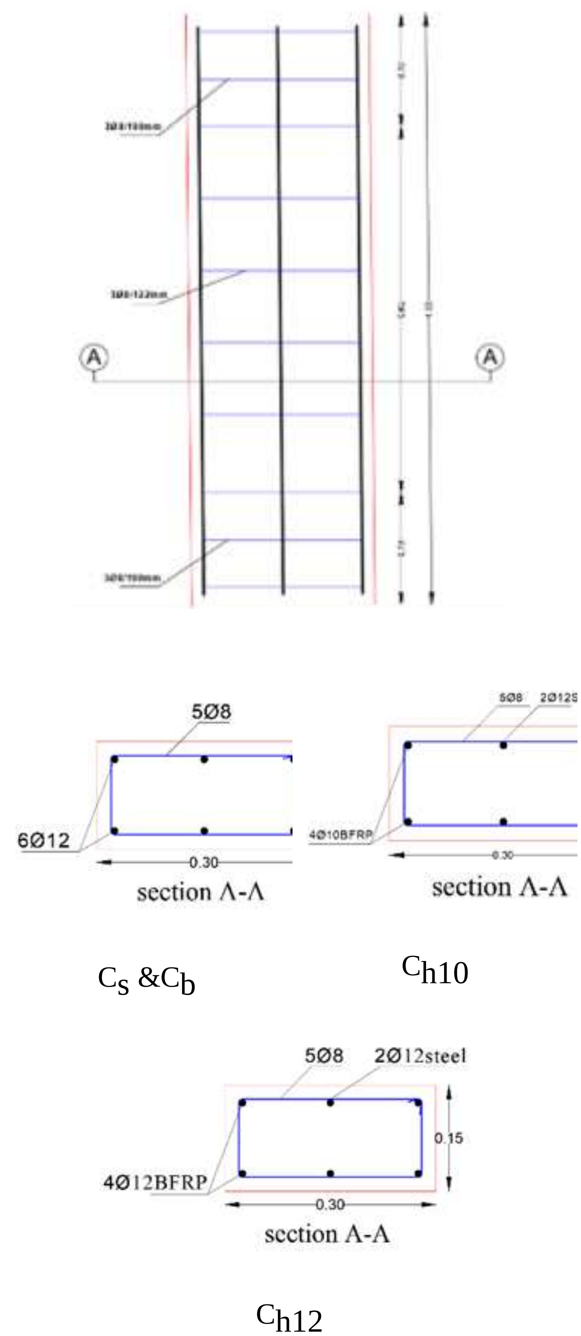

Figure 1.2: Details of specimens.

b. Material Properties

The specimen used in this study was casted with (HSC) that provided by a local supplier. The average compressive strength was 60 MPa at 28-day. Table 1.1 shows the different ingredients of the concrete mix that gave the required strength.

Table 1.1: concrete mix ingredients.

Cement Kg/m^3	Water Kg/m^3	Sand Kg/m^3	Basalt Kg/m^3	S.F Kg/m^3	S.P Kg/m^3
545	202	700	1105	60	6

Materials which used were Ordinary Portland Cement (Qena Cement) with grade of 42.5 from Mass factory, coarse aggregate (basalt) obtained from Safaga city at El-Bahr Al-Ahmer – Egypt, fine aggregate (sand) obtained from 78401542515, and other additions which used to get HSC like, Silica Fume (S.F) which produced by Ferro silicon alloys. Egyptian Ferro-Alloys Company, Edfu, Aswan, and Super Plasticizers (S.P) (Sikament R2004) a high range water reducer admixture which added to the concrete mixtures to improve their workability and at the same time converse its compactness without increasing the water content.

The reinforcement used were steel, basalt fiber, and hybrid reinforcement. Table 1.2 show mechanical properties of BFRP Bars.

Table 1.2: Mechanical properties of BFRP bars.

Type	Actual Diameter (mm)	Tensile strength (MPa)	Tensile modulus of elasticity (GPa)	Elongation (%)
BFRP	12	1085	49.3	2.2

c. Casting and Curing Procedure

The specimens were casted in steel formworks with an inner dimensions (150*300mm) cross section and 1000mm height after cleaning as shown in figure 1.5. The specimens were casted and curing in Faculty of Engineering at Assuit University.

Figure 1.3: preparing of steel formwork.

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The specimen's details were shown in table 1.3 as indicated below.

Table 1.3: Details of tested columns specimens.

Column ID	Type of reinforcement	A_c (mm^2)	A_s
C_s	Steel	150*300	6Ø12 Steel
C_b	BFRP	150*300	6Ø12 BFRP
C_{h10}	Hybrid	150*300	4Ø10BFRP+2Ø12steel
C_{h12}	Hybrid	150*300	4Ø12BFRP+2Ø12steel

Where C_S & C_b were control and others tested under axial load.

3. Test procedure

To ensure uniform loading the columns were capped with a head having 150mm height. As shown in figure1.4.

Figure 1.4. Head cap.

Each end of the specimens had 3Ø8mm stirrups at distance equal 190 mm to strength this area and prevent premature failure. Data logger used for recording data after connecting with LVDT and strain gage to measure deflections and strain of steel and concrete as shown in figure 1.5. Also, data logger has been shown in figure 1.6

Figure 1.5: LVDT setup.

Figure 1.6: Data logger.

4. Results and discussion

Test result will be discussed in this section as failure mode, reinforcement strain and concrete strain and deformation have been measured and recorded. Results of test specimens shown below.

a. Column reinforced with steel reinforcement

In this section the results of column reinforced with steel reinforcement were investigated and discussed. Failure mode and cracks were indicated in figures below.

Figure 1.7: shape of cracks

Failure of column under axial load were compression failure and values of ultimate load, lateral and horizontal deflections and reinforcement strain were indicated in table 1.4.

Figure 1.8: failure mode.

b. Column reinforced with basalt fiber reinforcement

Column reinforced with basalt fiber reinforcement were tested under axial load as shown in figure 1.9.

Figure 1.9: BFRP Column tested under axial load.

By testing column, the result shown that failure of column reinforced with BFRP was brittle failure figure 1.8 show failure mode and shape of cracks.

Figure 1.8: Failure mode of (Cb).

Deformation and strain of various types of reinforcement and concrete were introduced below. Ultimate load (p_u), percentage of reinforcement (ρ_s), ultimate vertical deflection at Y-axis (δ_v), ultimate horizontal deflection at x & z axes (δ_{h1} & δ_{h2}) were introduced in table 1.4. charts in figures 1.9-1.13 show the relation between load and deflection or strain of column reinforced with BFRP. All charts indicated that with increasing of load strain and deflection increased. Figure 1.12 and figure 1.13 indicated that the stirrups had elongation due to this axial load and longitudinal reinforcement had shorten due to buckling.

Table 1.4: Test results for column specimens.

Specimen	ρ_s %	P_u (t)	δ_v(mm) Y -axis	δ_{h1}(mm) x -axis	δ_{h2}(mm) Z -axis
Cs	1.5	227.0	11.80	1.65	0.71
C_b	1.5	218.5	12.03	1.90	0.80
C_{h10}	1.2	208.4	11.72	1.59	0.67
C_{h12}	1.5	221.5	11.87	1.78	0.76

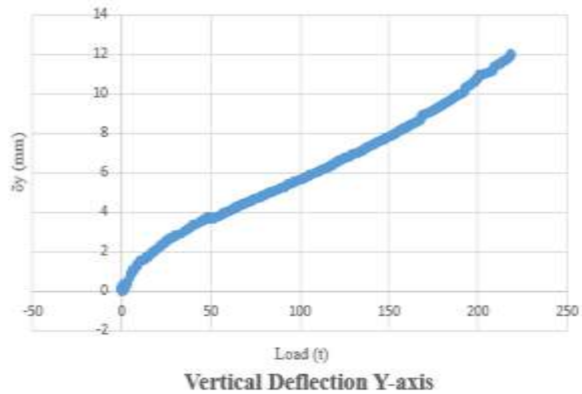

Figure 1.9: load verses vertical deflection.

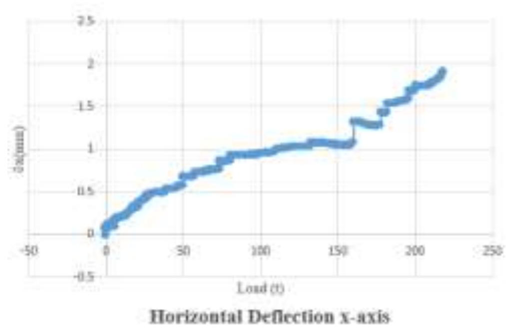

Figure 1.10: load verses horizontal deflection at x-axis.

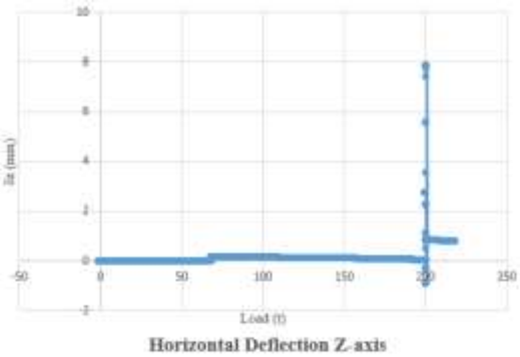

Figure 1.11: load verses horizontal deflection at z-axis.

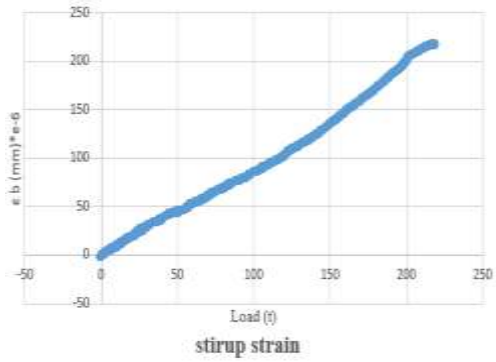

Figure 1.12: load verses transvers reinforcement strain.

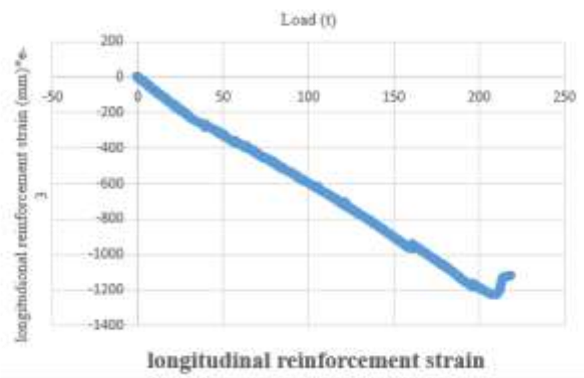

Figure 1.13: load verses longitudinal reinforcement (BFRP) strain.

5. Conclusions

A rectangular HSC column reinforced with steel, basalt fiber reinforcement and hybrid reinforcement have been casted and tested under axial loading. The behavior of HSC column has been investigated and discussed. The result obtained indicated that:

- Capacity of column reinforced with steel and tested under axial loading was higher than that in case of other type of reinforcement.
- Failure of column reinforced with BFRP only was brittle failure as the column failure was sudden and brittle.
- Using hybrid reinforcement made failure not sudden.
- Column reinforced with BFRP had value of longitudinal reinforcement strain higher than its value in other specimens that reinforced with steel and hybrid reinforcement.

References: -

1- Jenkins, P. G. et al. (2015). “Investigation of the strength of thermally conditioned basalt and E-glass fibres”. ICCM 20, 20th *International Conference on Composite Materials*, Copenhagen, Denmark.

2- Mingchao, W. et al. (2008). "Chemical Durability and Mechanical Properties of Alkali-proof Basalt Fiber and its Reinforced Epoxy Composites". *Journal of Reinforced Plastics and Composites.*27(4):393-407.

3- Dias, D. P. and Thaumaturgo, C. (2005). "Fracture Toughness of Geopolymeric Concretes Reinforced with Basalt Fibers". *Cement and Conctete Composite*, 27: 49–54.

4- Dias, D. and Thaumaturgo, C. (2005) "Fracture toughness of geopolymeric concretes reinforced with basalt fibers", *Cement and Concrete Composites*, 27(1): 49-54.

5- Thorhallsson, E., Kubens, S. and Konradsson, A. (2011). "Strengthening of concrete columns by wrapping basalt fiber matrix", *Nordic Concrete Research Symposium conference*, Hämeenliina, Finland.

6- Sivakumar, A. and Santhanam, M., (2007). "Mechanical properties of high strength concrete reinforced with metallic and non-metallic fibres". *Journal of Cement and Concrete Composites*, 29(8):603-608.

7- Chena, B. and Liu, J. (2012). "Residual strength of hybrid-fiber-reinforced high-strength concrete after exposure to high temperatures", *Journal of Cement and Concrete research*, 34(6):1065-1069.

8- Al Shadidi, R.M., Hassan, H.F. and Al-Dahlaki, M.H., (2016). "Behavior of high-strength fiber concrete columns reinforced with glass fiber-reinforced polymer bars and strengthened by carbon fiber-reinforced polymer wrap", *Journal of Engineering and Sustainable Development*, 20(3), 194-206.

9- Lee, H.J. et al., (2018). "Behavior and modeling of high-strength concrete tied columns under axial compression", *Journal of The Chinese Institute of Engineers*, 41(10), 353-365.

10- Hadi, M.N.S., (2006). "Behaviour of FRP wrapped normal strength concrete columns under eccentric loading", *Composite Structures*, 72, 503–511.