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Effect of Basalt Fibers Ratio on High Strength Concrete Columns Reinforced with Hybrid Reinforcement Bars

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ABSTRACT: This paper presents an experimental investigation of the influence of fibers ratio on columns reinforced with hybrid reinforcement (steel and basalt reinforcement polymers (BFRP)). Three columns with 150*300 mm cross-section were casted and tested under axial loading. The column specimens were reinforced with 6Ø12 (4Ø12BFRP+2Ø12 steel fiber). The behavior of high-strength concrete columns was discussed and the test measurements were (load capacity, failure shape, lateral and vertical concrete strain, lateral and vertical concrete deflection, and steel strain). Basalt fibers with a percentage of 0.5%, 1%, 1.5% were used in this study. The study gives a clear result for judge the effect of fibers ratio in HSC columns reinforced with hybrid reinforcement.

I. INTRODUCTION

HSC has been used in a lot of structures due to its advantages as it provides a higher strength than NSC so it carries more loads which lead to a reduction in structure members size, also it has some disadvantages like having lower ductility for resisting accidental overloading, also members made of HSC fail in a brittle manner than NSC [1] and [2]. Because of this disadvantage the ductility of HSC members has been a major concern. High strength concrete is defined as concrete having 41 MPa strength [3].

In recent years, using fiber reinforced polymer (FRP) bars as longitudinal reinforcement spread. Steel reinforcement has disadvantages as it has heavyweight, corrosion, and durability compared with (FRP) reinforcement. Due to steel disadvantages a lot of researches had been introduced and discussed the behavior of concrete element reinforced with FRP.
FRP are composite materials composed of fibers embedded in a plyometric resin which types are glass fiber, steel fiber, carbon fiber, basalt fiber, and aramid fibers. FRP have many types as it can be in bar shape, sheets, and chopped fibers. Figure 1 show various types of FRP bars, and figure 2 show various types of chopped fibers.

A Steel fiber **b) Glass fiber** **c) Basalt fiber** **d) Carbon fiber**
Fig.1: various types of FRP a) steel fiber b) glass fiber c) basalt fiber and d) carbon fiber.

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a) Steel fibers b) Basalt fibers c) Glass fibers

Fig.2: various types of chopped fibers a) steel fibers, b) Basalt fibers and c) Glass fibers.

Chandramouli K et.al [4] carried out an experimental investigation on the alkali resistant glass fibers and studied the effect on tensile strength, split tensile, compressive and flexural strength on various grades of concrete. The test result show that the percentage increase of compressive strength of various concrete grades of glass fiber concrete mixes compared with 28 days compressive strength to be from 20 to 25%. Also, reduction in bleeding observed by addition of glass fibers in the glass fiber concrete mixes.
De Luca et al. [5] conducted an experimental program to investigate whether the compressive behavior of longitudinal GFRP bars impacts the column performance, and to understand the contribution of GFRP ties to the confinement of the concrete core, and to prevent instability of the longitudinal reinforcement. Five specimens were tested under axial loading: one control steel RC column and four GFRP RC columns. The results showed that the GFRP RC specimens behaved similarly to the steel RC counterpart, while the spacing of the ties strongly influenced the failure mode. ZrarSedeeq and Ahmed Heidayet [6] conducted an experimental program consisted of 18 reinforced rectangular concrete columns which tested under different eccentric loadings. A number of 15 column, were reinforced with CFRP longitudinal rebars and ties and 3 were reinforced with conventional steel rebars and ties as reference columns. Their study included various parameters like, eccentricity of load, the replacement of steel with CFRP bars, tie spacing, and longitudinal reinforcement ratios. Test results in terms of load-strain, load-mid height deflection curves, and crack patterns showed that the column reinforced with CFRP bars behaved similarly to the concrete column reinforced with conventional steel bars with a slight difference in axial and flexural capacity. The increment in CFRP longitudinal reinforcement ratios from 1.4% to 2.0% and 3.6% reasonably increased the maximum carrying capacity for different eccentricities used.
Basalt rock is melted at high temperature and used for manufacturing BFRP bars which is a high-performance non-metallic fiber. Basalt fiber has good thermal properties and hardness [7]. At lower cost basalt fibres show comparable mechanical properties to glass fibres good resistance to chemical and high temperature exposure [8]. Replacing FRPs with BFRP has big attention in recent researches because of ease of manufacture, its cost effectiveness, freeze-thaw performance, high temperature resistance, good resistance to acids, corrosion, vibration and impact and loading [9], [10] and [11].

II. EXPERIMENTAL PROGRAM

A. Test Specimens

The program of this study consisted of four HSC columns with 150 mm ×300 mm cross-section and 1000 mm in overall height, The column are short columns as it has an aspect ratio equal 3.33. To make sure that the load moves to middle of the effective height head cap fixed at each end of column. Four columns were casted and tested. Table 1 show the columns specimen’s reinforcement details. All specimens have 56 MPa compressive strength.

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Table 1: Details of test specimens.

Column ID	Ac	As	% Fibres
H0.5, 1.5	150*300	4Ø12BFRP+2Ø12 steel fiber	0.5%
H1, 1.5			1%
H1.5, 1.5			1.5%

Numbers in columns ID refers to, first one refers to percentage of fibers, second refers to percentage of reinforcement in section. Columns specimen's reinforcement details shown in figure 3. As they have 6Ø12 reinforcement four of them were BFRP bars and were in columns corners and tow of the were steel put in middle of the columns as shown.

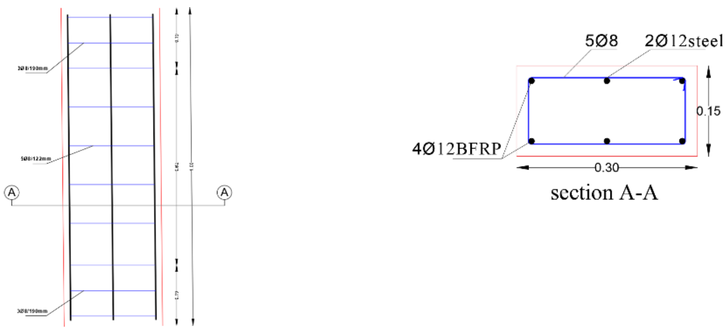

Fig.3: Details of specimens.

B. Material Properties

All specimens used in this study were casted with (HSC) having an average compressive strength 56 MPa at 28-day. concrete mix ingredients that gave the required strength have been shown in table 2.

Table 2: 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 qena, 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 hybrid reinforcement. Table 3 show mechanical properties of BFRP Bars.

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Table 3: 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 wood formworks with an inner dimensions (150*300mm) cross section and 1000mm height after cleaning as shown in figure 4. The specimens were casted and curing in Qena Faculty of Engineering at Al-azhar University.

Fig.4: Columns casted in wooden formwork.

III. TEST PROCEDURE

To ensure uniform loading the columns were capped with a head having 200mm height. As shown in figure5.

Fig.5: Head cap.

Each end of the specimens had 5Ø8mm stirrups at distance equal 190 mm to strength this area and prevent premature failure. Data logger used for recording data after connecting with LVDTs and strain gage to measure deflections and

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strain of steel and concrete as shown in figure 6. Also, data logger has been shown in figure 7 and figure 8 show column fixed and tested with universal compression testing machine.



Fig.6: LVDTs setup. **Fig.7: Data logger.** **Fig.8: Universal testing machine.**

D. Results and discussions

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

A. Failure mode

Failure mode and cracks were shown and discussed in this section. Table 4 show ultimate load and deflection in concrete for all specimens. These values show that there was an increase in load capacity with increase of fibers ratio. Also increasing percentage of fibers causing decreasing in vertical concrete deflection.

Table 4: Ultimate load and deflection for columns specimens.

Column ID	P_u (t)	δ_v(mm) Y -axis	δ_{h1}(mm) x -axis	δ_{h2}(mm) Z -axis
H0.5, 1.5	85.5	21.4	1.76	1.64
H1, 1.5	89	20.15	0.53	1.19
H1.5, 1.5	196.5	4	0.49	0.98

Also, failure was less brittle with the increase of fibers ratio. Failure of column under axial load were compression failure as shown in figures below. Figures 9-11 show cracks and failure mode of columns.


Fig.9: Failure mode for column H0.5, 1.5.

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Fig.10: Failure mode for column H1,1.5.

Fig.11: Failure mode for column H1.5,1.5.

By testing column, the result shown that failure of column reinforced with hybrid reinforcement was brittle failure. Deformation and strain of HSC columns reinforced with hybrid reinforcement and having various ratio of basalt fibers for reinforcement and concrete were introduced below.

Ultimate load (pu), ultimate vertical deflection at Y-axis (δv), ultimate horizontal deflection at x & z axes (δh1 & δh2) were introduced in table 4. charts in figures 12-17 show the relation between load and deflection or strain of column reinforced with hybrid reinforcement and having various percentage of basalt fibers.

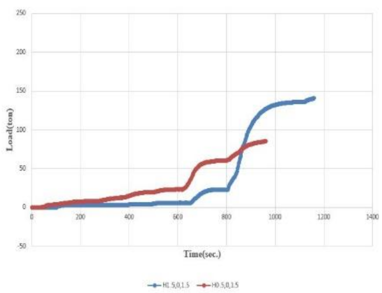

Fig.12: Time verses ultimate load.

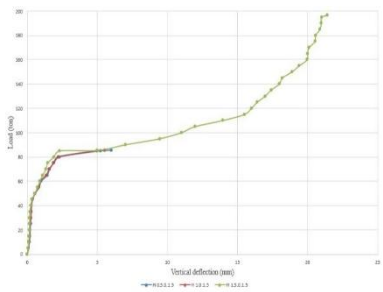

Fig.13: Ultimate load verses vertical deflection.

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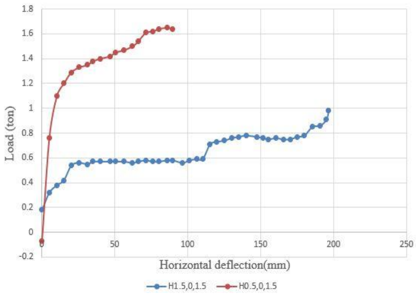

Fig.14: Ultimate load verses horizontal deflection.

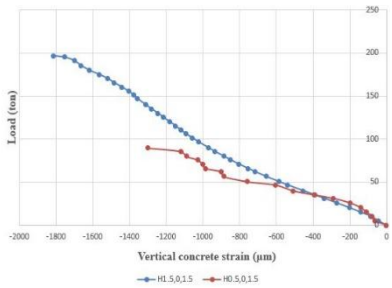

Fig.15: Ultimate load verses Vertical concrete strain.

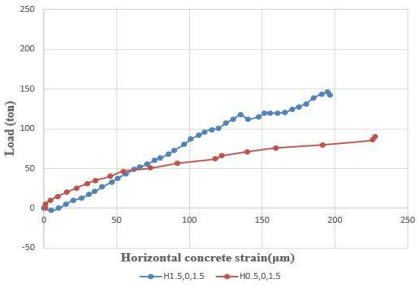

Fig.16: Ultimate load verses Horizontal concrete strain.

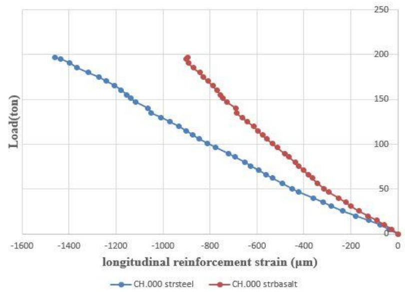

Fig.17: Ultimate load verses longitudinal reinforcement strain column H1.5,0,1.5.

All charts indicated that with increasing of load strain and deflection increased. Figure 17 indicated that BFRP bars had small strain than steel bars in column H1.5,0,1.5 which had the higher percentage of basalt fibers.

IV. CONCLUSION

A total of 3 rectangular HSC columns reinforced with hybrid reinforcement having different percentage of basalt fibers have been casted and tested under axial loading. The behavior of HSC column has been investigated and discussed in terms of load capacity, lateral and axial deflection, and longitudinal and transvers reinforcement. The results obtained show that: -

- Failure of column reinforced with hybrid reinforcement that having 0.5% basalt fibers was more brittle than that have 1% and 1.5% basalt fibers.
- Load capacity for column reinforced with hybrid reinforcement and tested under axial loading was increased with the increase of basalt fibers ratio.
- Using hybrid reinforcement made failure not sudden.
- BFRP bars had value of longitudinal reinforcement strain in compression was lower than its value in steel bars in the same specimens.

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