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Evaluation and comparison of capacity and rupture of elliptical columns, with and without casing, and application of single-layer and double-layer wrapping, under pure axial pressure

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ABSTRACT: The effect of pure axial pressure on elliptical reinforced concrete columns made of normal (NC) and high-strength concretes (HSC) enclosed by glass-fiber reinforced pipes (GRP), as well as a carbon-FRP, was investigated. Behavior refers to compressive capacity (CC). The effect of concrete type, casing, wrapping and its layers were investigated. Totally 12 columns with 200×120 and 600 mm height were constructed; they were divided into 2 groups of NC and HSC; each group was divided into two parts of 3. The first part had a casing and the second part did not. From each part, the first column lacked a reinforcing layer, the second with one layer and the third with two twisted layers. The wrapping and casing improved the columns, behavior. Using one and two wrapping layers increased the CC by 19.7% and 28.7% on average in the first and 11.0% and 28.7% in the second groups, respectively; the use of casing resulted in an average increase in the CC of the columns in the first group by 4.15 times and in the second group by 3.51 times. Although the wrapping and the casing both create confinement, the casing has a much greater effect on improving the columns behavior due to its greater confinement, and the effect of the confinement on the behavior of the first group is also greater. Comparing the effect of casing enclosure with wrapping showed that the casing is much more effective, and its effect is more on columns made of NC.

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1- Introduction

CFRP has been used in civil engineering for several years to strengthen and improve existing structures as well as to build new structures. In recent years, various methods have been developed to reinforce concrete columns using CFRP, of which the wrapping of columns with these fibers is known as the most common method of reinforcing concrete columns. Enclosing structural components with CFRP increases the load-bearing capacity as well as the ductility of the structure. When concrete is enclosed using this type of coating, its behavior changes and its stress-strain curve will be different. So far, much research has been done on the axial compressive behavior of CFRP enclosed concrete. The vast majority of studies agree that the use of CFRP wrapping increases the strength and axial ductility of the columns. CFRP fiber reinforced polymers are the most common type of composites used for structural reinforcement due to their suitable mechanical properties, easy installation and high strength to weight ratio. In addition to these advantages, low fire resistance and the inability to apply on wet surfaces and at low temperatures can be considered as disadvantages of CFRP composites [1-3]. Another method of reinforcing columns is to use casing tubes. To date, various studies have been conducted on the use of plastic pipes and steel pipes as casings for concrete members, which have had positive results, but so far, the use of GRP pipes has been less studied. The use of GRP pipes to enclose the columns increases the compressive strength, reduces the slenderness ratio and increases the buckling resistance [4]. Also, the use of elliptical GRP pipes has been less studied so far, and the results and calculations indicate that the elliptical cross-section is the best cross-section in reducing shear stress and thus reducing scour around the bases of the piers [5].

The aim of this study was to investigate the effect of separate and simultaneous application of GRP casing and CFRP wrapping on the behavior of reinforced concrete columns with elliptical cross-section and made of ordinary and high-strength concrete, by making 12 specimens of reinforced concrete columns; elliptical with diameters of 120 and 200 and height of 600 mm, with and without the presence of CFRP wrapping and GRP casing, and determination of their compressive capacity and axial deformation, this goal is pursued.

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Table 1. Mechanical properties of CFRP wrapping and GRP casing

Composite specifications	CFRP wrapping	GRP casing
Thickness (mm)	0.166	8
Density (kg/m^3)	-	1800
Weight per unit area (g/m^2)	300	-
Tensile stress (MPa)	4900	75
Static elastic coefficient (GPa)	230	120
Poisson's ratio	0.3	0.4
Ultimate strain (%)	2.5	1.3

2- Research methodology

2- 1- Specifications of CFRP and GRP

The CFRP composite sheets used in the research are one-way and made by TORAY Japan Company. Elliptical GRP composite pipes are made by the Shiraz Faravard factory and are produced with resin-impregnated glass fibers. The mechanical properties of CFRP wrapping and elliptical GRP pipes based on the manufacturer's data are presented in Table 1.

2- 2- Experimental program

In the casting of high-strength concrete (HSC) micro silica gel was used. Also, to increase the compressive strength of concrete, the ratio of water-binder was reduced to 0.2. The slump was 80 mm in ordinary concrete and 190 mm in HSC. The details of the mixing design of normal concrete and HSC in the construction of specimens are presented in Table 2. The results of compressive strength tests at the age of 28 days are given in Table 3.

2- 2- 1- Specifications of specimens

Table 3 presents the specifications of laboratory research specimens.

2- 2- 2- Column test

The columns were tested by a hydraulic jack with a capacity of 5000 kN. The experiments were performed by the deformation control method with a loading rate of 10 kN/s [6].

3- Results and discussion

3- 1- The ultimate capacity of the columns

The ultimate capacity of the columns is shown in Figure 1. Comparing the capacity of different types of columns is evident from the figure.

4- Conclusions

The key results of the research are as follows:

1- The use of GRP as a formwork and reinforcing casing of elliptical reinforced concrete columns significantly increased their compressive capacity, so that the compressive capacity of columns with casing compared to similar columns without casing, respectively, and on average in columns made of ordinary and high-strength concretes were 315% and 251% more.

2- Reinforcement of reinforced concrete columns with CFRP wrapping increases the compressive capacity of the columns. On average, the use of wrapping in columns without GRP casing and made of ordinary and high-strength concrete,

Table 2. Details of the mixing design of ordinary and high-strength concrete in the construction of research columns (kg/m3)

w/b	Super-plasticizer	Micro silica gel	Sand	Gravel	Water	Cement type 2	Type of concrete
0.4	-	-	906	904	160	400	ordinary
0.2	3	55	720	930	123	550	High-strength

Table 3. Specifications of research laboratory specimens

12	11	10	9	8	7	6	5	4	3	2	1	**Row**
GHF2	GHF1	GH	HF2	HF1	H	GNF2	GNF1	GN	NF2	NF1	N	**Name of specimen**
A	A	A	NA	NA	NA	A	A	A	NA	NA	NA	**GRP casing**
A	A	NA	A	A	NA	A	A	NA	A	A	NA	**CFRP wrapping**
2	1	-	2	1	-	2	1	-	2	1	-	**Number of wrapping layers**

The cross-sectional dimensions and height of all columns are 120 x 200 and 600 mm, respectively.

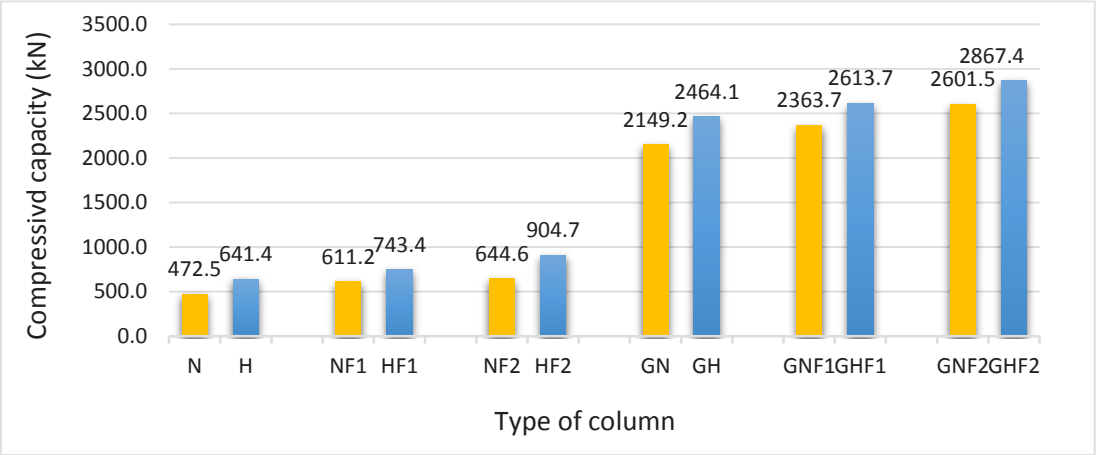
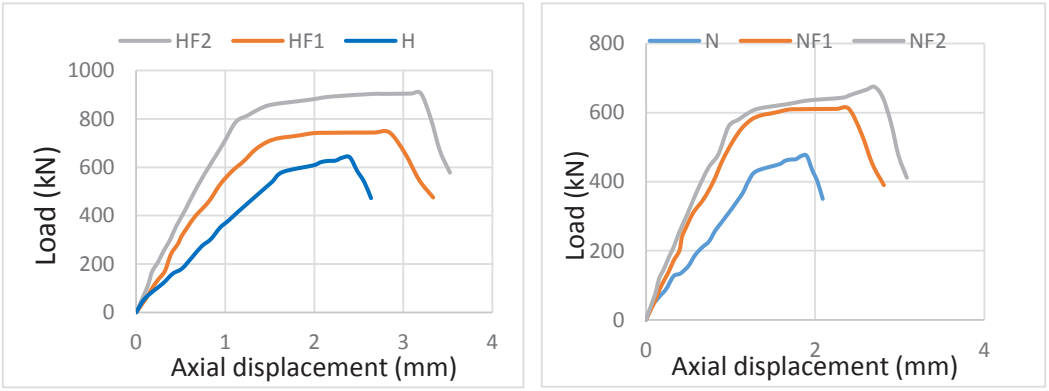
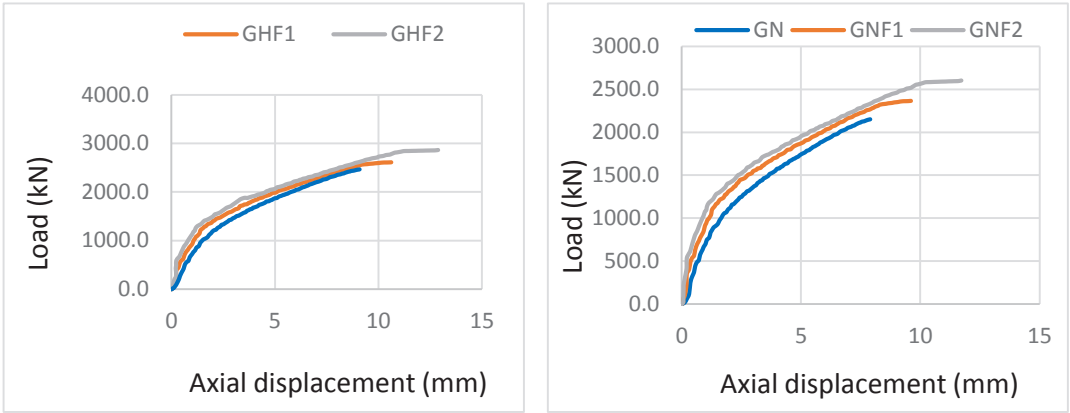


Fig. 1. The compressive capacity of research columns



(a) Columns made of high-strength concrete (b) Columns made of ordinary concrete

Fig. 2. Load-axial displacement curve of columns without GRP casing



(a) Columns made of high-strength concrete (b) Columns made of ordinary concrete

Fig. 3. Load- axial displacement curve of columns with GRP casing

by 33% and 10%, respectively, and in columns with casing and made of ordinary and high-strength concrete, by 28% and 11% showed an increase. These results show that the effect of wrapping on increasing the capacity of columns without casing made of high-strength concrete is less.

3- Examination of the failure of elliptical reinforced concrete columns showed that most of the columns were broken due to buckling of longitudinal rebars. In GRP-free columns, rupture occurred mostly locally and gradually. In these columns, rupture occurred at one of the two ends of the column, which could be due to the lower confinement of the concrete core at both ends of the column by the network of rebars. Whereas in columns with casings, complete rupture occurred in the form of destruction and with the sound of the explosion along the entire length of the column, which can be attributed to the very high degree of confinement caused by the casing; This amount of confinement prevented premature buckling of the rebars, reaching all parts of the column to their maximum tolerable strain, buckling of the longitudinal rebars, cutting of the helical rebar and finally rupture of the column.

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