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The Structural Performance Of Short Circular Concrete Columns Made With Reactive Powder Concrete And Externally Reinforced With Textile Fabric

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ABSTRACT

In the current laboratory investigation, the behavior of hollow circular concrete columns exposed to vertical compressive force is examined. The columns are externally strengthened with Glass Fibre Reinforced Polymer bars and textile fabric (one layer and two layers). The longitudinal reinforcement cast using concrete Reactive Powder Concrete has an outer diameter of (250 mm), a bore diameter of (100 mm), and a length of (1000 mm). The number of textile layers (one or two layers) is one of the main variables used in this experiment study. According to the experimental findings, the hollow circular concrete columns raised the tested concrete columns' bearing capacities by roughly (9.93%) and (17.8%), respectively, after the specimens were allowed to cure for 28 days. This improvement was made for strengthening columns that were subjected to compressive loads and had one or two layers of textile fabric.

1. Introduction

Reinforced concrete (RC) is a common building material used all over the world. Columns transfer weight to the foundation from beams and slabs. Superstructures, like massive buildings and long-span structures, use columns to support high compressive pressures. Furthermore, because of the limited strength and elasticity of concrete, overloading and natural disasters like fire and earthquakes can harm columns [1]. Columns are vertical load-bearing elements that support the majority of axial compressive loads. The load of the structure is transferred to the foundation by means of this structural element. The floors, columns, and beams of reinforced concrete structures are monolithic [2]. The use of hollow reinforced concrete (RC) columns has increased due to their reduced material requirements and inherent weight [3]. The foundation of hollow column sections is cost savings from reduced material and design moments as opposed to more complex construction and subsequently higher labor costs [4]. When hollow columns are utilized in reinforced concrete (RC) bridge construction, there may be major advantages over columns with solid sections [5]. Because steel-reinforced hollow concrete columns have higher strength- and stiffness-to-mass ratios than solid concrete columns with the same cross-section area, they have been used for utility poles, piles, and bridge piers [6]. Materials like CFRP, GFRP, and AFRP were widely used at this time. Depending on the intended use, these materials can be found as bars, fibers, tubes, and plates, among other sorts and shapes. Glass fiber, a type of high-strength fiber, is commonly used for

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reinforcement in organic polymer composites. Because of its high tensile strength and tensile modulus, glass fiber is widely used to strengthen organic composite materials in a variety of industries [7]. Textiles can be made of class fiber, carbon fiber, or a combination of class and carbon fiber, and come in a variety of threads and forms depending on the need [8]. The next type of concrete is called reactive powder concrete (RPC), and it's incredibly tough, resilient, and strong. Compressive strength, Young's modulus, and fracture energy in the range of (200-800) MPa, (50-75) GPa, and (12-40) kJ/m2 are among the exceptional mechanical parameters attained [9]. RPC, or reactive powder concrete, offers superior durability and mechanical qualities. Metallic fibers can be used to reinforce concrete in order to improve its ductility and flexural strength [10].**(Lignola et al, 2007) [11]** The structural performance of hollow concrete columns reinforced with strips (CFRP) was examined in this study. Each of the seven hollow concrete column examples that were evaluated had a concrete wall thickness of (60) mm, an effective length of (1300) mm, and a square cross section measuring (360×360) mm. and a compression load (eccentric loads at a distance of (52.80) mm) was applied to the specimens. Whole cloth (CFRP) reinforcement was present in the exterior specimens. For specimens loaded with smaller eccentricities, improvement in strength was more significant, while improvement in ductility was more significant for specimens loaded with larger eccentricities. Curvature ductility indices were used to estimate the ductility measures. Compare the seismic performance of solid piers with hollow piers that have not been strengthened in terms of ductility and poste peak behavior.**(Bournas et al, 2007) [12]** This study looked at reinforced concrete columns with textiles in the mortar. Fifteen small prisms, each with a length of 380 mm and a cross section of 200 mm, are poured. To reinforce these prisms longitudinally, steel bars with a diameter of (12) mm have been added. Model textile application entails encircling the models with a fabric that is completely covered in mortar, has a width of three millimeters, and a spacing of seven millimeters between the two movers. The TRM jackets used in this study perform somewhat less well in terms of increasing strength and deformation capacity by about 10% when compared to FRP jackets of equivalent stiffness and strength.

(Khorramian et al, 2017) [13] This work presents the experimental and computational analysis of short concrete columns reinforced with bars (GFRP) subjected to eccentric loads. Fourteen concrete column specimens, each with dimensions of (500 mm) in length and (150 mm) in width, were created for the experiment. Nine columns have bars composed of glass fiber reinforced polymer (GFRP); the other five specimens do not. At the end of the experiment, it was found that the GFRP rods used had an elastic modulus and compressive force greater than their tensile strength, and that there had not been any crushing or twisting of the rods before the samples failed.**(Shan et al, 2021) [14]** This study investigates the seismic behavior of tubular columns made of reactive powder concrete. Eight specimen columns—seven CFRPCT model columns and a benchmark conventional reinforced concrete specimen—were subjected to a series of low-cycle lateral loading tests with quasi-statically applied cyclic lateral loading and a constant axial load in order to assess the seismic performance of CFRPCT columns. Every column has an external diameter of 300 mm and a length of 1500 mm. The spiral spacing of the specimens ranged from 20 to 60 mm. The interior concrete (C40, C60, and C80) was also subject to strength variations, and it was subject to both monotonic and cyclic applied stress. When subjected to cyclic lateral loading, CFRPCT specimens exhibited a typical flexural failure mechanism, wherein the plastic hinge formed at the base of the column in a length that was almost equal to the column diameter. Compared to ordinary reinforced concrete columns, CFRPCT columns were more prone to deterioration because of the steel fibers.

2. Experimental Work

2.1 Experimental program

In order to assess the mechanical characteristics of hardened reactive powder concrete (RPC), the experimental program comprises the casting and testing of three specimens of hollow circular concrete columns in addition to a number of control specimens (cubes, cylinders, and prisms). One or two layers of textile fabric are among the factors that have been employed.

2.2Column Specimens Description

The hollow circular concrete columns that were tested all had the same cross-section, outside diameter (250 mm), and inner diameter (100 mm); the specimens were all (1000 mm) long and had (10 mm) diameter GFRP bars. The tested columns were split into two groups: group (1) comprises one specimen without strengthening with textile fabric and the longitudinal reinforcements made of (6) GFRP bars, and group (2) comprises two specimens strengthening externally the First specimen with one layer and second specimen with two layers of textile fabric. Compression forces were applied to all three of the tested columns until they failed. The details of the tested columns are displayed in Table (1) and Figure (1).

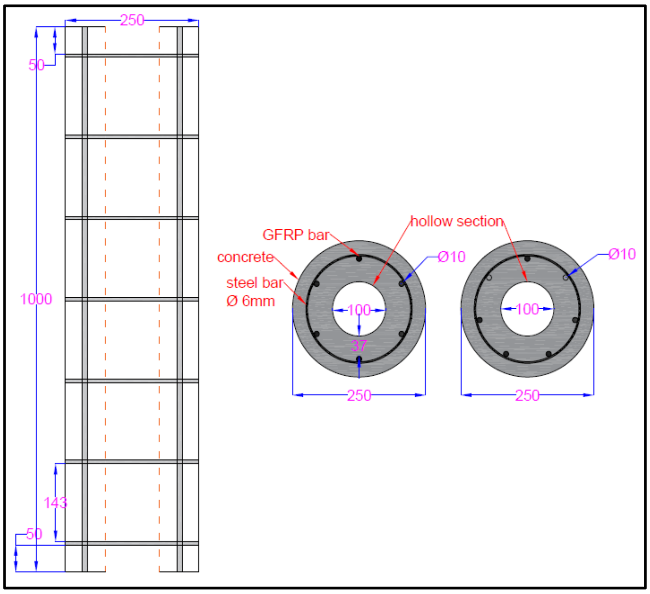

Figure 1. Specifics of the Specimen Cross-Section

Table 1: Specimen Details and Descriptions

Column naming	Dimension (mm)			No of GFRP Longitudinal Bars	Strengthening by Textile	
	D_{out}	D_{in}	L		Location of Layer	No of Layer
CG1-T0-R1	250	100	1000	6	none	none
CG1-T21-R1	250	100	1000	6	Externally	(1) layer
CG1-T22-R1	250	100	1000	6	Externally	(2) layers

3. Materials

After testing, Portland cement type (I) is used to prepare the specimen mix for casting hollow concrete columns and control specimens, and it satisfies Iraqi specifications (No.5/1984) [15]. Iraqi specifications are followed when using natural sand in the design mixture for casting specimens and control specimens. (No.45/1984) [16]. Using only pure tap water, the concrete columns were mixed and the specimens were cured. Fly ash of type C is added to the concrete mixture. Fine slag is a part of the concrete mixture. They removed the slag from the furnace. Steel stones of varying sizes are obtained as slag once the remaining molten steel has cooled. Lastly By adding plasticizer (Conplast sp. 2000) to the concrete mixture, the amount of water is decreased and hollow concrete columns and control specimens are cast. Steel bars serve as ring reinforcement, or steel ties, in all concrete column specimens with a diameter of 6 mm for reinforced material. These specimens were tested in compliance with specifications (ACI 318-19) [17]. Glass fibre Reinforced polymer (GFRP) bars with 10 mm in diameter, are utilized for longitudinal reinforcement in hollow concrete columns instead of steel bars. Grids composed of textile fabric with high load and alkali resistance are used. They are arranged either vertically or horizontally depending on how they will be used for studying.

3.1 Steel Bar and GFRP Bar Distribution

The ring reinforcement (tiles) are first made of steel bars with a diameter of (6) mm, spaced (143 mm) apart, and seven tiles spaced 50 mm apart from top to bottom. For longitudinal reinforcement, (10 mm) diameter glass fiber reinforced polymers (GFRP) are used. A concrete cover is positioned between the mold and the reinforcement, which has a thickness of 25 mm, and six GFRP bars are used, as shown in Figure 2.

Figure 2. GFRP and Steel Bar Distribution

3.2 Preparing Textile for Strengthening

The arrangement to use textile fabric to strengthen the sample is made after the reinforcing bars have been distributed evenly. Two hollow concrete column specimens-one with single-layer strengthening and the other with two-layer strengthening-have were externally strengthening. Two external reinforcement specimens, external strengthening, and textile-wrapped reinforcing bars are depicted in Figure 3.

Figure (3) Two Specimens Externally Strengthening by Using Textile Fabric

3.3 Concrete Mix, Casting, and Curing of Specimens

Concrete mix used in this study content: cement, sand, slag, fly ash, water, and superplasticizer were: (574 kg), (1418 kg), (64 kg), (32 kg), (255 kg), and (3.2 kg), respectively. Specimens were cast by the concrete mix and installed (RPC),

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then processed as concrete columns. Hollow circular concrete columns measuring 1000 mm in length are fitted with PVC pipes that have a diameter of 250 mm and a thickness of 6 mm. The pipes are secured from below by a wooden base that is divided into four layers with a total thickness of eighteen (18) mm. In order to ensure that the concrete mixture does not leak out during the casting process, excavate a wooden basis that is 54 mm thick, or the equivalent of three layers. After that, spacers are used to separate the PVC mold from the reinforcing network (steel and GFRP), producing a concrete cover that is 25 mm thick. A 100 mm-diameter cork tube is then inserted into the centre of the mold to hollow out the concrete columns. The mold is then pounded from the outside, top to bottom, using a steel hammer, After the casting process is complete, the curing process is completed. After two to three days, the molds are removed from the hollow circular concrete columns and kept in basins filled with water alongside control specimens (cubes, cylinders, and stools) for a total of 28 days, Figure 4.

Figure 4. Column Specimens' Casting, Processing, and Curing

4. Measurements of Specimens

First, in order to prepare the hollow circular concrete columns for testing, steel cabs are used to be positioned at the top and beneath the specimens. The steel used has an inner diameter of (250 mm), which is the same diameter as the circular concrete columns, and a height of (150 mm). Its thickness is (15 mm). At the top and bottom of the specimens are steel cabs that have the same inner diameter as the hollow circular concrete columns (250 mm), height of (150 mm), and thickness of (15 mm). The steel cabs is divided into two pieces with a radius of (135 mm), and the two pieces are connected together using steel screws from the right and left sides of the steel caps, assuming there is no movement between the specimen and the steel caps. To make sure the caps are placed correctly, there are two bolts on each side, as shown in figure (5).

Figure 5. Specimens' Steel Caps

Next, using a dial gauge with an accuracy of 0.01 mm/div, the vertical displacement of the tested concrete hollow column sample was measured in the middle. Lastly, in the construction laboratory, every hollow concrete column specimen is inspected using the universal hydraulic inspection device (MFL system). The maximum load capacity of this device is 3000KN, as shown in Figure (6).

Figure 6. Tested Column Specimens Set Up

5. Tests for Concrete Columns and Control Specimens

5.1 Testing of Concrete Columns

Following the completion of the GFRP bars, fabric specimens, and cast specimens, and the placement of measurements (dial and strain gauges) in the proper places. The tested hollow column specimens made of concrete are prepared for testing. The steel circular caps have been fastened to the top and bottom of the specimens and firmly pinned close to stop any movement or problems during the application of the load. After the models are arranged and processed to determine the centrality of the load until all three specimens fail, the circular hollow concrete columns are placed in the center of the applied load. Following their appropriate preparation, the specimens are subjected to a load that is progressively increased until the specimens failure.

6. Examination of Control Samples

The compressive strength of RPC is measured using concrete cubes in accordance with the British Standard (BS 1881-116 1983) [18] and aconcrete cylinder in accordance with the American standard (ASTM C39/C39M-01) [19] in order to ascertain the mechanical properties of RPC. A cylinder is used to test the splitting tensile strength of RPC concrete in accordance with the American standard (ASTM C496-2014) [20].The American standard (ASTM C78-02) states that a prism is used to examine the modulus of rupture [21].A cylinder is cast, and a compressive force is applied to it in accordance with American Standard No. (ASTM C469-02) [22] in order to measure the concrete's modulus of elasticity (RPC). It should be noted that all control specimens underwent testing following a 28-day curing period in water. Table 2 displays the mechanical property test results for the control specimens.

Table 2. displays the control specimens' mechanical property results

Property	f'_c (MPa)	f_{cu} (MPa)	f'_c / f_{cu}	f_r (MPa)	f_t (MPa)	E_c (MPa)
Results	70	79.6	0.879	4.9	4.2	35624

7. Tensile test for steel bars

Steel bars were used as ring reinforcement (steel ties) in all concrete column specimens with a diameter of six millimetres, as was previously mentioned in the material part. A tensile strength test machine (ACI 318-19) is used for direct testing to ascertain the tension in steel bars based on the standard [17]. The tensile test results for the steel bars used in concrete columns are displayed in Table 3.

Table 3. Steel Bar Tensile Test Properties

Property	Diameter of Steel Bar	f_u (Mpa)	f_y (Mpa)	Elongation
Results	6	563.4	471.6	0.1546

8. Results and Discussion

8.1 Strengthening's Impact on First Crack and Ultimate Load

In comparison to non-textile-strengthened columns, hollow circular concrete columns reinforced with textile have demonstrated resistance to both the first crack and the maximum load capacity. The hollow concrete columns exhibit good resistance to the maximum load capacity and the onset of the first crack regardless of whether they are strengthened externally, with one or two layers, or both with a textile. But regardless of whether the strengthening was external or internal, it was found that specimens strengthened with a single layer of textile fabric displayed less resistance than specimens strengthened with two layers. The maximum load capacity rose by 9.93% and 7.2% of the maximum for these examples. load capacity for failure and by (10.2%), (28.9%), and the first fracture load for specimens that were externally fortified with one layer of textile fabric. Models reinforced with a single layer of textile fabric exhibit an increase in comparison to models reinforced with two layers, as illustrated in Table (4).

Table 4. Maximum Load Capacity and Specimens' First Crack

Column Coding	Textile Layer	P_u (KN)	P_{cr} (KN)	Increasing in P_u (%)	Increasing in P_{cr} (%)	Notes
CG1-T0-R1	**-**	**1510**	**380**	**-**	**-**	Reference column
CG1-T21-R1	**1**	**1660**	**490**	**9.93**	**28.9**	With Respect to CG1-T0-R1
CG1-T22-R1	**2**	**1780**	**540**	**7.2**	**10.2**	With Respect to CG1-T21-R1

8.2 Mood of Failure for Concrete Columns

One and two layers of textile fabric were used to reinforce the exterior of two hollow circular concrete column specimens (on steel stirrups before casting the specimens) and the three one Specimens was not strengthening with textile fabric. For (CG1-T0-R1), in addition to grabbing a portion of the concrete cover close to the vertical cracks, experienced vertical cracks running from top to bottom at the top of the specimen. (CG1-T21-R1) became entangled in the concrete cover, and the outer fabric (textile) began to show at the top of the column. The concrete cover of the model (CG1-T22-R1) has grabs at the top and bottom of the column, Figure 7.

Figure 7. Cause of Tested Specimens' Failure

8.3 Behavior of Load-Displacement Curves

For one layer and two layers of textile reinforcement on the exterior, and six GFRP bars for vertical reinforcement the displacement curve gradually increases as the load on the specimens is applied, but the curve's behavior changes as a result of the textile fabric's reinforcement's placement. the load applying constant and unchanged. The specimens (CG1-T21-R1) and (CG1-T22-R1) were found to have maximum failure load displacements of 1.96 mm and 1.82 mm, respectively. From the maximum displacement, we can observe that the specimen strengthened with one layer externally has a displacement that is approximately 8% higher than the column strengthened with two layers of textile fabric externally. For the specimens (CG1-T0-R1), the maximum displacement that was recorded was 5.66 mm. In terms of maximum displacement, it produced good results when comparing specimens strengthened with and without the use of textile fabric

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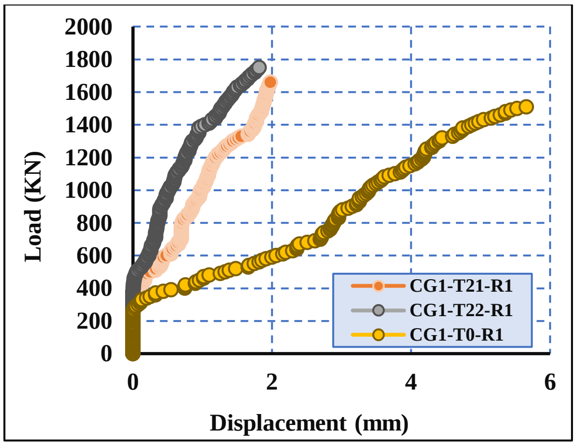

Figure 8. Behavior of Load-Displacement Curves for Tested Specimens

4. Conclusions

1. Compared to specimens strengthened with two layers of textile fabric, hollow circular concrete columns strengthened with one layer of textile fabric demonstrated less resistance to the maximum load capacity of failure and the first crack load by (6.74%) and (9.25%), respectively.

2. The compression load was applied, the specimens reinforced with textile fabric whether in one or two layers had a smaller maximum displacement than the columns reinforced with textile fabric externally.

3. Compared to non-strengthening specimens, concrete columns strengthened externally with textile fabric (in one or two layers) exhibited higher resistance to the maximum load capacity to failure by (9.93% and 7.2%) and by (28.9%, and 10.2%) for the first crack load.

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