

Research Article

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Enhancing structural behaviour of polypropylene fibre concrete columns longitudinally reinforced with fibreglass bars

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Abstract: The research aims to study the behaviour of concrete columns reinforced with fibreglass as bars exposed to seawater. Firstly, hardened concrete properties as the compressive strength and the tensile strength were investigated at ages 14, 28, and 56 days. Secondly, the experimental testing also involved casting 18 short concrete columns that have a length of 300 mm with the cross-sectional dimensions of 100 mm × 100 mm. Six samples were plain concrete, six were reinforced with a diameter of 6 mm longitudinal fibreglass bars, and six polypropylene fibre concrete columns were reinforced with a diameter of 6 mm fibreglass bars. The results added useful information using fibreglass bars (anti-corrosion materials) as reinforced longitudinal concrete columns, so the ultimate load of the reinforced concrete column with fibreglass rod exposed to seawater was 174.8 kN that it was higher than that of the plain concrete column at 104.9 kN. Thus, the fibreglass reinforcement technology enhances the capacity of the columns. So, it could be used in non-impacting structural parts. Meanwhile, the ultimate load of the fibre-reinforced concrete column with fibreglass rod exposed to seawater was 201.8 kN. It is 15.4% higher than that of the ultimate axial load of the reinforced concrete column with fibreglass rods only. Also, the results achieved of this research were encouraging, as the maximum failure load for short columns reinforced with fibreglass rods

reached approximately 84 to 87% of failure load relative to polypropylene fibre concrete columns containing reinforcing fibreglass bars. As a result, the structural behaviour bars have been enhanced using fibreglass rod and polypropylene fibre.

Keywords: fibreglass bars, polypropylene fibre, concrete, sea water, short columns, axial load

1 Introduction

Much research shows the corrosion problems of steel, so it is possible to use alternative materials for reinforcing concrete structures of these materials, and fibreglass rods could be used to produce reinforced concrete [1–3]. These polymeric materials' advantages are their corrosion resistance, without rust, lightweight, and reduced construction costs. The importance of the service in concrete bridges and ultimate behaviour was noted by using fibre-reinforced polymer rods to reinforce the bridge decks built in North America [4]. The carbon fiber reinforced polymer bars used in the reinforcement of the concrete samples continued to serve for many years without being affected [5,6].

Also, researchers are using glass fibre-reinforced polymer (GFRP) reinforced concrete columns for their corrosion resistance as an alternative to traditional steel. It was found that the concrete columns improved ductility and confinement efficiency by using GFRP [7]. The GFRP bars had retard concrete crushing under axial load, delaying the failure of the column [5]. Meanwhile, the GFRP concrete columns were up to 15% more ductile [8]. Kharal and Sheikh also found that GFRP bars enhanced the columns' earthquake resistance [9].

Meanwhile, El-Gamala and AlShareedah studied the behaviour of circular concrete columns reinforced with GFRP rods. The results showed that the GFRP-concrete columns had a slightly lower ultimate strength than their steel-concrete columns counterparts [10]. The amplitude of the obtained GFRP-concrete column was 17% less than that of the steel-concrete column [11]. Thus, the peak axial compression and

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lateral stiffnesses had been decreased satisfactorily [12,13]. In many research studies, GFRP bars have been successfully used as longitudinal reinforcement in concrete columns instead of reinforcing steel [14]. Thus, large-scale studies use GFRP bars in concrete columns compared to conventional steel bars [15]. However, to save water, it is necessary to study the effect of seawater on concrete columns reinforced with fibreglass bars compared with polypropylene fibre concrete columns reinforced with fibreglass bars to note the extent of its effect. So, this research aims to verify the efficiency of polypropylene fibre concrete columns reinforced with fibreglass rods treated by seawater subjected to axial load. In conclusion, from the aforementioned findings, there are specific research works in which the behaviour of longitudinal reinforcement with fibreglass bars in concrete columns was studied. Moreover, there has been no study of the effect of seawater on the axial behaviour of these concrete columns so far. The experimental study focused on the structural behaviour of short columns reinforced by fibreglass bars with or without polypropylene fibres. Moreover, the effect seawater on these short columns is also investigated.

2 Experimental test

This study used the following materials (cement–sand–gravel–water–superplasticizer) with mixing proportions (1:1.92:2.66:0.5), and the superplasticizer was 150 mL (i.e., 2% of the weight of the cement for normal concrete mixes). The 0.50% fibre weight of cement has been added to the polypropylene fibre concrete product mixes [14]. The size of gravel used was 5 mm. The samples were treated with potable water and salty water. So, treated salty water had salt of 35 g for 1,000 L [16].

The compressive strength of concrete was model cube with a volume of 0.001 m^3 . The tensile strength of concrete was model cylinder with a diameter of 0.1 m and a height of 0.2 m. Eighteen short-column models were cast with dimensions of 0.1 length, 0.1 width, and 0.3 m height. The short concrete columns are divided into several groups: the first group without reinforcement, the second group reinforced with longitudinal fibreglass rods with a diameter of 6 mm, and the third group polypropylene fibre concrete columns reinforced with longitudinal fibreglass rods with a diameter of 6 mm (Figure 1). It is worth noting that the reinforced concrete columns have four longitudinal fibreglass bars with a diameter of 6 mm (see Figures 1 and 2). Meanwhile, the diameter of stirrups is 4.5 mm at 45 mm c/c in the end and 90 mm c/c in the middle of the column. Based on tensile tests for fibreglass bars, the ultimate tensile strength is 820 N/mm^2 . Each group consisted of six samples: three were treated with potable water, while the others were treated with salty water. The samples were tested at the ages of 14, 28, and 56 days. The properties of hardened concrete were studied to determine the effect of curing by seawater. Firstly, the density of the polypropylene fibre concrete, the compressive strength, and the tensile strength of the concrete were measured at 14, 28, and 56 days after half of the concrete samples were treated with drinking water. In contrast, the other samples were treated with seawater, and the results were compared. Secondly, the experimental test also included casting 18 short concrete columns. Six samples were of regular concrete, six of which were reinforced with 6 mm diameter longitudinal fibreglass rods, and six polypropylene fibre concrete columns were reinforced with 6 mm diameter longitudinal fibreglass rods that were subjected to axial load in the laboratory. The concrete columns were reinforced longitudinally with



Figure 1: Weight of material.



Figure 2: Casting of samples.

fibreglass bars to enhance structural behaviour by adding polypropylene fibre to the concrete.

3 Result and conclusion

From Figure 3, it noted that the value of slump test without adding superplasticizer to the concrete mixture was 7 cm. To obtain self-compacting concrete without using vibrators, it used superplasticizer, so the flow rate was 50 cm.

The results show the effect of salt water treatment on concrete density, compressive strength, tensile strength, and strength of short concrete column. Table 1 shows that there is no effect of the salt water treatment on the concrete density values, which are close to the values of the density of the concrete treated with potable water. At the same time, the effect of the saltwater treatment was found on the compressive and indirect tensile strength values, which are marginally less than the values of the

treatment with potable water, as given in Tables 2 and 3, respectively, meaning that there is a closeness in the results to a large extent. But it is noted that the older the curing age, it affects semi-obvious the resistive values. The reason may be a possibility of its effect on the hydration of the cement, which led to the crumbling of the concrete during the test, as shown in Figures 4 and 5.

At the same time, the effect of the salt water treatment was found on the compressive, indirect tensile strength values of the concrete and maximin loading on short

Table 1: Effect of treated water on concrete density (g/cm^3)

Code concrete mix	At 28 days
C-PW	2.28
C-SW	2.28
CF-PW	2.35
CF-SW	2.34



Figure 3: Value of slump test with or without adding superplasticizer to the concrete mixture.

Table 2: Effect of treated water on compressive strength of concrete (MPa)

Code mix	At 14 days	At 28 days
C-PW	16.42	21.28
C-SW	16.35	21.19
CF-PW	17.32	23.18
CF-SW	17.17	22.86

Table 3: Effect of treated water on tensile strength of concrete (MPa)

Code concrete mix	At 14 days	At 28 days
C-PW	1.598	2.301
C-SW	1.599	2.298
CF-PW	1.608	2.301
CF-SW	1.611	2.293

Where code concrete mix as: C-PW denotes the concrete treated with potable water. C-SW denotes the concrete treated with salt water. CF-PW denotes the polypropylene fibre concrete treated with potable water. CF-SW denotes the polypropylene fibre concrete treated with salty water.

concrete column, which are marginally less with the values of the treatment with potable water as found in Tables 2 and 3, respectively. However, it should be noted that the longer the curing period increases of samples, the more it affects the strength values. The reason may be a possibility of its effect on the hydration of the cement, which led to the crumbling of the concrete during the test, as shown in Figures 4 and 5.

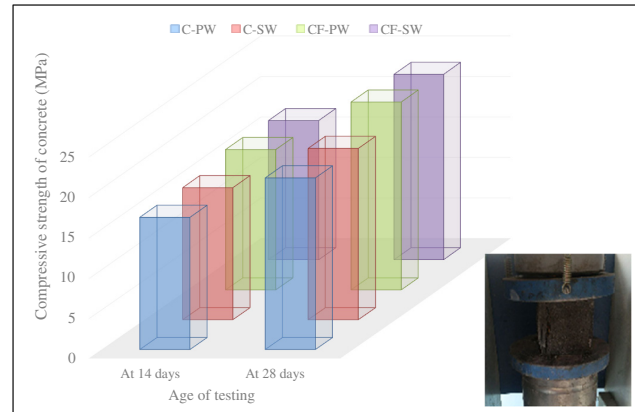
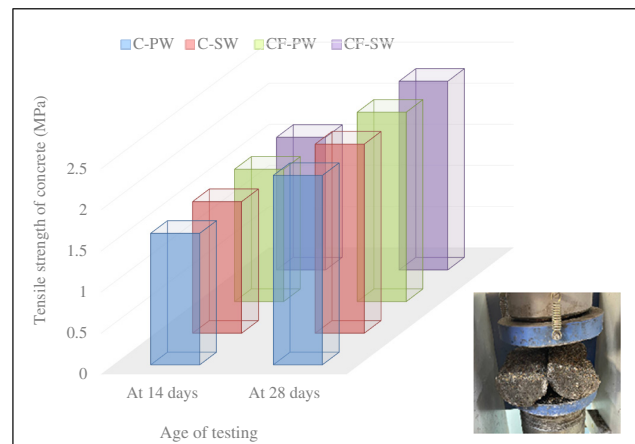
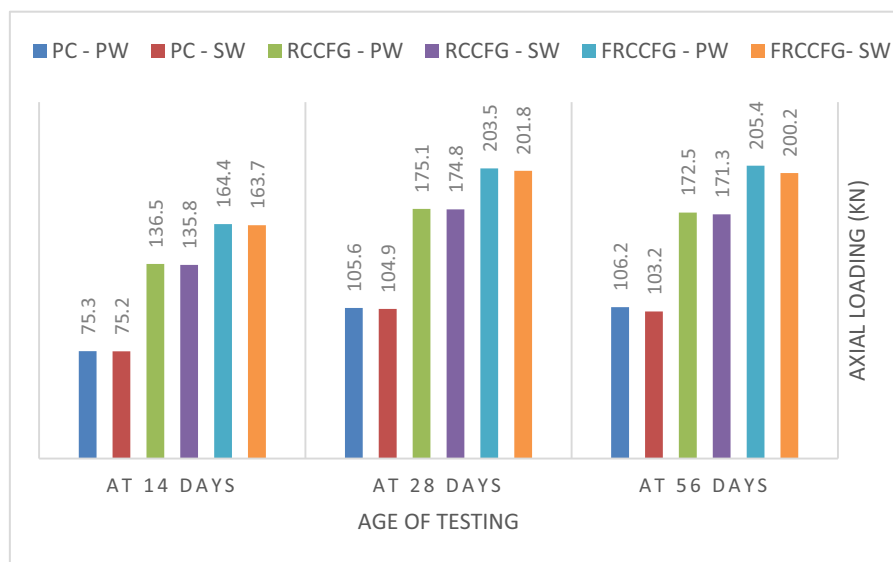
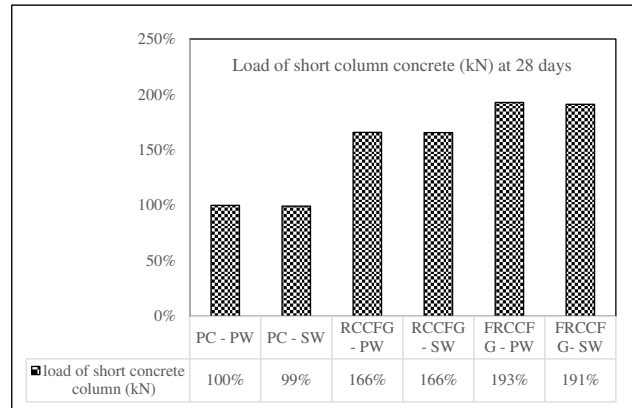
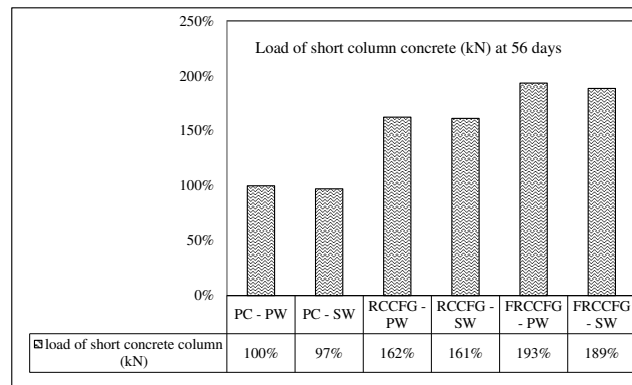
**Figure 4:** Effect of treated water on compressive strength of concrete.**Figure 5:** Effect of treated water on tensile strength of concrete.**Figure 6:** Effect of treated water on axial load on various short concrete columns.

Table 4: Effect of treated water on axial load of short concrete columns (kN)

Code short concrete column	At 14 days	At 28 days	At 56 days
PC-PW	75.3	105.6	106.2
PC-SW	75.2	104.9	103.2
RCCFG-PW	136.5	175.1	172.5
RCCFG-SW	135.8	174.8	171.3
FRCCFG-PW	164.4	203.5	205.4
FRCCFG-SW	163.7	201.8	200.2

Where code short concrete columns as: PC-PW denotes the plain concrete column treated in potable water. PC-SW denotes the plain concrete column treated in salty water. RCCFG-PW denotes the reinforced concrete column with fibreglass treated in potable water. RCCFG-SW denotes the reinforced concrete column with fibreglass treated in salty water. FRCCFG-PW denotes the fibre reinforced concrete column with fibreglass treated in potable water. FRCCFG-SW denotes the fibre reinforced concrete column with fibreglass treated in salty water.

After conducting the test, the short concrete column in the laboratory was subjected to an axial load. The maximum loading on a short concrete column was investigated, as shown in Figure 6. Table 4 presents the effect of treated seawater on an axial load of concrete columns with or without polypropylene fibre (plain and reinforced fibreglass). The ultimate load of the reinforced concrete column with fibreglass rods exposed to seawater reached 174.8 kN, and it was higher than that of the plain concrete column at 104.9 kN at 28 days. Therefore, the ratio of increase was 67%, so the technique of strengthening fibreglass as longitudinal reinforcement works to enhance the capacity of columns, which can be used in non-impacting structural parts. At the same time, the ultimate axial load of the fibre-reinforced concrete column with fibreglass rods exposed to seawater was 201.8 kN, which is 15.4% higher than that of the ultimate axial load of the reinforced concrete column with fibreglass rods. The results research was encouraged by fibreglass bars for the reinforced concrete columns, as the maximum axial load for fibreglass-concrete columns reached approximately 84–87% of the maximum axial load relative to polypropylene fibre concrete columns (Figures 7 and 8). Thus, the fibreglass bar enhances the capacity of the concrete columns. So it could be used in non-impacting structural parts. The use of fibreglass bars as longitudinal reinforcement of short concrete columns has provided important results in the literature. As a result, polypropylene fibre concrete columns longitudinally reinforced with fibreglass bars have enhanced the ultimate strength and structural behaviour (Table 4).

**Figure 7:** Maximum axial load on various short concrete columns at 28 days.**Figure 8:** Maximum axial load on various short concrete columns at 56 days.

The results also show the failure patterns of the short concrete column until the failure load. It was found that the short concrete columns began to fail and peel off the concrete at the loading point. The plain columns' failure is large and clear, especially at the top, facing the middle of the short column. On the other hand, all fibreglass-reinforced short columns begin to fail from the upper part of the rod sheathing.

In detail, the failure was in the corners of the short columns due to the concentration of the loading stress, so concrete cracks occurred in the corner. For short columns reinforced with fibreglass bars, hairline corner cracks occurred in the upper corners of the concrete casing face. In the polypropylene fibre concrete columns reinforced with fibreglass, cracks occurred in the middle of faces at the beginning, then cracks in the corners of the upper and middle faces of the samples (Figure 9). Concrete flaking due to the lack of thickness of the concrete cover was noted, which directly affected the reinforcing steel,

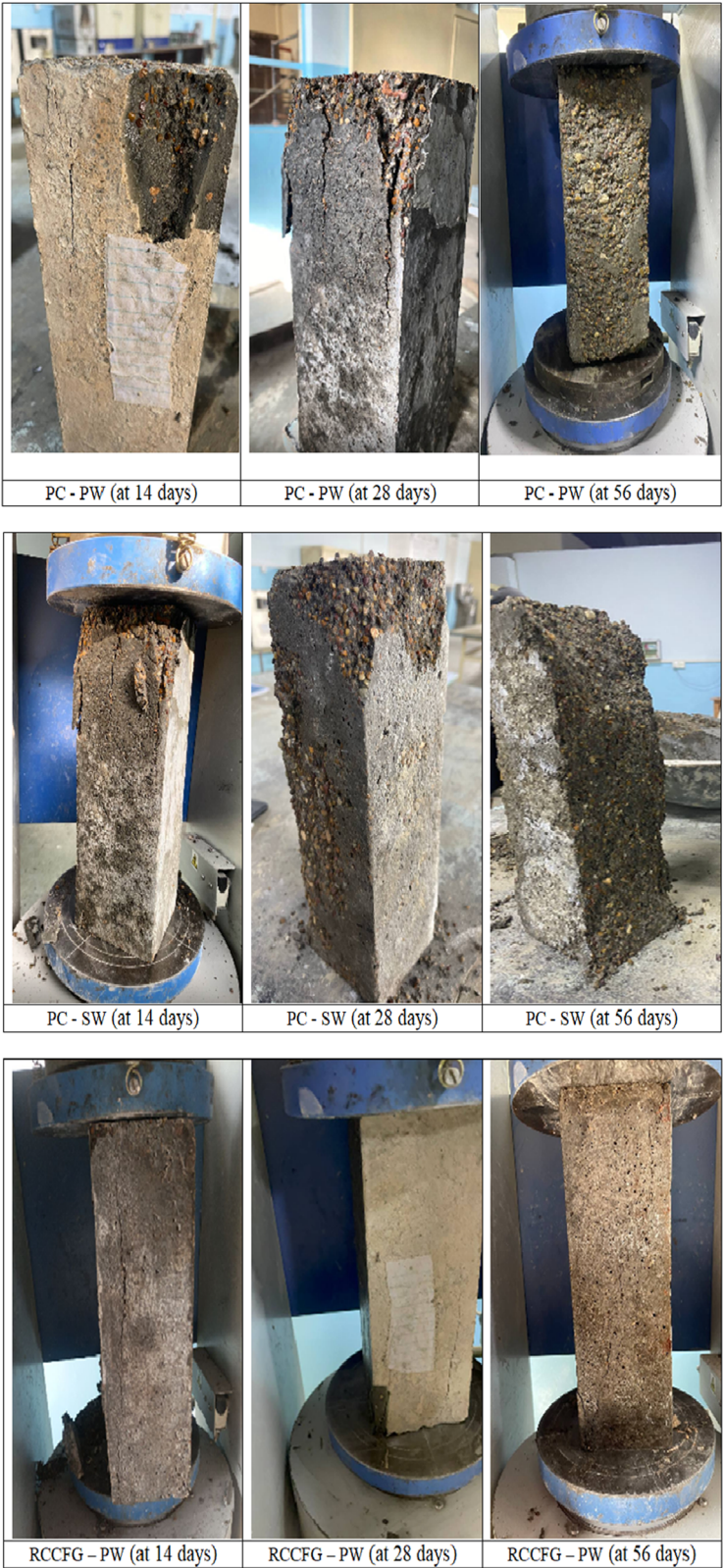


Figure 9: Crack pattern of all concrete columns.



Figure 9: (Continued)

thus rusting it. Therefore, the importance of using fibre-glass in reinforcing the concrete columns exposed to seawater becomes clear.

As a result, seawater used in curing concrete decreases strength slightly but causes rebar to rust with time. Here, the importance of research using fibreglass rods with concrete columns as reinforced longitudinal is evident. To protect the reinforced columns from corrosion, it used anti-corrosion materials that are an alternative to steel rods.

4 Conclusion

In this research, the achieved results are encouraging as follows:

The compressive strength and the tensile strength of concrete samples treated with potable water have the closest results to those of the seawater-treated concrete samples.

The maximum axial compression of short concrete columns reinforced with fibreglass rods reaches approximately 84–87% relative to polypropylene fibre concrete columns reinforced with fibreglass rods.

Fibreglass as reinforcement technology enhances the columns' capacity without rusting and can be used in typical buildings.

It was found that salt water has no noticeable effect on concrete. However, over the long term, it causes rusting of the longitudinal reinforcement of columns, which is a positive advantage of using fibre-class bars for concrete columns.

Thus, this study provides valuable information using fibreglass as longitudinal reinforcement in concrete columns.

As a result, the structural behaviour of concrete columns made of polypropylene fibres longitudinally reinforced with fibreglass bars exposed to harsh conditions is improved.

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Data availability statement: Most datasets generated and analysed in this study are comprised in this submitted manuscript. The other datasets are available on a reasonable request from the corresponding author with the attached information.

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