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Comparative Study of Fiber Glass Reinforced Polymer and Carbon Fiber Reinforced Polymer on Cube and Cylinder

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Abstract. A comparative analysis of polymers reinforced with glass fiber and polymers reinforced with carbon fiber was carried out on a cube and a cylinder in the laboratories of Baghdad. 36 samples were taken with fiber percentages of 1.0, 2.5 and 5.0 % by weight of cement. The methodology of this study included the use of composite polymer fibers in the external reinforcement of concrete beams for the purpose of improving their performance when bending by gluing polymer fibers to the surface. Group A tests of non-reinforced concrete beams with other reinforced polymer fibers were also implemented. Excellent results were obtained by adding two types of polymer fibers to a concrete sample. It was found that the polymer reinforced with glass fiber showed better results than the polymer reinforced with carbon fiber when testing samples for bending strength. However, in splitting strength, the carbon fiber reinforced polymer achieved higher performance than the glass fiber reinforced polymer. Whereas the results of a group of previous studies conducted to study the effect of fiber additives on the mechanical properties of concrete proved that their addition led to an increase in compression, tensile and bending resistance at rates that reached 25, 75 and 80 %, respectively.

Keywords: fiber, carbon fiber, fiberglass, polymer, bending, splitting, samples, beam, alkali resistance, epoxy resin, stress, composites, mechanical properties, failure

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Сравнительное исследование полимера, армированного стекловолокном, и полимера, армированного углеродным волокном, на кубе и цилиндре

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Реферат. В лабораториях Багдада проведен сравнительный анализ полимеров, армированных стекловолокном, с полимерами, армированными углеродным волокном, на кубе и цилиндре. Было отобрано 36 образцов с процентным содержанием волокна 1,0, 2,5 и 5,0 % от массы цемента. Методика данного исследования включала использование композиционных полимерных волокон во внешнем армировании бетонных балок для повышения прочности при изгибе при наклеивании полимерных волокон на поверхность. Выполнены испытания группы А неармированных бетонных балок с другими полимерными волокнами. Отличные результаты получены при добавлении двух типов полимерных волокон в бетон. Установлено, что полимер, армированный стекловолокном, имеет более высокие результаты, чем полимер, армированный углеродным волокном, при испытании образцов на прочность при изгибе. Однако прочность на раскалывание армированного углеродным волокном полимера достигла более высоких показателей, чем, армированного стекловолокном. Результаты группы предыдущих исследований, проведенных с целью изучения

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влияния добавок фибры на механические свойства бетона, показали, что их добавка приводила к повышению сопротивления сжатию, растяжению и изгибу при скоростях, достигавших 25, 75 и 80 % соответственно.

Ключевые слова: волокно, углепластик, стекловолокно, полимер, изгиб, раскалывание, образцы, балка, щелочестойкость, эпоксидная смола, напряжение, композиты, механические свойства, отказ

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Introduction

Polymer fibers have been successfully used for a long time in the aircraft and vehicle industries. Currently polymer fibers have found their use in civil engineering applications [1, 2] where external reinforcement was used to improve the performance of structures, such as strengthening concrete columns by a collar with polymer fibers is made around the outer circumference of the shaft to increase resistance and ductility, as well as it is used to increase the resistance to bending and shearing by attaching polymer fibers to the outer surface of the beams of the bishop [3–5].

There are usually three types of polymer fibers that are used in civil engineering, namely glass, aramid, and carbon fibers. Physical and mechanical properties differ not only between the types of these fibers but also for the same type of fiber [6–8].

According to the shape and length glass fiber can be divided into continuous fiber, fixed-length fiber and glass wool fiber [9–11] and according to the composition of the glass it can be divided into non-alkali, chemical resistant, high alkali, medium alkali, high strength, high elastic modulus and alkali resistant [12–14].

Polymer fibers alone are of limited use in civil engineering applications because they can transfer loads from one surface to another, and for this the matrix material plays a role [15–18].

Important in the function of polymer fibers as it works to bind polymer fibers together is to enable them to transporting loads and providing them with protection against various environmental influences and damages resulting from handling. Binders are of several types such as polyester and epoxy. It is one of the most common polymeric materials and is usually used with high performance fibers [19–21].

Material and method

In this study 36 samples were collected from laboratories and distributed according to cube and cylinder with percentage of added fiber (1.0, 2.5, 5.0 %) from weight cement.

Flexural strength is defined as the maximum stress that the material exhibits at failure due to the three or four point elastic load. According to literature review studied bending behavior of concrete with compressive strength and density ranging from 10 to 25 MPa. By using the modified polymer and the test device it is possible to measure the flexural modulus in polymer composites.

In general, the strength of fiber-reinforced composites depends on the properties of the components and the interactions of the interface. It is well known that for fiber-reinforced composites, as the interfacial region plays a leading role in transferring the load between the fibers and the matrix, thus affecting mechanical properties such as strength, the flexural failure depends mainly on the adhesion of the fibers and the matrix. The tests were relied on to examine the cubes and the cylinder (Fig. 1) where the U-test device was used to test the samples (Tab. 1).

Fig. 1. U-test device

Table 1

Results of cylinder 11×15 cm applying splitting strength

Symbol sample of concrete	Stress, MPa	Load, kN	Range of splitting strength	Time, s	Area, mm^2	Pace, kN/s
Without fiber						
C1	2.10	57.2	2.050	5	17671.459	11.44
C2	1.95	55.0		5	17671.459	11.00
C3	1.90	52.0	1.850	4	17671.459	13.00
C4	1.80	50.0		4	17671.459	12.50
C5	1.80	55.1	1.865	4	17671.459	13.70
C6	1.93	53.0		5	17671.459	10.60
Fiber glass reinforced polymer						
C1 (1 %)	7.05	124.64	7.080	12	17671.459	10.30
C2 (1 %)	7.11	125.50		12	17671.459	10.45
C3 (2.5 %)	6.93	130.00	7.385	13	17671.459	10.0.
C4 (2.5 %)	7.84	132.00		12	17671.459	11.00
C5 (5 %)	7.90	137.60	7.505	13	17671.459	10.58
C6 (5 %)	7.11	135.00		13	17671.459	10.38
Carbon fiber reinforced polymer						
C1 (1 %)	7.11	126	7.55	11	17671.459	11.4
C2 (1 %)	7.99	127		11	17671.459	11.5
C3 (2.5 %)	7.22	128	7.28	12	17671.459	10.6
C4 (2.5 %)	7.34	130		12	17671.459	10.8
C5 (5 %)	7.50	132	7.85	11	17671.459	12.00
C6 (5 %)	8.20	134		11	17671.459	12.18

The diagram below shows the comparison of control samples cylinder against glass fiber reinforced polymer and carbon fiber reinforced polymer in splitting strength. The highest value was obtained when carbon fibers were mixed with 5 % μ as shown in (Fig. 2).

18 samples were collected for the flexural strength assay, where a comparison was made between the control samples and the samples to which fiber was added, and the highest percentage was found when fiber glass reinforced polymer was added with 5 % (Tab. 2).

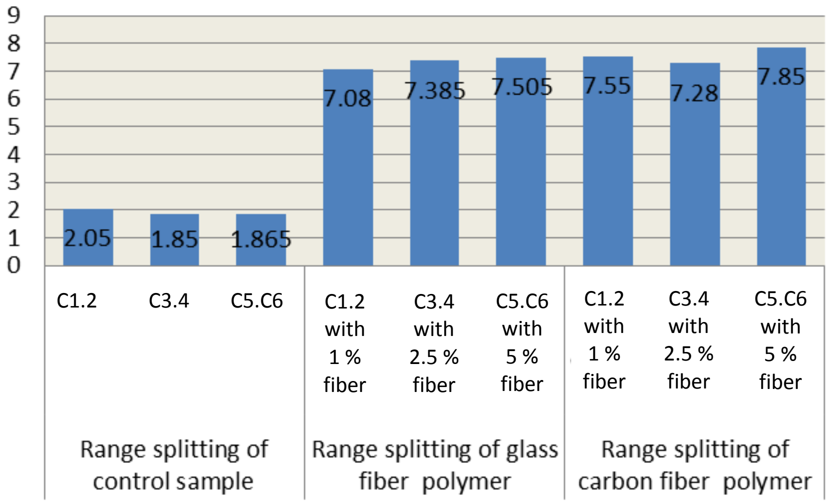


Fig. 2. Comparison of control samples cylinder against glass fiber reinforced polymer and carbon fiber reinforced polymer in splitting strength

Table 2

Results of cube 15×15×45 cm by applying to flexural strength

Symbol sample of concrete	Stress, MPa	Load, kN	Range flexural strength	Time, s	Area, mm^2	Pace, kN/s
Without fiber						
C1	4.522	34.14	4.375	3.4	7500	10.040
C2	4.230	33.00		3.2	7500	10.310
C3	5.634	42.90	5.202	5.0	7500	8.580
C4	4.770	40.00		5.0	7500	8.000
C5	4.900	44.70	4.955	4.0	7500	11.175
C6	5.010	41.00		6.0	7500	8.200
Fiber glass reinforced polymer						
C1 (1 %)	6.11	55	6.405	6	7500	9.16
C2 (1 %)	6.70	52		6	7500	8.66
C3 (2.5 %)	6.82	58	6.960	6	7500	9.66
C4 (2.5 %)	7.10	56		6	7500	9.33
C5 (5 %)	7.50	57	7.690	5	7500	10.60
C6 (5 %)	7.88	57		5	7500	11.40
Carbon fiber reinforced polymer						
C1 (1 %)	6.40	52	6.395	6	7500	8.66
C2 (1 %)	6.39	49		5	7500	9.80
C3 (2.5 %)	6.80	56	6.700	7	7500	8.00
C4 (2.5 %)	6.60	50		6	7500	8.33
C5 (5 %)	6.99	57	6.895	7	7500	8.14
C6 (5 %)	6.80	51		6	7500	8.50

Each two samples were collected separately depending on the added percentage to know the resulting differences as shown in (Fig. 3).

The mean value was taken to the three samples with respect to the cylinder and the cube without the fibers, and the mean value for splitting strength test for the cylinder samples was 1.92 MPa, while for the cube was 4.844 MPa (Fig. 4).

The amount of addition was determined during the examination of the splitting strength samples and compared with the control samples, and developments and increases were found when adding fibers at all levels as shown (Fig. 5, 6).

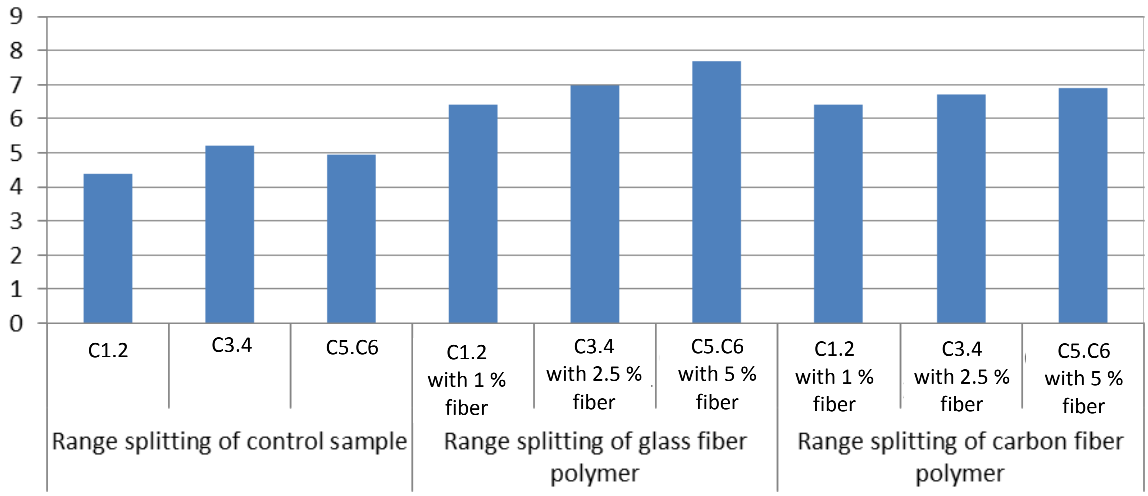


Fig. 3. Comparison between control samples cubes against fiber glass reinforced polymer and carbon fiber reinforced polymer in flexural strength

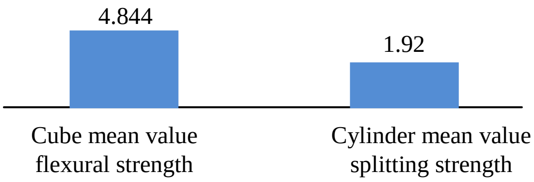


Fig. 4. Means value of flexural and splitting strength

Discussion

Samples were collected in this study where they depend on added fibers of carbon polymer and fiberglass where the percentage of added fibers was 1.0, 2.5 and 5.0 % and then the samples were tested by U-test for flexural and splitting strength. The samples were distributed depending on the type of examination that was used in this study. The samples were collected from cylinders and with dimensions of 11×15 cm, and 18 samples were collected with dimensions of 15×15×45 cm.

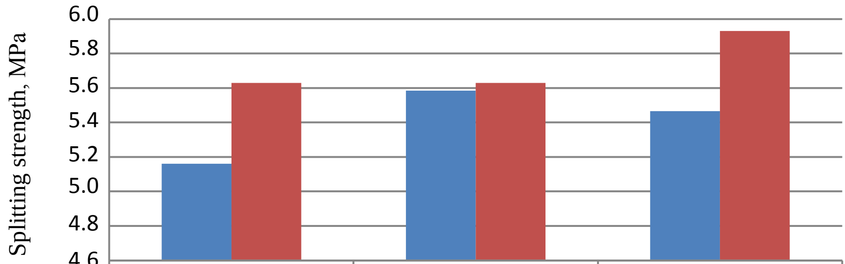
By examining the splitting strength to the cylinder, the average value of 6 samples without fiber was 1.92 MPa, and in the next stage, fiber glass reinforced polymer was added with (1.0, 2.5 and 5.0 %), respectively. Excellent results were obtained when examining the splitting strength and when adding fibers with 5 % of the splitting strength (7.505 MPa).

As for the second side of the comparison with carbon fiber reinforced polymer, the splitting strength rates were high when they were compared with fiber glass reinforced polymer, and the rates were the highest when 5 % was added with 7.85 MPa. Tab. 2 shows the results of cube 15×15×45 cm by applying to flexural strength at 7 days. Where 18 cubes were collected, including 6 samples without fibers, 6 samples of fiber glass reinforced polymer, and 6 samples of carbon fiber reinforced polymer.

The mean value of the cube samples without fiber was 4.844 MPa, and the flexural strength value increased when fiber glass reinforced polymer was added, and it achieved the highest rates of flexural strength to 7.69 MPa with 5 %, and the same was the case when carbon fiber reinforced polymer was added and it was higher flexural strength ratings at 6.895 MPa.

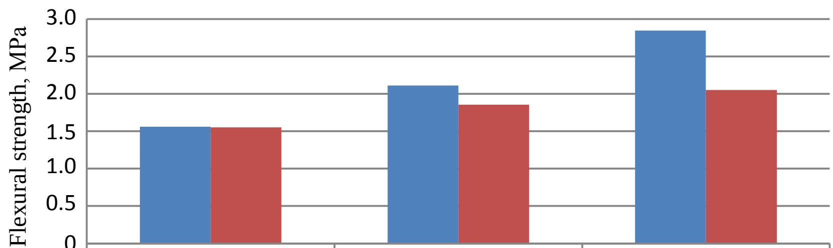
Fig. 5 and 6 show the amount of increase in splitting strength and flexural strength when adding types of fiber. A comparison was made between the two types of fibers with the control group used in these shapes, and it was noted that the percenttage of increase in splitting strength was higher when carbon fiber reinforced polymer was added when adding the three percentages[18, 22].

But it was not the case when examining the cubes, so the amount of increase in flexural strength rates when adding fiber glass reinforced polymer is higher than carbon fiber reinforced polymer (Fig. 3, 4).



	1 % add	2.5 % add	5 % add
glass fiber reinforced polymer	5.16	5.585	5.465
carbon fiber reinforced polymer	5.63	5.63	5.93

Fig. 5. Amount of increase in splitting strength when add types of fibers



	1 % add	2.5 % add	5 % add
glass fiber reinforced polymer	1.561	2.11	2.846
carbon fiber reinforced polymer	1.551	1.856	2.051

Fig. 6. Amount of increase in flexural strength when add types of fibers

CONCLUSION

The conclusion was drawn based on the amount of evolution in ratio splitting strength of cylinder and flexural strength to the examination of cubes. When comparing the two types of fibers, we notice that splitting strength. It was higher when added carbon fiber reinforced polymer compare fiberglass reinforced polymer [23, 24]. But when examining the flexural strength, we found that fiberglass reinforced polymer had achieved higher results than carbon fiber reinforced polymer [25], although the differences were slight between the two types of fibers [26–28].

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