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FLEXURAL PROPERTIES OF CARBON FABRIC WITH EPOXY RESIN COATING CONCRETE WITH SAND–CEMENT

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ABSTRACT
Recently, Fiber reinforcement concrete was rapidly growing both in terms of civil engineering and fundamental research. Owing to their mechanical properties, these materials have replaced steel and steel plates for external crack repairs in deteriorated structures. In this article, carbon fabric and its reinforced epoxy laminated composite material are used to coating concrete of a sand–cement mixture by an adhesive with epoxy. Later, composite panel of carbon coating concrete was subjected to flexural test using Tonindustrie Machine. The maximum load has been obtained to compare with concrete of a sand–cement without coating. The results evaluated from flexural test have shown that the carbon coating concrete increased the strength and durability five times more than uncoated concrete.

Keywords: Carbon Fabric; Concrete; Flexural Test; Strength and Durability

1. INTRODUCTION

Researchers all over the world are attempting to develop high performance concretes by using fibers and other admixtures in concrete up to certain proportions. In the view of the global sustainable developments, it is imperative that fibers like glass, carbon, polypropylene and aramid fibers provide improvements in tensile strength, fatigue characteristics, durability, shrinkage characteristics, impact, cavitation, erosion resistance and serviceability of concrete [1 - 3]. In buildings and civil engineering field, the reinforcement of structures among others is the first area of application of carbon fibers with favored advantages of lightweight and high strength. To increase durability of concrete structures such as bridges by covering them with carbon fiber sheets is being recognized as an effective reinforcement measure to increase resistance against earthquakes [4].

Construction of bridges with CFRP as the main structural material in progress as many part of the world. Application of reinforcement concrete, to the cables for suspension bridges and the substitute for steel frames are under serious study and CFRP is expected to be a qualified building material in the future. Have proved to be a phenomenal success, carbon fiber is one of these materials, which is usually used in combination with other materials to form a composite [5, 6].

Concrete is the most widely used construction material has several desirable properties like high compressive strength, stiffness and durability under usual environmental factors. At the same time concrete is brittle and weak in tension Due to the presence of these uniformly dispersed fibers, the cracking strength of concrete is increased and the fibers acting as crack arresters. Fibers suitable of reinforcing concrete having been produced from steel, glass and organic polymers. Many of the current applications of FRC involve the use of fibers ranging around 1% by volume of concrete. Recent attempts made it possible to incorporate relatively large volumes of steel, glass and synthetic fibers in concrete.

Nowadays strengthening is one of the most common cases for applying carbon fibers in building engineering. The main idea is to glue textiles or laminates onto outer surfaces of the structure to improve strength and rigidity. This type of external reinforcing is used to provide fail-safe usage of unique, expensive and historically important structures, when construction teardown or replacement of structures is much more expensive than repairing or not even possible.

Barros et.al [10] study the flexural strengthening, and the shear strengthening of concrete beams, four beam series of distinct depth and longitudinal tensile steel reinforcement ratio are tested. Each series is composed of one beam without any shear reinforcement and one beam using the following shear reinforcing systems. Using obtained experimental results, the performance of the analytical formulations proposed by ACI. Dias and Barros [11] presented, the influence of the following parameters was investigated: concrete strength; percentage of existing steel stirrups; percentage and inclination of the CFRP laminates; existence of cracks when the RC beams are shear strengthened with NSM CFRP laminates. The results show that the higher is the concrete strength class the larger is the effectiveness of the NSM technique. The effectiveness of the CFRP laminates was higher in the beams with the lower percentage of steel stirrups.

The main objectives of this study to investigate beam of concrete coated with carbon fabric structures, to know the effects of the fabric on the damage resistance of concrete. Also compare the relative results on the mechanical properties of concrete coated with carbon fabric with uncoated concrete.

2. MATERIALS and METHOD

2.1 Carbon fabric

The fabric used in this article was carbon non-woven fabric bundles of filament tie together by polyester filament with high specific strength and stiffness as shown in Fig.1, the carbon fabric properties are shown in Table.1. The material supplied from Mitsubishi Rayon Co., Ltd.

Table 1: Description of the properties of carbon fiber material being used

Property	Value
Longitudinal stiffness, E_{11} (GPa)	109
Transverse stiffness, E_{22} (GPa)	8.82
Out-of-plane stiffness ,E_{33} (GPa)	8.82
Poisson's ratio , ν_{12}	0.342
Poisson's ratio , ν_{13}	0.342
Poisson's ratio, ν_{23}	0.52
Shear modulus, G_{12} (GPa)	4.32
Shear modulus, G_{13} (GPa)	4.32
Shear modulus, G_{23} (GPa)	2.2
Longitudinal tensile strength, X_t (MPa)	1132
Longitudinal compressive strength, X_c (MPa)	1132
Transverse tensile strength, Y_t (MPa)	50
Transverse compressive strength, Y_c (MPa)	150
Longitudinal shear strength, S_{12} (MPa)	50
Transverse shear strength, S_{23} (MPa)	75
Density, ρ (kg/m^3)	1532
Volume fraction ν_f %	67

Figure 1: Carbon fabric bundles of filament tie together by polyester

2.2 Epoxy

Epoxy used in this article was Sikadur 31 CF Component-A, 100% solids, solvent-free, moisture-tolerant, high-modulus, high strength, and structural epoxy paste adhesive. It conforms to the current ASTM C-881, Types I and IV, Grade-3, Class-B/C and AASHTO M-235 specifications.

2.3 Concrete

A strong hard building material composed of sand and gravel and cement and water. Components of concrete: Gravel, Water concrete, sand and cement

2.3.1 Portland cement:-

A building material that was a powder made of a mixture of calcined limestone and clay, used with water and sand or gravel to make concrete and mortar.

2.3.2 Sand:-

A loose material consisting of grains of rock or coral

2.3.3 Aggregates:-

Are inert granular materials such as sand, gravel, or crushed stone that along with water and Portland cement, an essential ingredient in concrete.

2.4 Schmidt Hammer test

Developed in 1948 by a Swiss engineer named Ernst Schmidt the device measures the hardness of concrete surfaces using the rebound principle. The device is often referred to a Swiss hammer as shown Fig.2. The test is also sensitive to other factors local variation in the sample, to minimize this it is recommended to take a selection of readings and take an average value and water content of the sample, a saturated material will give different results from a dry one.

This test method for testing concrete is governed by ASTM C805. ASTM D5873 describes the procedure for testing of rock [11].

Fig 2: Hammer test

2.5 Flexural test

Flexural strength is one measure of the tensile strength of concrete as shown in Fig.3. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 6 x 6-inch (150 x 150 mm) concrete beams with a span length of at least three times the depth. The flexural strength is expressed as Modulus of Rupture (MR) in psi (MPa) and is determined by standard test methods ASTM C 293 (center-point loading) [12].

Fig 3: Flexural test (center-point loading)

2.6 Specimens Preparation

After 11 days of casting the specimens that shown in Fig.4, that was made by mixture as shown in Table.2. The concrete was coated by sheet of carbon fabric (50×60 cm) and painted with epoxy (mixing epoxy for three minutes) after that specimen left for two hour until become dry as shown in Fig.5.

Table 2: The mixing of materials

Mix	Volume
Cement	10.5 kg
Agg	35 kg
Sand	22.4 kg
Water	5.5 kg

Fig 4: Specimens of concrete

(a)

(b)

(c)

(d)

Fig 5: Coated and painted concrete with carbon fabric

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3. RESULTS and DISCUSSION:-

The spacemen's were taking 13 days after Cast. All testing was caring in University of Khartoum (Building and road Research Institute).

3.1 Hammer test

The Schmidt hammer test was based on the elastic rebound of hammer which presses on concrete surface and it measures the surface hardness of concrete. Since the test was very sensitive to the presence of aggregates and voids at the concrete surface, it was necessary to take more than 10.

The surface texture significantly affects the R-number obtained in Table 3 and 4. Tests performed on a rough-textured finish will typically result in crushing of the surface paste, resulting in a lower number. Alternately, tests performed on the same concrete that has smooth texture will typically result in a higher R-number. Therefore, it was recommended that test areas with a rough surface be ground to a uniform smoothness. After doing the hummer test, it was noticed that the carbon fiber does not effect on the resistance of the outside surface of the concrete coated with carbon fabric comparing to uncoated concrete, decreased resistance of the outside by 5.43%. Then the concrete coated with carbon fiber had a rough-textured finishing comparing to uncoated concrete.

Table 3: Results of hammer test for concrete

Distance (cm)	5	10	15	20	25	30	35	40	45	50
C_1 left side R(KN)	32	30	31	30	29	28	30	30	28	29
C1 right side R(KN)	28	30	30	29	30	30	30	28	29	28

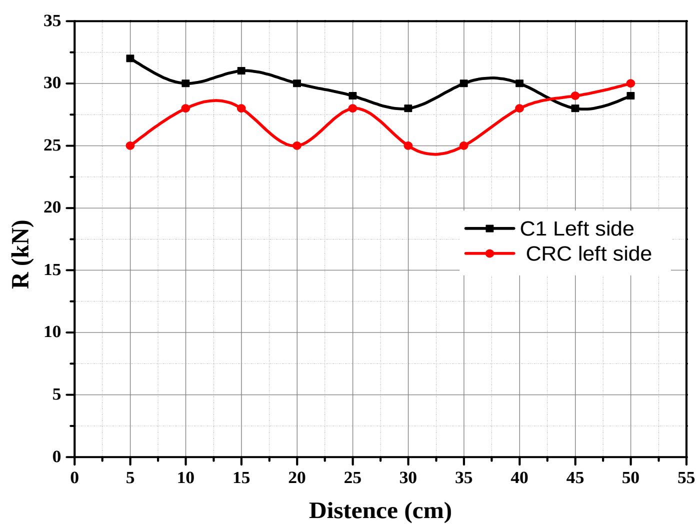
Table 4: Results of hammer test for concrete coated with carbon fiber

Distance (cm)	5	10	15	20	25	30	35	40	45	50
CRC left side R(KN)	25	28	28	25	28	25	25	28	29	30
CRC right side R(KN)	25	28	30	32	29	28	28	29	29	28

readings over the area of test as shown in Fig.8 and 9. However, it should be noted that Schmidt hammer test measures surface hardness only but not the strength of concrete. Therefore, it may not be considered a good substitute for concrete compression test.

This test method covers the determination of a rebound number (R) of hardened concrete using a spring-driven steel hammer. Normal concrete (C1) results shown in Table.3 for a sample of concrete coated with carbon fiber (CRC) shown in Table 4.

Fig.6 and 7 shows the rebound number (R) with distance curves of concrete and concrete coated with carbon fabric for left and right side. Each points of uncoated concrete was higher than concrete coated with carbon fiber, except for points of 20 from the right and points of 45 and 50 from the left concrete coated with carbon fiber was highest than uncoated concrete. This due to the uncoated concrete has a rough-textured finishing surface.



Fig

6: Rebound distance curve of left side for concrete and concrete coated with carbon fabric.

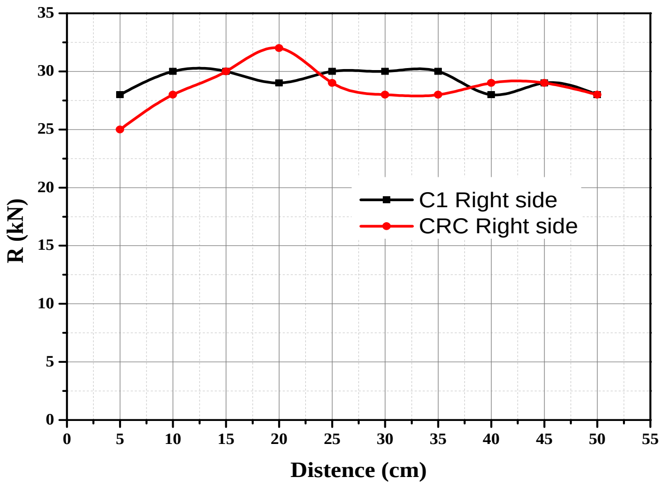


Fig7: Rebound distance curve of left side for concrete and concrete coated with carbon fabric

Fig 8: Hammer test for concrete

Fig: Hammer test for carbon fabric coated concrete

3.2 Flexural strength test:-

The load shall be applied through two similar rollers mounted at the third points of the supporting span that was spaced at 20 or 13.3 cm center to center. The load should be divided equally between the two loading rollers, and all rollers mounted in such a manner that the load was applied axially and without subjecting the specimen to any tensional stresses or restraints.

Table 5: Results of flexural strength test

Sample	Weight(kg)	Flexural strength (tone)
C1	12.4	1.25
CRC	14.6	6.05

Flexural strength (KN) = F × g × R

Where: F ≡ Flexural strength (tons), g ≡ acceleration gravity ($9.81 m/s^2$), R ≡ correction factors for machine (1.0073)

Table 6: Results of flexural strength test

Sample	Weight (kg)	Flexural strength (KN)
C1	12.4	12.35
CRC	14.6	59.78

The concrete coated with carbon fiber collapsed at 59.78 KN while the concrete without coating collapsed at 12.35KN as shown in Table.6. This implies that the carbon fiber increases the durability and the strength of concrete. Concrete tensile strength increased because the sheet of carbon fabric has high tensile strength.

The carbon fabric contributed on reducing types of concrete deformation , according to the experiments when coating the concrete with carbon fabric the durability and strength increased five times more than uncoated concrete

Adding adhesive (epoxy) made the concrete and fiber work together and give the large difference in durability and strength.

3.3 Deformation types

In the moment of collapsing a voice can be heard in the concrete, in the coated concrete the crack did not reach the inside of the concrete but stopped at the fabric that shown in Fig.10, While the uncoated concrete fully cracked (broke) as shown in Fig.11. This may be attributed to the fact that fibers suppress the localization of micro-cracks into macro-cracks and consequently the apparent tensile strength of the matrix.

Fig 10: Cracking of carbon fabric coated concrete

Fig 11: Cracking of uncoated concrete

4. CONCLUSIONS

Carbon fabric and its reinforced epoxy laminated composite material were used to coating concrete of a sand–cement mixture by an adhesive with epoxy. Later, composite panel of carbon coating concrete was subjected to flexural test using Tonindustrie Machine. And the results were compared with the uncoated concrete.

For the hummer test, it was resulted that the carbon fabric does not effect on the resistance of the outside surface of the concrete coated with carbon fiber comparing to uncoated concrete.

The carbon fabric reinforcement concrete increases the concrete strength and durability five times more than the normal concrete.

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