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Original Research Paper

Engineering

USE OF CARBON FIBER AS A STRENGTHENING MATERIAL IN BUILDINGS

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ABSTRACT

The rehabilitation, repair and strengthening of concrete structure has increased worldwide with a growing number of systems employing externally applied fiber-reinforced polymer (FRP) composites. For applications of structures, an overview of different FRP composites is provided by various polymer composites and in civil structures FRP composites are used for reinstatement or firming up the elemental constituent. This paper examines ability of a woven carbon fiber reinforced polymer fabric wrapping to enhance the strength of various building components. Six concrete cubes of M20 grade and with dimensions of 15cm x 15cm x 15cm were casted for this purpose. Proper curing of 7 days for three cubes and 28 days for another three cubes was done. Later on compressive tests were carried out on these cubes using standard compression testing machine until the first crack appeared. The cubes were then wrapped with the carbon fiber fabric of 300 GSM 12k unidirectional. Along with the cubes the same procedure was carried out on a column in a live building situated at Vani, a village near Nasik city. Non-destructive tests were carried out on this column and wrapping was done with the same grade of carbon fiber fabric and further tests were carried out.

KEYWORDS :

I.INTRODUCTION

A large number of existing reinforced concrete (RC) infrastructure in developed countries including bridges, municipal buildings, transportation systems and parking facilities are suffering from distress due to overuse or inadequate maintenance. Demolition and building a new structure is very costly and time consuming. Structural strengthening is more economical solution and hence frequently required to extend the functional service lives of deficient RC structures. Reinforced concrete and grout-injected steel jacketing systems are the most common methods developed in past to upgrade RC columns. Although both methods are effective in increasing the structural capacity, they are labor consuming and sometimes difficult to implement on site. In addition, the RC jacketing system would result in substantial increase in the column's cross-section. A steel jacketing system is often heavy and performs poorly in resisting adverse environmental conditions. Hence, an innovative, durable, easy-to-install and cost effective strengthening system is required to replace outdated techniques.

Carbon fiber fabric has emerged as promising alternative strengthening material for upgrading deficient RC infrastructure. This fabric can be easily wrapped around the column's cross-section with a high-strength adhesive to provide a confining.

RESEARCH ELABORATIONS

1. EXPERIMENTAL PROGRAM

TEST SPECIMEN - CONCRETE CUBES

The test specimens were six square concrete cubes of M20 grade of size 15cm x 15cm x 15cm. Proper curing of 7 days for three cubes and 28 days for another three cubes was done. Later on compressive tests were carried out on these cubes using standard compression testing machine until the first crack appeared. The cubes were then wrapped with the carbon fiber fabric of 300 GSM 12k unidirectional. After wrapping the increase in the size of the cubes was negligible. For wrapping purpose the araldite solution was used. The araldite and hardener were mixed in the suitable proportion and applied on the surface of the cubes with the help of spatula. Immediately after applying the solution on four sides of the cube the carbon fiber fiber fabric was applied and another coat of the araldite solution was applied over the fabric. The cubes were then allowed to dry and strengthen for two days and again the same compression test was carried out on the cubes.

The test matrix is given in table no. 1 and 2. The parameters included in the test werespecimen, compressive strength.

Table 1 – Strength before carbon wrap

7th day reading		28th day reading	
Specimen	Compressive strength (MPa)	Specimen	Compressive strength (MPa)
Cube 1	451.4	Cube 1	609.5
Cube 2	429.8	Cube 2	659.5
Cube 3	341.6	Cube 3	790.4

Table 2 – Strength after carbon wrap

7th day reading		28th day reading	
Specimen	Compressive strength (MPa)	Specimen	Compressive strength (MPa)
Cube 1	441.9	Cube 1	357.57
Cube 2	316.6	Cube 2	850.2
Cube 3	536.8	Cube 3	1080.5

2. COLUMN OF THE BUILDING

A building was found in Vani, a village near Nashik city. It is a government building built about four years ago which components failed due to inadequate maintenance. Non-destructive test was carried out on all the columns, beams and slab. A column which was completely failed was selected for carbon fiber wrapping. The selected column was wrappedwith carbon fiber fabric and was allowed to dry and

gain strength for 2 days. After 2 days the non-destructive test was performed again and the readings were recorded as follows-

Table 3 –Readings before carbon wrap

Face 1	Face 2	Face 3	Face 4
20	20	22	24
20	28	27	22
28	22	20	20
22	24	24	28
24	28	20	26
28	20	20	24

Table 3 – Readings after carbon wrap

Face 1	Face 2	Face 3	Face 4
28	26	34	30
36	34	34	32
26	26	28	28
30	28	28	28
28	24	26	26
38	30	38	40

Table 4: Material Properties

Material	Size	Density	Specific Gravity	Quantity
Cement	50 μm	3.15 g/cm^3	3.15	33 kg
Sand	< 4.75 mm	1.68g/cm^3	2.60	59.4 kg
Aggregate	>4.75mm	1.6g/cm^3	2.65	99 kg
Water		1g/cm^3		18.5 lit
Carbon Fiber	0.0002 to 0.0004	1.75 to 2.0 g/cm^3	1.8	5.5m^2
Epoxy Resin (Aeraldite)		1.1 to 1.2 g/cm^3	1.2	4.5kg

CFRP Wrapping System

Full wrapping system is used in the resent study. For full wrapping scheme, one layer of continuous CFRP laminate was wrapped around the column's section in the test region with fibers oriented in transverse direction. To avoid premature failure of at the ends of the test region, the strip width was increased to 125mm at each end. The CFRP laminates had an overlap of 50mm in transverse direction.

The CFRP wrapping included surface preparation and CFRP application. The concrete surface was ground to remove any dust and loose particles from the concrete surface. The epoxy resin was them applied directly onto the prepared surface using trowels. The CFRP fabrics, precut in desired dimensions, were then placed onto the resin coating and smoothen out with gloved hands. Adequate pressure was applied until the resin was squeezed out between the fabric's ravings. A final sealer coat of resin was then applied onto the exposed surface.

RESULTS AND CONCLUSION

The construction industry is ever lasting and ever expanding without any break. The need of shelter, buildings, roads, airports, etc. is never ending. In the same way renovation, innovation and creation of new techniques, new infrastructure is also continuous. There is a constant need of correction, rebuilding, improvement in all kinds of structure.

So as to cope up with this need, we have tried to implement another new, innovative and easy method to correct and rectify the failed structures or those in need of renovation.

During our testing we observed that the loading patterns and the direction of the woven fiber plays an important role in the strength results of the Carbon fiber reinforced Fabric. The fabric gives out more strength if it is applied with its fibers longitudinal to the axis of loading of the member.

During the testing of the cubes, it was observed that if the cubes were loaded in the direction perpendicular to the fibers, the carbon fiber reinforced fabric failed to give strength, as in the case of the following cubes.

Table 5: Readings of Cube that were tested in direction perpendicular to that of the fibers; before and after carbon wrap.

Description	Cubes	Compressive Strength without Carbon Fiber Fabric Wrapping.(KN/m^2)	Compressive Strength with Carbon Fiber Fabric Wrapping.(KN/m^2)
7 Days.	Cube 1	20.06	19.64
	Cube 2	19.10	17.18
	Cube 7	21.29	19.56
	Cube 9	18.34	17.83
28 Days.	Cube 1	27.09	19.36
	Cube 8	31.60	31.59
	Cube 9	29.76	28.90

We have found very amazing results with very less efforts. In comparison with other methods like steel-concrete jacketing and retrofitting, Carbon Fiber Fabric Wrapping has proven to be better in almost all the aspects.

As stated earlier, Carbon Fiber Reinforced Fabric has several advantages over conventional methods of retrofitting, like:

1. Thickness of the repaired member does not increase.
2. Initial Cost required is less comparatively.
3. No skilled labor is required.
4. Time required for carbon fiber reinforced fabric wrapping is less.
5. Handling of the material is easier, etc.

Based on the experiments and tests conducted and mentioned above, it can be inferred that the carbon fiber material increased the strength of the specimens effectively.

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