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Torsional performance of reinforced concrete beam with carbon fiber and aramid fiber laminates

S. Shanmugasundaram [1*], R. Mohanraj [2], S. Senthilkumar [3], P. Padmapoorani [4]

[1] Department of Civil Engineering, Excel Engineering College, komarapalayam, Namakkal, Tamilnadu (India), sssunderamcivil@gmail.com
[2] Department of Civil Engineering, Excel Engineering College, komarapalayam, Namakkal, Tamilnadu (India), rsrirammohan@gmail.com
[3] Department of Civil Engineering, KSR College of Engineering, Thiruchengode, Namakkal, Tamilnadu (India), senthil.env@gmail.com
[4] Department of Civil Engineering, KSR College of Engineering, Thiruchengode, Namakkal, Tamilnadu (India), pooraninagaraj@gmail.com
*Correspondence: rsrirammohan@gmail.com

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Abstract: In the presented research paper, investigated the torsional performance of reinforced concrete beams with light emissions grade of cement utilizing Carbon fiber and its relative investigation with aramid fiber, for its torsional conduct, utilizing both exploratory and insightful strategies. A distinctive example of its strips folded over RC beams and the torsional conduct of these restrengthened beams is considered. Carbon fiber (CF) is utilized as outside support. Reinforced concrete beam retrofitted with CF tried for torsional disappointment utilizing lever arms exposed to torque. The beams have dimensions of 150mm in width and 200mm in depth and 1 m long, as planned according to IS456-2000. Three bars are intended for a twist. Steel has a stronger ultimate strength but a lower density than aramid FRP, as well as being easier to install and requiring no interim support until it reaches its full strength. The impact of various sorts and designs of CF on the initial stage of breaking load, extreme load conveying limit, and disappointment method of the beam are thought about and its relative examination utilizing finite element programming with aramid fiber gives a better outcome for additional investigation.

Keywords: carbon fiber, aramid fiber, retrofitting, torsional analysis, ANSYS.

1. Introduction

The utilization of strands to work on post strength of considerable conduct is exceptionally well known nowadays. Since the most recent 4 decades, a few diverse fiber types and materials have been utilized to further develop the solidness of concrete and furthermore its actual properties (Abed, El-Chabib, & AlHamaydeh, 2012). Demonstrating such different free examination results shows the capacity of such filaments, which further develop the toughness of concrete and its actual properties. Notwithstanding the beginning, cracking, when initiated by a few cycles like mechanical, chemical, and natural cycles, brings about disintegrated and less-strong concrete (Al-Mahmoud, Castel, & François, 2013). Likewise, the expanded penetrability brought about by breaking can speed up other disintegration measures bringing about less-strong concrete (Askandar, Mahmood, & Kurda, 2020). The greater part of RCC structures have experienced extreme degradation since their development, because of the joined impacts of forceful environmental conditions, essentially expanded live loads (Banjara & Ramanjaneyulu, 2017).

To save, retrofit, and keep up with these falling apart designs is a serious issue that is being looked at by structural engineers today. Execution and advancement of most recent and monetary repair techniques are needed to expand the help life of these RCC structures (Chen & Teng, 2003). These RC structures were basically intended to withstand the mechanical loadings, yet these designs were likewise continually exposed to physio-substance phenomena which bring about early decay, which eventually lessens its dependability of execution with adequacy (Amer M. Ibrahim & Amer M. Ibrahim, 2009). The early weakening is a significant issue for any public, as public security will be at serious risk and therefore the expense to fix it will straightforwardly influence the future economy(Islam, Mansur, & Maalej, 2005). To limit this issue and furthermore to keep up with the different uses of these RC structures, the recurrence of repair and term of fixing ought to be kept to the base likely level (Kilic & Gokce Gok, 2021). As the mechanical properties of carbon strands are extraordinary, it tends to be used to reinforce those zones where the construction is presented to high mechanical or cyclic loading, to restore such zones and serious natural conditions (Anadee M. Kulkarni & Debarati Datta, 2019). Just the external part of the more established structure gets wrapped which will work on the strength of concrete; rather than upsetting different pieces of construction (Mostofinejad, Tabatabaei Kashani, & Hosseini, 2016). Hence, this reasonable thought will significantly work on the usefulness and life-cycle costs decrease of the designs contributes unavoidably towards reinforcing the structure under flexure and twist and expanding its solidness (Sethuraman Muthusamy Kavitha, G. Venkatesan, Siva Avudaiappan, & Erick I. Saavedra Flores, 2020).

Despite the fact that continuous jackets are sometimes less cost-effective than strips, T-shaped beams with them are nevertheless preferred. Recent research has demonstrated that the basic deformation of torsion-enhanced beams is comparable to that of un-enhanced ones; however, the externally bonded FRP prevented the crack's width propagation and broadened the crack spacing, increasing the torsion contribution of concrete. But the issue of externally strengthened flanged beams under severe torsion utilizing the FRP system is not addressed. The torsional performance of RC beam members was enhanced in this study using AFRP and CFRP laminates. Part of the RC beam was covered with AFRP and CFRP laminates, which have high tensile strength and good tensile ductility. A pure torsion test was performed on 10 beam specimens that were constructed. The torsional performance of various RC beam specimens was compared and discussed using the experimental results.

2. Materials and methods

2.1. *Carbon fiber*

A Unidirectional Carbon Fiber is one in which most of the carbon strands run one way as it were. A modest quantity of carbon fiber runs in different ways with the fundamental goal being to stand firm on the essential carbon filaments in the situation (Mohammadizadeh, Fadaee, & Ronagh, 2009).

2.2. Aramid fiber

The production of Aramid fibers known under their trademark name is Kevlar, has unique and beneficial properties. Aramid fibers are known by the brand name Kevlar, which is owned by DuPont. Poly-para-phenylene terephthalamide was the chemical name for Kevlar when it was first developed in the 1960s. Kevlar has idiosyncratic properties such as excellent impact resistance and low density (Pellegrino & Modena, 2006). The three different patterns of AFRP sheets used in this study (Rooholamini, Hassani, & Aliha, 2018) and their properties are listed in Table 1. Kelvar 29 is having knitted mesh reinforcement shape, Kelvar 49 is having chicken mesh reinforcement shape and Kelvar 149 is having honeycomb reinforcement shape. Kelvar 29, 49, and 149 shapes are depicted in Fig.1., Fig.2., and Fig.3 respectively.

Table 1. Properties of different AFRP sheets

AFRP patterns	Density	Tensile strength	Modulus
Kelvar29	1.44 (g/cm^3)	2920 MPa	83 GPa
Kelvar49	1.44 (g/cm^3)	3600 MPa	124 GPa
Kelvar149	1.47 (g/cm^3)	3650 MPa	174 GPa

Figure 1. Kelvar29.

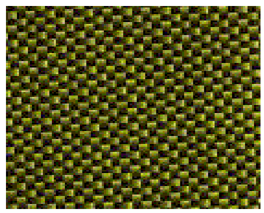

Figure 2. Kelvar49.

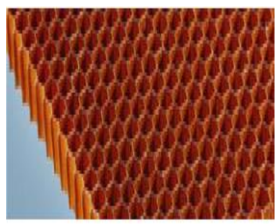

Figure 3. Kelvar149.

2.3. ANSYS

An approximate solution to a wide range of engineering issues can be found using the Finite Element Method (FEM), a numerical analysis. The most effective method now used for the numerical resolution of numerous engineering issues is the finite element method. Applications include solving acoustical phenomena, neutron physics, and heat transfer issues, in addition to stress analysis of solids.

The area of computer-aided engineering has made significant strides over the last 20 years, and several engineering sectors have benefited greatly as a result. The facilities offered by advanced finite element programs and high-performance computing are used by many universities to conduct research and development projects in collaboration with the private sector. The employment of cutting-edge finite element tools in the construction sector has been made possible by the development of precise design methodologies as well as the introduction of effective and cutting-edge building products. Hybrid rubber reinforced composite slabs can be correctly simulated using finite element models, which drastically reduces the need for costly and time-consuming large-scale experiments.

Finite element analysis software for FEA is offered commercially under the name *ANSYS*. In addition to steady-state and transient issues, mode frequency and buckling analyses, acoustic and electromagnetic issues, various field and coupled-field applications, static and dynamic structural analysis (both linear and nonlinear), steady-state and transient issues, and more are among these issues. A Graphical User Interface (GUI) is offered throughout the curriculum to help new users learn the material. Multiple windows, dialogue boxes, pull-down menus, toolbars, and online documentation are all available to users. Using the library of elements found in ANSYS, any geometry may be digitally represented. A variety of linear and nonlinear simulation applications are available with ANSYS. By matching the geometry defining each piece with the proper material models and establishing component interactions, problems with multiple components can be modeled. During the nonlinear analysis, Ansys automatically selects the proper load increments and convergence tolerances and continuously modifies them to achieve an accurate result.

2.4. Specifications of beam

The 3 beams are intended for a twist, 3 beams are planned as a normal beam, and 9 beams are intended to restrengthen utilizing carbon filaments which expands its torsional limit. For the theoretical work, all rectangular RC beams were cast (More & Kulkarni, 2014). The dimensions of the beams are 150mm x 200mm x 1000mm of Fe 415. The beams intended for twists for example-controlled beams have 2Nos-12 mm width bars utilized at the lower part of each beam as flexural support, and 2Nos-8 mm bars and 6 mm gap across stirrups staggered 160 mm c/c for shear support at the top and midspan of each beam. The beam planned as should be a normal beam has 2Nos-8 mm distance across bars are utilized at the highest point of each beam, and 3 Nos-8 mm bars and 6 mm diameter stirrups dispersed 160 mm c/c for shear stability at the bottom section of each beam. The projecting of the beam was made according to IS detail utilizing M40 grade concrete with 20 mm coarse aggregate (CA), fine aggregate (FA), and Portland concrete. These beams were tested under 2-point loading on a UTM with a maximum load of 1000 kN after being relieved in refined water for 28 days. Cross-sectional details are given in Fig. 4(a) and 4(b).

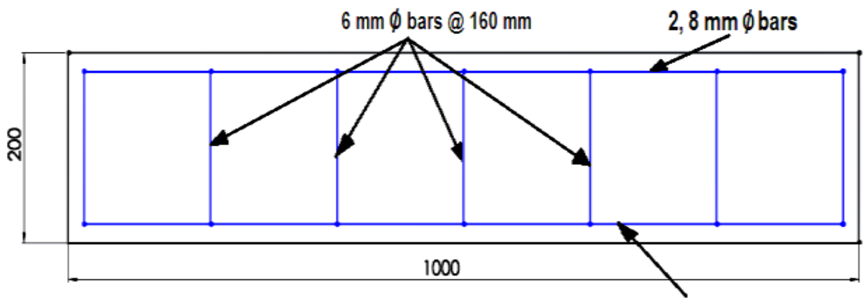

Figure 4(a). Detailing of the beam in a longitudinal direction.

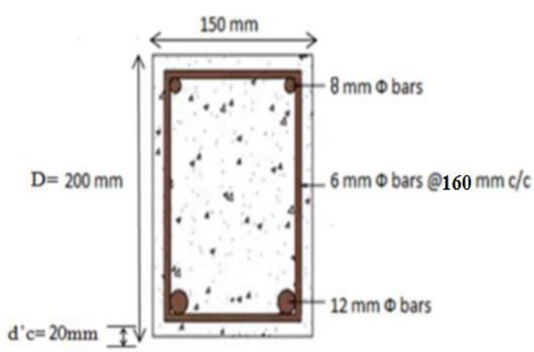

Figure 4(b). Detailing of the beam at the cross-section.

2.5. Retrofitting of beam

To guarantee the ideal and right utilization of the outer fortifying materials with no provisos, it was viewed as important to work on the attributes of the concrete surface at the contact regions (Nabil F. Grace, George Abdel-Sayed, & Wael F. Ragheb, 2002). As indicated by the maker's guidance, the surface arrangements were finished. It incorporates eliminating the residue on a superficial level and furthermore eliminating the concrete glue, covering the surface by utilizing groundwork clay. The epoxy glue was then applied to the Carbon Fiber as well as the substantial surface. At last, the Carbon Fiber sheets were completely wrapped (Pellegrino & Modena, 2006) and beam specifications are listed in Table 2.

Table 2. Beam specification.

Beam No.	Beam designation	No. of layers
1	B conventional	-
2	B FRP K29	1
3	B FRP K29	2
4	B FRP K29	3
5	B FRP K49	1
6	B FRP K49	2
7	B FRP K49	3
8	B FRP K149	1
9	B FRP K149	2
10	B FRP K149	3

2.6. Test arrangement

Every one of the beams was tried under two-point loading in UTM of a limit 1000 kN. The load arrangements for evaluating all sets of beams as illustrated in Fig.5. Two Kilonewton readings were recorded at explicit continuous expanded load span. Deflection of the beam under beam is estimated by dial check having 0.001 least tallies. The defections and load transformations were noted all, during experimental work. At the point when the first crack showed up on the beam that would set apart on it. Beam set-up was created as simply-supported which is manufactured particularly for experimental work (Roohol-amini, Hassani, & Aliha, 2018).

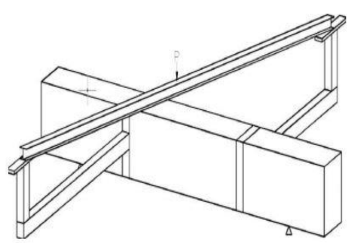

Figure 5. Arrangement of beam for test.

3. Experimental results and analysis

3.1. Comparison of test results

The test outcomes were contrasted and therefore the aftereffects of retrofitted beam utilizing Aramid fiber utilizing ANSYS programming, by FEM. The reinforcement details of the beam in ANSYS are shown in Fig. 6.

Following components and shells were utilized in Finite Element Analysis for demonstrating of RC beam wrapped with carbon fiber in three distinct examples; in which Concrete is supplanted by SOLID186 component as Fig. 7(a), supporting steel is supplanted by SOLID187 as Fig. 7(b) component and Carbon Fiber is supplanted by SHELL181 as Fig. 7(c)component.

Also, the following components and shells are utilized in ANSYS for demonstrating of RC beam wrapped with aramid fiber in three distinct examples; in which Concrete is supplanted by SOLID65 component as Fig. 7(d), supporting steel is supplanted by BEAM188 component as Fig. 7(e) and aramid fiber is supplanted by SHELL91 component as Fig. 7(f).

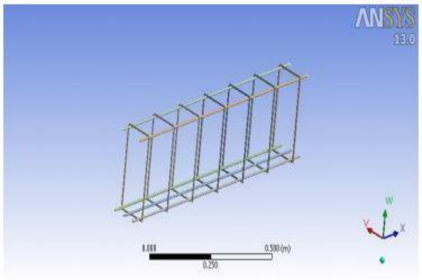

Figure 6. Beam Reinforcement model in ANSYS.

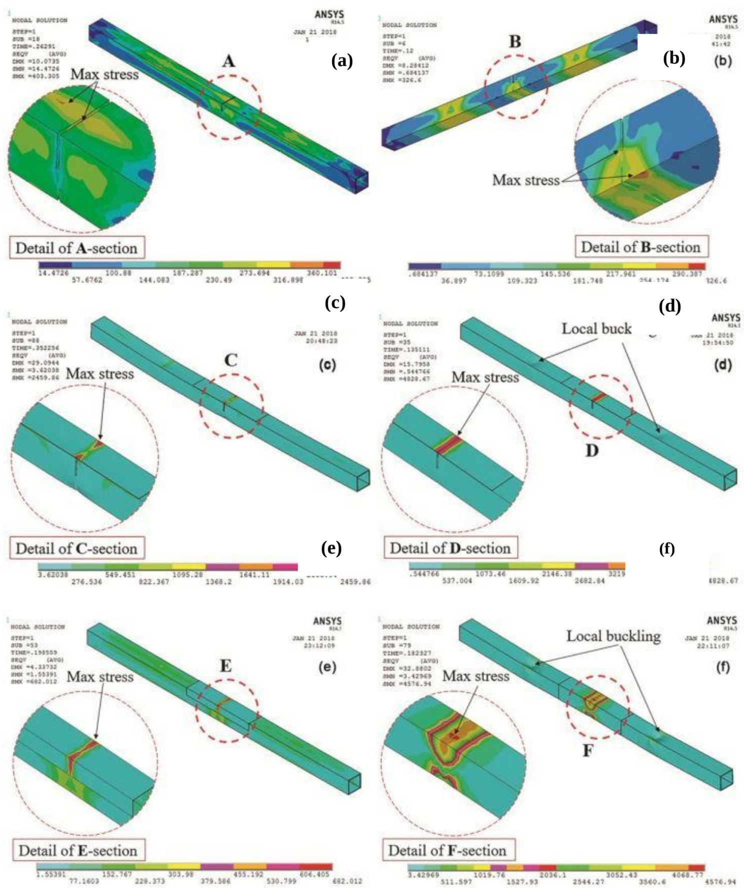

Figure 7. (a). Element of SHELL 186, (b) element of solid 187, (c) element of solid 181, (d) element of solid 65, (e) element of beam188, (f) element of SHELL 91.

3.2. Crack shape

For crack pattern, the typical and wrapped beam nearly read. The flexural and shear break patterns in both beams were found to be identical (SIDDIQUI, 2010). At unrestrained twisting, vertical way flexural fractures were generated. At the shear boundary closer to the supports; shear cracks were created in a slanted pattern (Sundarraja & Rajamohan, 2009). Experiment test results are listed in Table 3.

Table 3. Experimental result.

Beam type	Torsional moment	
	At initial stage	Ultimate
Wrapped with carbon strip	8.50	7.8
Wrapped carbon strip 45°	6.04	4.71
Fully wrapped carbon fiber	3.84	3.25
Controlled beam	2.62	6.775
Design for torsion	6.35	4.67

3.3. Discussion

Prior to yielding support, all reinforced specimens showed restricted disfigurement and cracks. At the lower part of the beam, the initial crack was started and advanced towards the up bearing. The reinforced concrete beam was wrapped with CF and their results have been compared with the aramid fiber retrofitted beam. Fig. 8 compares the torsional capacities of controlled, standard, and beams with CFRP and AFRP.

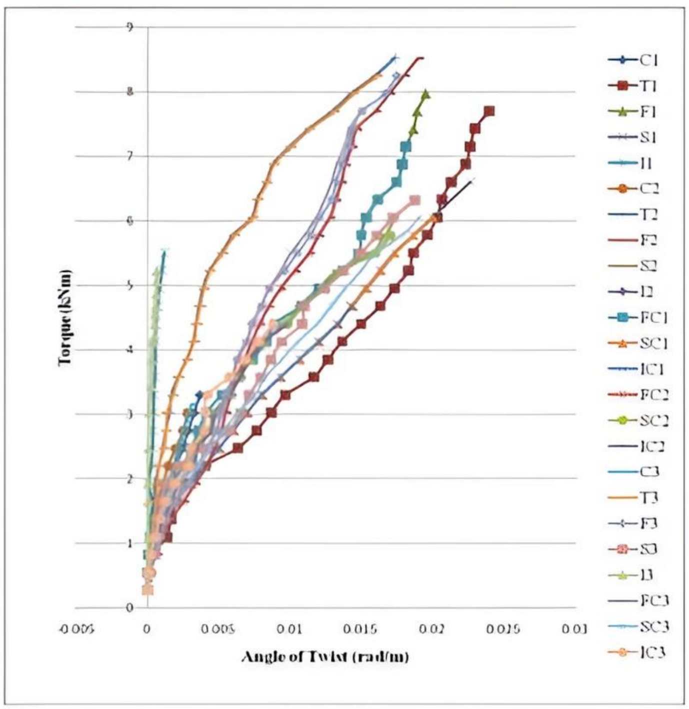

Figure 8. Comparison of the torsional capacity of controlled beam, normal beam, beam with CFRP and AFRP.

4. Conclusions and comments

From the experimental work and logical examination, the following a few ends:

The torsional limit of the least reinforced beam for example wrapped with CF strips at a point of 45° was 46.5% highly viable when contrasted with the control beam. The load conveying limit of the reinforced beam wrapped with carbon fiber strip at a point of 90° was observed to be 6.91% lesser than the beam wrapped with aramid fiber strip at a point of 90° what's more, the load conveying limit of the reinforced beam wrapped with carbon fiber strip at a point 45° was observed to be 16% lesser than the beam wrapped with aramid fiber strip at a point 45°. Compared to a standard beam, a retrofitted beam strengthened by CFRP increases its strength by 45–140 percent, whereas AFRP materials are around 15% more powerful.

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