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Strengthening of R.C. Beam using Carbon and Aramid Fibre for its Torsional Behaviour

Sanket Rathi[1], Sachin Kandekar[2]

Civil Engineering Department
Amrutvahini College of Engineering, Sangamner, India
[1]rathisanket@yahoo.in, [2]sbkandekar@gmail.com

Dr. R.S.Talikoti

Civil Engineering Department
Late G.N. Sapkal College of Engineering, Nashik, India
rstalikoti@gmail.com

Abstract: *This paper presents the strengthening of reinforced concrete (RC) beams of M30 grade of concrete using Carbon fiber and its comparative study with Aramid fiber, for its torsional behaviour, using both experimental and analytical method. Different pattern of its strips wrapped around RC Beams and torsional behavior of these restrengthened beams is studied. Carbon fiber is used as an external reinforcement. RC beam retrofitted with carbon fiber tested for torsional failure using lever arms subjected to torque. The beam size is 150 mm x 300 mm and of 1.3 m in length, designed as per IS456-2000. Three beams are designed for torsion. In this experimental work full wrapped carbon fiber and carbon fiber strips of width 100 mm on all face of beam and also with 900 and 450 orientation with the longitudinal axis of beam by using epoxy resin. The effect of different types and configuration of carbon fiber on first crack load, ultimate load carrying capacity and failure mode of the beams were taken into consideration and its comparative study using ANSYS software with Aramid fiber gives better result for further study.*

Keywords: *Carbon fiber, aramid fiber, torsion, angle of twist, epoxy resin*.

1. Introduction

The use of fibers to improve post strength of concrete behavior is very popular now-a-days. Since last 48 years, several different fiber types and materials have been used to improve durability of concrete and also its physical properties. To prove such various independent research results shows the ability of such fibers; which improve durability of concrete and its physical properties. Regardless of origin, cracking, when induced by several processes like mechanical, chemical, environmental processes, results in deteriorated and less-durable concrete. Also the increased permeability caused by cracking can accelerate other deterioration processes resulting in less-durable concrete. Most of RCC structures, have suffered severe degradation since their construction due to the combined effects of aggressive environments, significantly increased live loads. To save, retrofit, and maintain these deteriorating structures is the major problem which is being faced by civil engineers today. Implementation and development of latest and economic repair methods are required to increase the service life of these RCC structures. These RC structures were primarily designed to withstand the mechanical loadings, but these structures were also constantly subjected to physio-chemical phenomena which results in early deterioration; which ultimately reduces its reliability of performance with adequacy. The early deterioration is a major issue for any society, as the public safety will be in danger and the cost to repair it will directly affects the future economy. In order to minimize this problem and also to maintain various functionality of these RC structures, the frequency of maintenance and duration of repairing should be kept to the minimum probable level. As the mechanical properties of carbon fibers are outstanding, it can be use to strengthen those zones where the structure is exposed to high mechanical or cyclic loading, to rehabilitate such zones and severe environmental conditions. Only the outer part of the older structure get wrapped which will improve the strength of concrete; instead of disturbing other parts of structures. Therefore, this conceptual idea will greatly improves the serviceability and life-cycle costs reduction of the structures contributes unavoidably towards strengthening of the structure under flexure and torsion and increasing its stiffness.

1.1. Unidirectional Carbon Fiber

A Unidirectional Carbon Fiber is one in which the majority of carbon fibers run in one direction only. A small amount of carbon fiber run in other directions with the main intention being to hold the primary carbon fibers in position. primary carbon fibers in position.

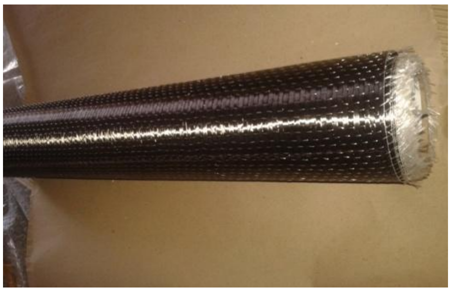


Fig1. *Unidirectional Carbon Fibre sheet*

2. Experimental Procedure

This includes casting RCC beams, with various degree of damaging, number of layer of applying the CFRP sheets and testing them under two point loading on a Universal Testing Machine of capacity 1000 kN.

2.1. Beam Specifications

Three beams are designed for torsion, three beams are designed as normal beam, nine beams are designed to restrength using carbon fibers which increases its torsional capacity. All rectangular RC beams were casted for the experimental work. The beams of dimensions 150 mm x 300 mm x 1300 mm of Fe 500. The beams designed for torsion i.e. controlled beam have 2Nos-8 mm diameter bars are used at the bottom of each beam as flexural reinforcement, and at the top and midspan of each beam 2Nos-8 mm bars and 6 mm diameter stirrups spaced 150 mm c/c for shear reinforcement. The beams designed as normal beam have 2Nos-8 mm diameter bars are used at the top of each beam, and at the bottom of each beam 3Nos-8 mm bars and 6 mm diameter stirrups spaced 150 mm c/c for shear reinforcement. The casting of beams were made as per IS specification using M30 grade concrete with 20 mm maximum size of coarse aggregate, sand and 53 grade ordinary Portland cement. These beams were cured in distilled water for 28 days and under two-point loading on a Universal Testing Machine of capacity 1000kN these restrengthened beams were tested.

2.2. Retrofitting of Beam

To ensure the perfect and correct application of the external strengthening materials without any loop holes, it was considered necessary to improve the characteristics of concrete surface on the contact areas to be bond. According to the manufacturer’s instruction, the surface preparations were done. It includes removing the dust on the surface and also removing the cement paste, coating the surface by using primer putty. After that the epoxy adhesive was applied to both the Carbon Fibre and the

Concrete surface. Finally the Carbon Fibre sheets fully wrapped and carbon fiber strips with two different patterns were applied to the beams.

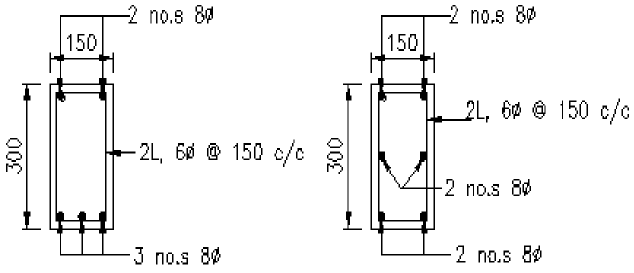


Fig2. *Cross section of normal beam and controlled beam*

2.3. Test Set- up

All the beams were tested under two point loading in Universal Testing Machine of capacity 1000 KN. At specific gradual increased load interval 0f 2 kN the readings were recorded. At the time of testing deflection is measured by dial gauge having 0.001 least count. The reading of load and deflection were noted down simultaneously at the time of testing. When first crack appeared on beam that would marked on it. The beams were placed as simply supported into assembly which was fabricated especially for testing.

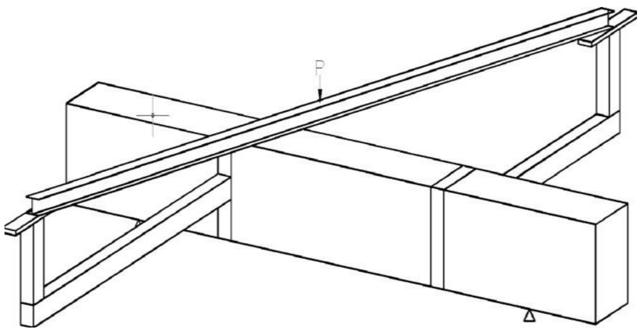


Fig3. *The Test Set-up*

Fig4. *The beam wrapped with carbon fibre for testing*

2.4. Comparision of Test Results with Aramid

The test results were compared with the results of retrofitted beams using Aramid fiber using ANSYS software, by finite element modeling.

Following elements and shell are used in ANSYS for modeling of RC beam wrapped with carbon fiber in three different patterns; in which Concrete is replaced by SOLID186 element, Reinforcing steel is replaced by SOLID187 element and Carbon Fibre is replaced by SHELL181 element.

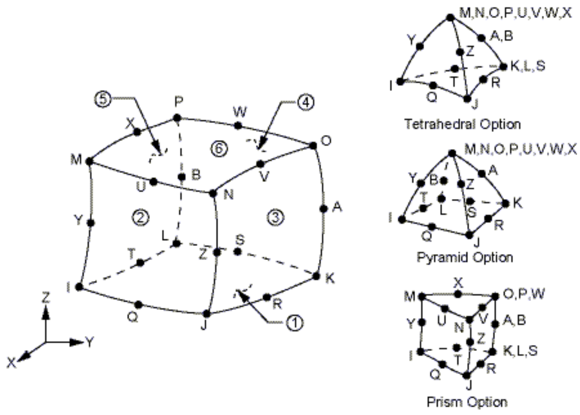


Fig5. *SOLID186 element*

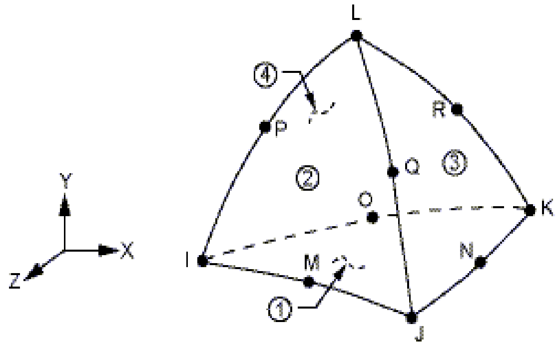


Fig6. *SOLID187 element.*

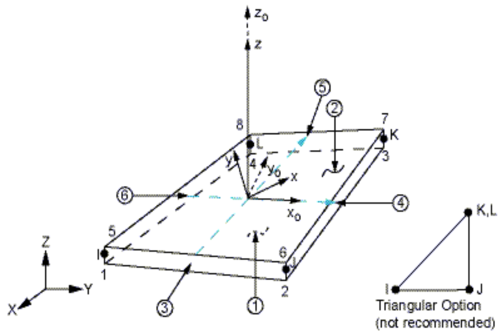


Fig7. *SHELL181 element.*

Following elements and shell are used in ANSYS for modeling of RC beam wrapped with aramid fiber in three different patterns; in which Concrete is replaced by SOLID65 element, Reinforcing steel is replaced by BEAM188 element and Aramid Fibre is replaced by SHELL91 element.

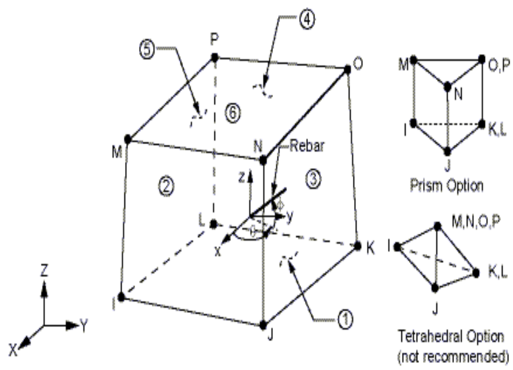


Fig8. *SOLID65 element*

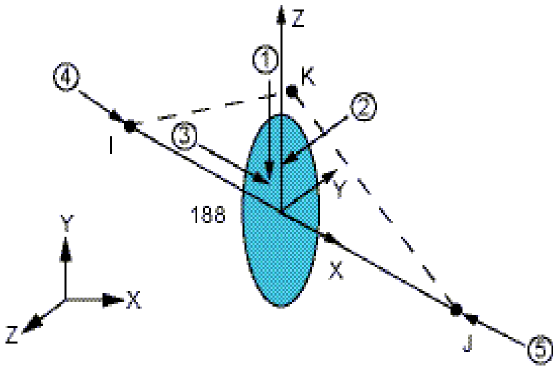


Fig9. *BEAM188 element*

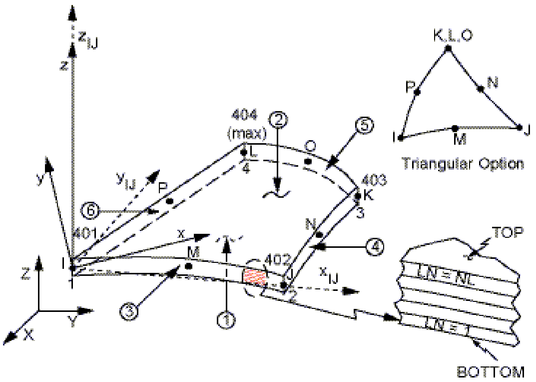


Fig10. *SHELL91 element*

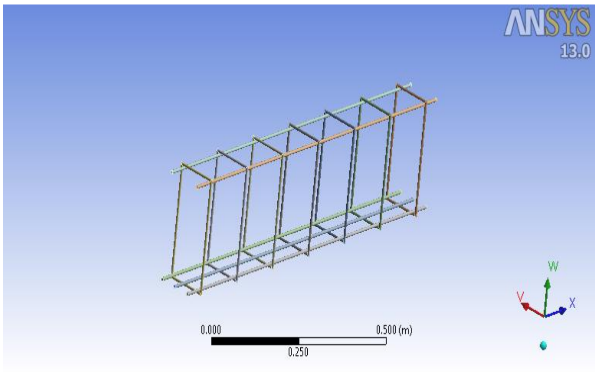


Fig11. *Reinforcement model in ANSYS for beam*

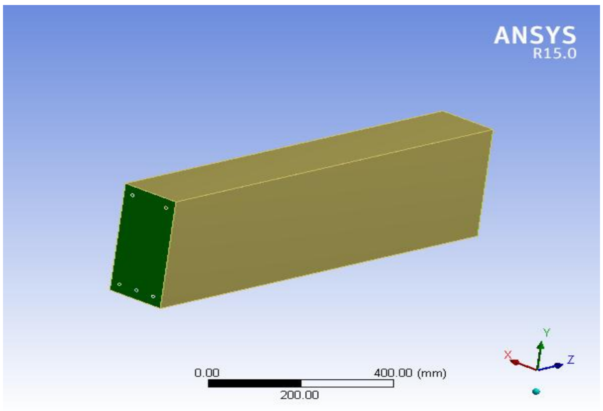


Fig12. *Beam model in ANSYS for controlled beam.*

2.5. Crack Pattern

In this the normal and wrapped beam comparatively studied for crack pattern. It was seen that flexural and shear crack pattern in both the beams was same. In vertical direction flexural cracks were developed at pure bending and shear cracks were developed in inclined pattern at shear zone nearer to support.

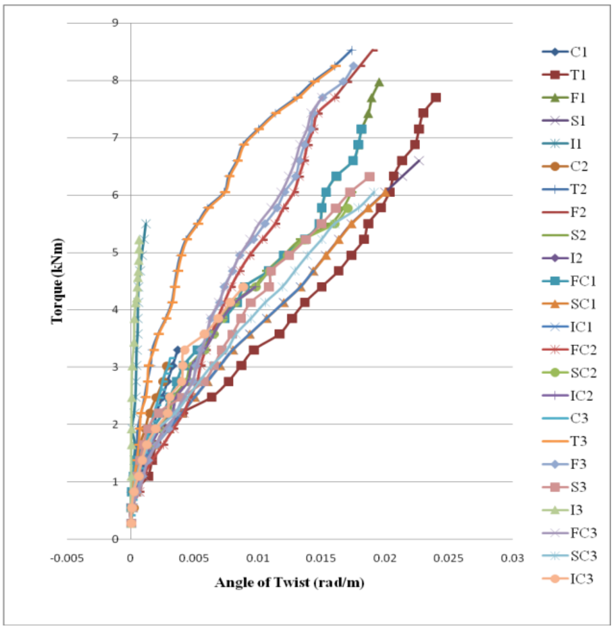
3. Results and Discussion

Before yielding of reinforcement, all strengthened specimens exhibited limited deformation and cracks. The initial cracks were initiated and progressed towards upward direction from bottom of beam. The results of retrofitted beam with carbon fiber were compared with Aramid fiber retrofitted beam and normal beam for its torsional behavior.

Table1. *Ultimate load and nature of failure for beams (Average experimental results)*

Type of Beam	Torsional Moment (kNm)	
	At initial crack	Ultimate
Controlled Beam	2.61	6.87
Design for Torsion	6.33	4.68
Fully wrapped Carbon fiber	3.85	3.3
Wrapped with Carbon strip	8.52	7.7
Wrapped Carbon strip 45°	6.05	4.675

Above all beams failure caused due to crushing of concrete.



Graph1. *Experimental results gives torsional capacity of normal beam, controlled beam and beams retrofitted with CFRP and AFRP*

4. Conclusion

From the experimental work and analytical study following some conclusions are drawn.

- The torsional capacity of lowest strengthen beam i.e. wrapped with carbon fiber strips at an angle 45° were 46% more effective as compared to the control beam.
- The load carrying capacity of the strengthened beam wrapped with carbon fiber strip at an angle 90° was found to be 6.93% lesser than the beam wrapped with aramid fiber strip at an angle 90° and the load carrying capacity of the strengthened beam wrapped with carbon fiber strip at an angle 45° was found to be 15% lesser than the beam wrapped with aramid fiber strip at an angle 45°.

- CFRP increases strength of retrofitted beam 45-140% more than normal beam; but AFRP material is approximately 6- 15% more effective than CFRP

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AUTHORS' BIOGRAPHY

Sanket Rathi, M.E. Structures pursuing (2013-15) from Amrutvahini College of Engineering, Sangamner, Maharashtra, India.

B.E. Civil (2008-13) from N.D.M.V.P. C.O.E., Nashik, Maharashtra, India.

B.E. Civil passed in first class with distinction.

Hometown is Bhusawal, which is in district Jalgaon.

Sachin Kandekar, M.E. Structures, Asst. Prof. In Civil Engg. Dept., Amrutvahini College of Engineering, Sangamner, Maharashtra, India

Dr. R.S.Talikoti, PhD Structures, M.E. Structures, Head of the Civil Engineering Department, Late G.N. Sapkal College of Engineering, Nashik, Maharashtra, India.