ANALYTICAL AND EXPERIMENTAL STUDY ON STRENGTHENIG OF CONCRETE FILLED STEEL TUBULAR BEAM USING FRP COMPOSITE

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Abstract : The concrete filled steel tubular (CFST) beam are the most commonly used one. Owing to their structural benefits such as reduced cross section, high strength, improved fire resistance, greater apparent stiffness and excellent seismic resistant structural properties. For a variety of reasons such as fire, ageing, environmental degradation and overloading, the infrastructure concerned with concrete filled tubular and other metallic structures become structurally unsatisfactory. Therefore, actions like implementation of strengthening techniques with the new materials become essential to combat this problem. Due to their in-service and superior mechanical properties such as high strength and stiffness, carbon fibre reinforced polymer (CFRP) composites make them excellent material for repairing, upgrading and retrofitting of metallic structure. This paper, study has been carried out to investigate the suitability of carbon fibre reinforced polymer for strengthening of concrete filled steel tubular sections under flexure. A Finite Element Model (FEM) has been developed using ANSYS to analyse beam with concrete filled steel tube beam and the Experimental study was carried out by applying two point loading. Thus the flexural behavior of both the results are compared and analysed.

***IndexTerms* - CFST beam, FEM, CFRP (Carbon Fibre Reinforced Polymer).**

I. INTRODUCTION

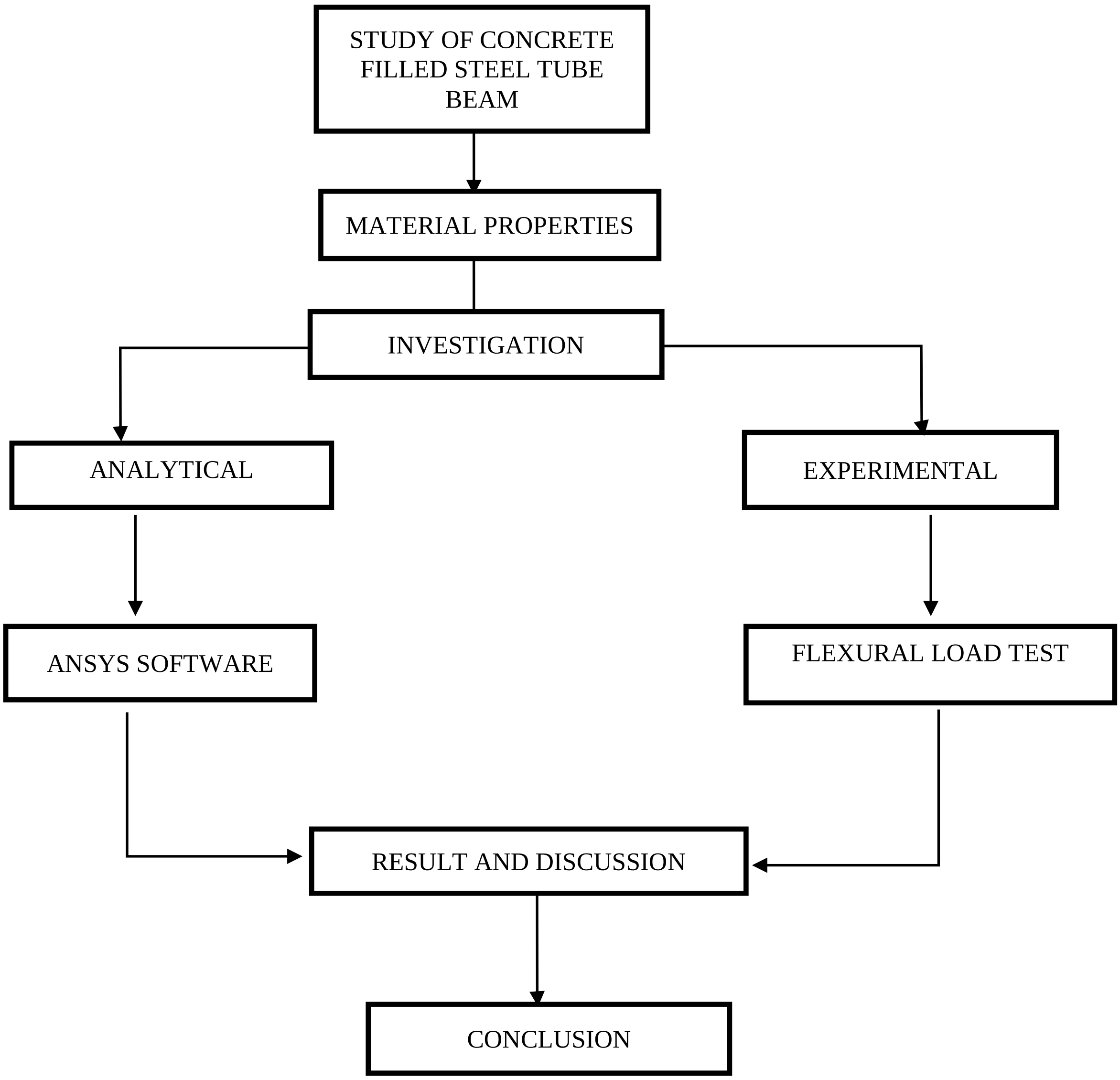
The flexural behaviour of square concrete filled steel tubular structures and more recently, some research related to strengthening of CFST beam members using CFRP composites have been reported. It is a rather simple and economical approach to meet the increased load carrying capacity for a structure. The external bonding of CFRP composites under increased load conditions reveals a reduced deflection and better enhancement in moment carrying capacity. Also use of composites offers several advantages like bonding to curved or irregular surfaces and flexibility to orient in a desired direction for strengthening.

In this study, another part of investigation focused on the effectiveness of the CFRP composites on strengthening of CFST members under flexural loading and aimed to develop optimum wrapping schemes that can be used to repair these structures and also to study the effect of increase in number of FRP layers in enhancing the moment carrying capacity. Two types of wrapping schemes such as Full wrapping (fibre bonded at the throughout entire length of beam), and Partial wrapping (fibre bonded in between loading points) were introduced. Furthermore, to eliminate the galvanic corrosion between steel tube and CFRP, a thin layer of glass fibre mat was introduced between steel and CFRP.

Beams were tested under two point loading until failure to understand the influence of CFRP in flexural behaviour of CFST beam members. Failure modes of each strengthened and un-bonded beams were observed and also the enhancement in moment carrying capacity and reduction in mid-span deflection were also addressed. Since the Finite Element Method has reached a state of maturity, numerical simulation is an alternative method to validate with the experimental results and understand the behavior of CFRP strengthened CFST members. As a result, the present investigation also focused on modeling of CFRP strengthened beams using ANSYS 16.0. On the basis of experimental observations, a three-dimensional finite element model was developed to predict the load–deformation behavior of CFRP strengthened CFST members in which all the structural parameters and nonlinear properties of concrete, steel and FRP composites were included.

II. SUMMARY OF THE LITERATURE REVIEW AND METHODOLOGY

The concrete filled steel tubular beam can improve the flexural strength, Reduce cross section of the beam and more effective in RC beam, when compared concrete filled steel tube section. Reduced cross section, high strength, improved fire resistance, greater apparent stiffness and excellent seismic resistant structural properties like high ductility and energy absorption, the use of CFST beams. The software are ANSYS and ABAQUS are used to analyze the concrete filled steel tubular beam using FRP composites.



III. RESEARCH METHODOLOGY

3.1 Experimental Investigation

The objectives of this project are to assess the feasibility of strengthening of concrete filled steel tubular members subjected to flexural loading and to develop an adequate repair method for in-air applications. The materials used in the present investigation and their properties are briefly discussed below.

3.1.1 Mix Design

Mix design for M30 grade concrete by Indian Standard recommended of concrete mix design as per design code IS: 10262- 2009. The mix designs are considered the normal beam and CFST beams.

Table 1: Mix Design of concrete

Water	Cement	Fine Aggregate	Coarse aggregate
160	380 kg	711 kg	1283 kg
0.42	1	1.87	3.38

3.1.2 Compressive Strength Test

Cube of size 150x150x150 mm were cast. Three specimens were made and tested for 28 days.

Fig 1: compressive strength of concrete

Table 2: Cube Test Value

Specimen no's	Compressive strength(N)
1	32
2	31.5
3	33
Average	32.1

Compressive strength = load /area (N/mm^2)

The compressive strength test results of three specimens. Average compressive strength of cube 32.1N.

3.2.1.1 Conventional Beam

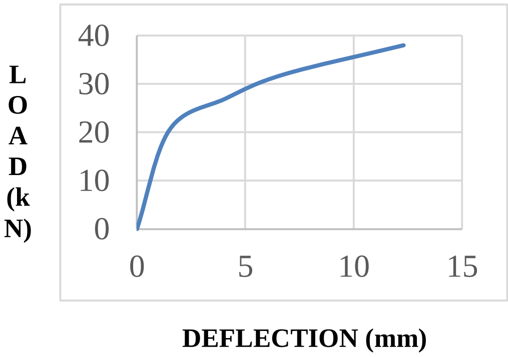
Conventional beam is developed of length 1000 mm and cross section of the beam is 150 x 150 mm. Where the mix design of M30 are used concrete as per IS: 456-2000 and IS 10262-2009.The concrete are mixed with the mix ratio of 1:1.87:3.38. where all the side of the beam are moulded properly to prevent concrete from leakage. After mixing, the concrete is poured immediately inside the beam. Concrete is filled in three layers, and each layer is compacted well by using a tamping rod of standard size, so as to avoid entrapped air inside the concrete beam and honey combing effect on the sides. The test specimens after compaction were kept as such for a period of 24 hours. After that period of time the moulds were removed and the specimen are cured. The beam was tested under two point loading. Where the load applied is 50 tons.

Fig 2: Conventional Beam

The conventional beam test results are mentioned below:

Table 3: Conventional beam results

S.No	LOAD (kN)	DEFLECTION (mm)
1	0	0
2	10	1.5
3	22	4.1
4	30	6.8
5	39	14.3



Graph 1: Conventional Beam

3.1.2.2 CFST Beam (Fully Wrapping)

Hot rolled steel tube was used for square section are made of dimension 150 x150 mm and thickness of 3.6mm. Yield strength of steel was 250N/mm^2. The required height of square hollow tubes was cut from 1m length hollow tubes. Inside portion of the hollow steel tubes were thoroughly wire brushed to remove the rust and loose debris presented. After that period of time the moulds were removed and the specimens were kept in ordinary curing tank and allowed to cure for a period of 14 days. The beam was tested under two point loading. Where the load applied is 50 ton. CFST beam (Fully Wrapping) in single layer of carbon fibre polymer reinforced.

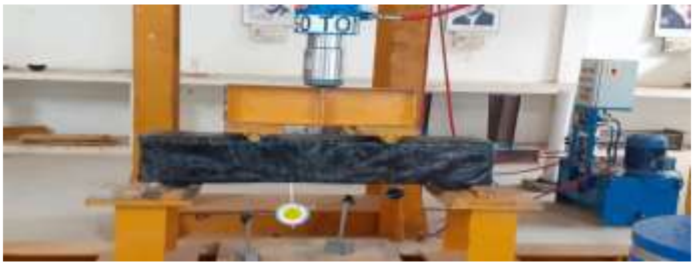
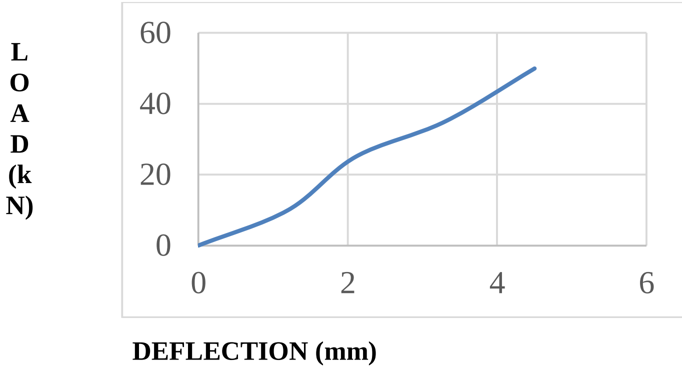


Fig 3: CFST Beam (fully wrapping)

The CFST (Fully Wrapping) Beam test results are mentioned below:

Table 4: CFST (Fully Wrapping) beam result

S.No	LOAD (kN)	DEFLECTION (mm)
1	0	0
2	12.5	0.7
3	25	1.6
4	37.5	2.3
5	50	3.9



Graph 2: CFST (Fully Wrapping) beam

3.1.2.3 CFST Beam (Partial wrapping)

Hot rolled steel tube was used for square section are made of dimension 150 x150 mm and thickness of 3.6mm. Yield strength of steel was 250N/mm^2. The required height of square hollow tubes was cut from 1m length hollow tubes. Inside portion of the hollow steel tubes were thoroughly wire brushed to remove the rust and loose debris presented. After that period of time the moulds were removed and the specimens were kept in ordinary curing tank and allowed to cure for a period of 14 days. The beam was tested under two point loading. Where the load applied is 50 ton. CFST beam (Partial Wrapping) in two layer of carbon fibre polymer reinforced.

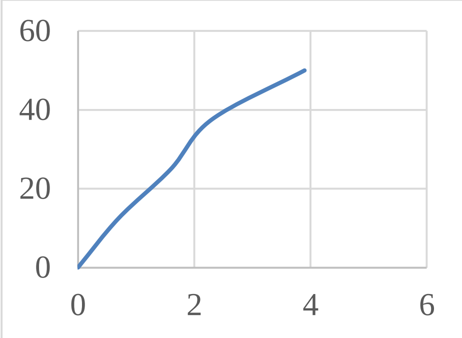
Fig 4: CFST(Partial Wrapping) Beam

The CFST (Partial Wrapping) beam test results are mentioned below:

Table 5 : CFST (Partial Wrapping) beam result

S.No	LOAD (kN)	DEFLECTION (mm)
1	0	0
2	12.5	1.2
3	25	2.1
4	37.5	3.3
5	50	4.5

LOAD (kN)



DEFLECTION (mm)

Graph 3: CFST (Partial Wrapping) beam

3.2 ANALYTICAL INVESTIGATION

The analytical investigation of CFST beam using ANSYS software. The class focuses on geometry creation and optimization, attaching existing geometry, setting up the finite element model, solving, and reviewing results.

3.2.1 Conventional Beam

Conventional beam are analysed using ANSYS Software. Where two point loading is applied of 50 tonne for conventional beam. The beam of 1000 mm length and cross section of 150 x 150 mm were developed.

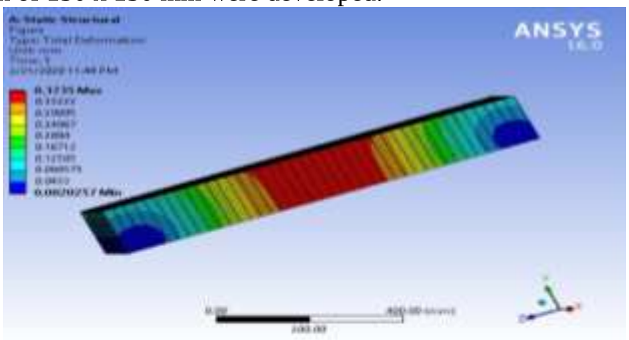


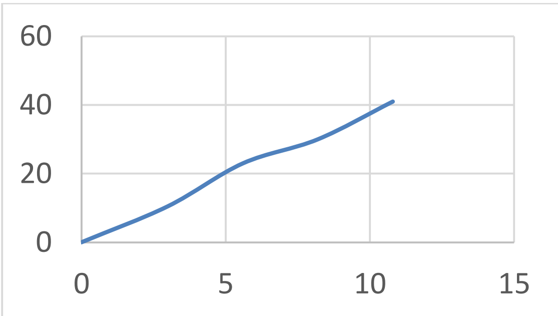
Fig 5: Conventional beam using ANSYS

The conventional beam test results are mentioned below:

Table 6: Conventional beam results using ANSYS

S.No	LOAD (kN)	DEFLECTION (mm)
1	0	0
2	10.5	3
3	23	5.6
4	30	8.2
5	41	10.8

LOAD (kN)



DEFLECTION (mm)

Graph 4: Conventional Beam

3.2.2 CFST Beam (Fully Wrapping)

CFST beam are analysed using ANSYS Software. Where two point loading is applied of 50 tonne for conventional beam. The beam of 1000 mm length and cross section of 300x150 mm and thickness of channel section is taken as 3 mm were developed. Thickness of steel tubular beam 3.6mm. CFST beam (Fully Wrapping) in single layer of carbon fibre polymer reinforced.

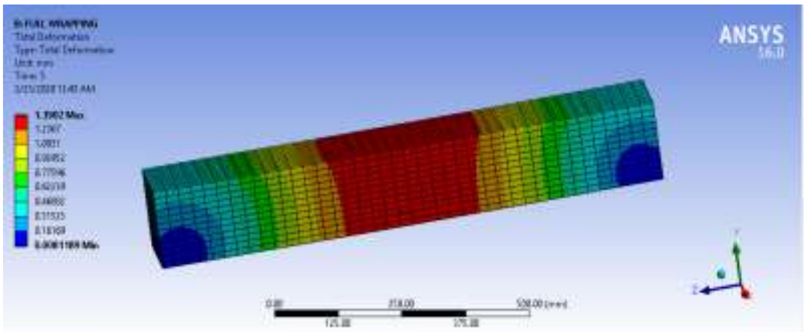
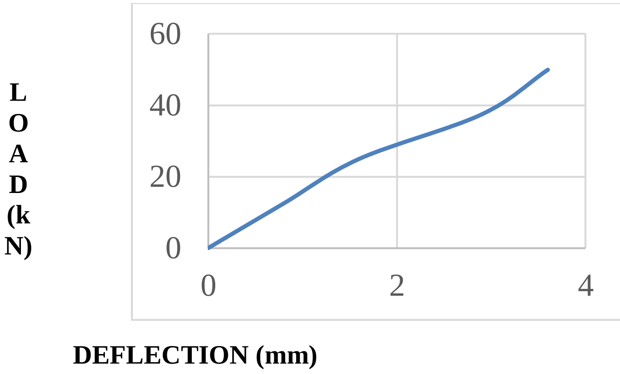


Fig 4: CFST (Fully Wrapping) beam using ANSYS

The CFST beam test results are mentioned below:

Table 7: CFST beam (Fully Wrapping) beam results using ANSYS

S.No	LOAD (kN)	DEFLECTION (mm)
1	0	0
2	12.5	0.8
3	25	1.6
4	37.5	2.9
5	50	3.6



Graph 5: CFST (Fully Wrapping) beam

3.2.3 CFST Beam (Partial Wrapping)

CFST beam are analysed using ANSYS Software. Where two point loading is applied of 50 tonne for conventional beam. The beam of 1000 mm length and cross section of 300x150 mm and thickness of channel section is taken as 3 mm were developed. Thickness of steel tubular beam 3.6mm. CFST beam (Partial Wrapping) in two layer of carbon fibre polymer reinforced.

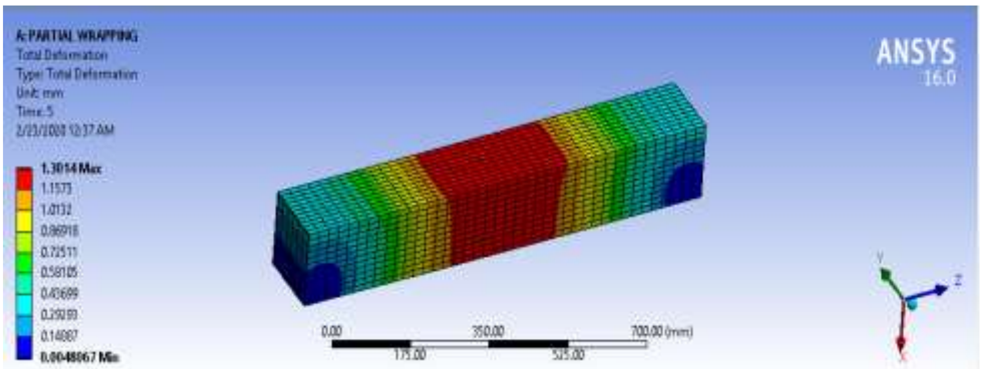
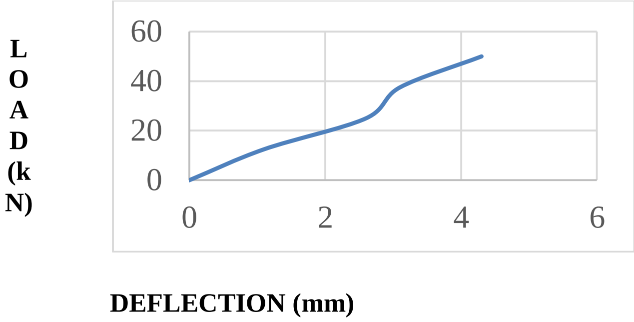


Fig 7: CFST (Partial Wrapping) beam using ANSYS

The CFST (Partial Wrapping) beam test results are mentioned below:

Table 8: CFST beam (Partial Wrapping) beam results using ANSYS

S.No	LOAD (kN)	DEFLECTION (mm)
1	0	0
2	12.5	1.3
3	25	2.6
4	37.5	3.4
5	50	4.3



Graph 6: CFST (Partial Wrapping) beam

IV. RESULTS AND DISCUSSION

4.1 Experimental Result

The comparison of conventional, CFST beam (Partial Wrapping) and CFST beam (Fully Wrapping) experimentally shows that the CFST Beam (Fully Wrapping) is more efficient than the conventional beam and CFST beam (Partial Wrapping).

4.2 Analytical Result

The comparison of conventional, CFST beam (Partial Wrapping) and CFST beam (Fully Wrapping) Analytically shows that the CFST Beam (Fully Wrapping) is more efficient than the conventional beam and CFST beam (Partial Wrapping).

V. CONCLUSION

In experimental and analytical results, the flexural strength is maximum at 50 KN for CFST Beams compared to the Normal beam.

- The load carrying capacity of CFST (Fully Wrapping) Beam is 63 to 68% more than Normal beam.
- The load carrying capacity of CFST (Partial Wrapping) Beam is 55 to 61% more than Normal beam.
- Comparing normal beam and CFST partial wrapping beam the load carrying capacity is more for CFST fully wrapping beam.

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