# ANALYSIS OF CARBON-FIBER COMPOSITE STRENGTHENING TECHNIQUE FOR REINFORCED BEAM

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**Abstract— The Carbone fiber reinforcement polymer has a wide range of application in the modern world; one of them is to be strengthening of civil structure. An analysis carried out for the strength of CFRP application in civil structure by module available in ANSYS. Static structure analysis of the beam element carried out with the bottom plane wrapped by CFRP is to be checked for deformation. Model validation attempted in ANSYS for beam wrapped at the bottom by two CFRP layer's and check displacement of the beam at different loading condition. Preparing structural models of beam (concrete) and provide layers of CFRP with suitable thickness. Static structural analysis of carbon fiber composite laminates is performed with the concrete using FEA package**.

**Key words— composites, ANSYS, CFRP, reinforcement.**

## I. INTRODUCTION

Most engineering structure are required to bear. So, the material properties of greatest interest has been very often its strength, but at at some stage strength alone is not always enough, weight of material matters. High strength at low weight is perhaps the principal advantage of fiber composites. CFRP (carbon fiber reinforce polymer) have also some point over other reinforcing material e.g. corrosion resistance, energy dampening, Thermal expansion (minimize thermal stress), production flexibility, non-brittle.

Earlier for RC beam strengthen with steel plates, which has been replaced by CFRP cause of its strength and stiffness with low weight, immunity from corrosion.

The deformation and strength of selected laminates under a variety of biaxial loads and compare their prediction with experimental results by P. D. Soden. For application of strengthening of structure the CFRP is better choice over conventional material like steel. Material properties of CFRP is taken as orthotropic material. Also strengthening depends on the orientation of fiber in laminates. Laminates are selected for different orientation 0°, (±30°/90°), (0°/.45°/90°), (±55°), 0°/90°, (±45°). [1]

High strength and high stiffness carbon fiber unidirectional woven sheet under uniaxial tension test for checking material properties and incremental deformation technique used for predict the flexural behavior of beam failure.[2] The main parameter study is to effect of CFRP wrapping scheme to beam.

Analysis taken for checking parameters were ultimate load, mid-span deflection 1/3 span deflection, composite action and failure mode by R. Balamuralikrishnan[4].

Four beams are analyzed, two of them are concrete control beams and other two are strength with CFRP by P. Jayajothi and from that obtain behavior of beams with and without CFRP layers [7]. If prestressed members externally reinforced then it's able to reach its full flexural capacity and composites use for its excellent durability in external reinforcing.

## II. MATERIAL MODELING

The nonlinear finite element analysis carried out for concrete beam for simulated for the flexural and shear behavior, strengthen with FRP laminates, In FEA package ANSYS.

### *A. Element type of concrete*

Concrete beam is the solid element which capable of cracking in tension and crushing in compression. When the rebar capability of solid element is available to reinforce, especially for concrete material. SOLID 65 element is used for 3-d modeling of concrete element in solid for with and without reinforcing bar (rebar). From the point of non-linear material properties aspect the valuable element; which capable of cracking, crushing, plastic deformation and creep as like concrete.

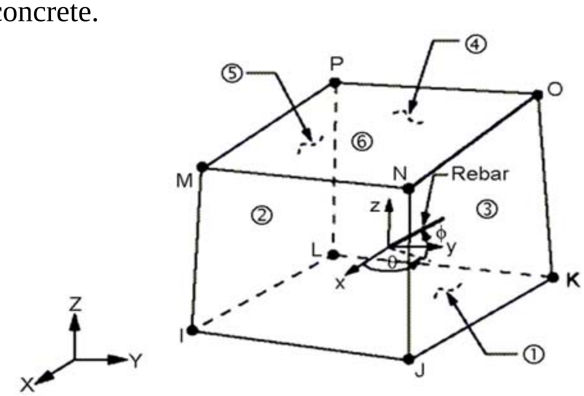



Figure 1. Solid 65 geometry.

### *B. Element type of CFRP*

CFRP is like layered base orthotropic material; which has strength depend on its fiber orientation. The CFRP is mainly very thin layered surface made of fibers. SHELL 181 is 4 nodes 3D modeling element; which has six degree of freedom at each node: translation in X, Y&Z direction and rotation about X.Y & Z axis. This element is mainly used for large strain nonlinear application.

SHELL181 also applied for layered application for Modeling laminated composite shell or sandwich construction. From the application point of view composite shells are governed by the first order shear deformation theory.

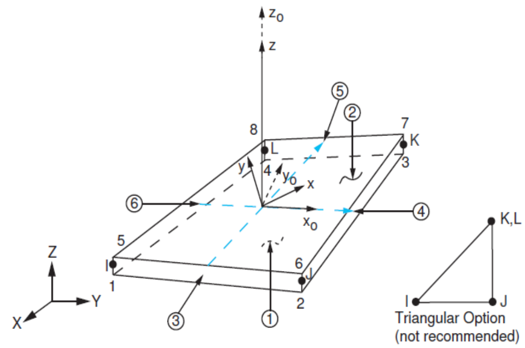



Figure.2 Shell 181 geometry

Input data for element formulation is based on logarithmic strain and true stress measure. Thickness for the shell is defined using real constant or by section definition. The real constants well suited for single-section shell, for more section type layered shell the SECTYPE command used in ANSYS.

## III. NUMERICAL ANALYSIS OF BEAM AND RESULT

The numerical analysis of the pre-stressed concrete beam is for checking strengthen. The analysis carried out in finite element package ANSYS. There are two type of beams analysis. One is of concrete beam without CFRP wrap and second one is with CFRP wrap, both cases for at 3 different loading span. From the literature experiment are conducted for it shows the initial hair crack from 60KN started before the load no failure occurs. By selecting appropriate element, meshing technique and load, generating the load-deflection curve.

For concrete solid 65 element and for CFRP shell81 element selected. Modeling of beam developed for150x250x3000 mm volume and the area of reinforced is of 150x3000mm.

| Parameter's | CONCRETE |
|---|---|
| Density(kg/m3) | 2300 |
| Elastic modulus in x direction(GPa) | 2.5e4 |
| Poisons ration in X-Y plane | 0.20 |

Table 1.Concrete material properties

Table 2. CFRP material properties

| Parameter's | CFRP |
|---|---|
| Density(kg/m3) | 1.518e-09 |
| Elastic modulus in x direction(GPa) | 1.2334e05 |
| Elastic modulus in y direction(GPa) | 7780 |
| Elastic modulus in z direction(GPa) | 7780 |
| Shear modulus in xy direction(GPa) | 5000 |
| Shear modulus in yz direction(GPa) | 5000 |
| Shear modulus in xz direction(GPa) | 3080 |
| Poisons ration in X-Y plane | 0.27 |
| Poisons ration in Y-Z plane | 0.27 |
| Poisons ration in X-Z plane | 0.42 |

Meshing of model is important for load distribution and result generation. Meshing is distribute the solid in to small element, which gives the behavior of the loading effects on each element. The bond between the beam and the CFRP is to be taken the perfect bond.

Before apply load on beam, there is need to be mention of constrains to the beam. Beam is constrained in all degree of freedom UX=0, UY=0, UZ=0and for mesh and constrained condition shown in figure 3.

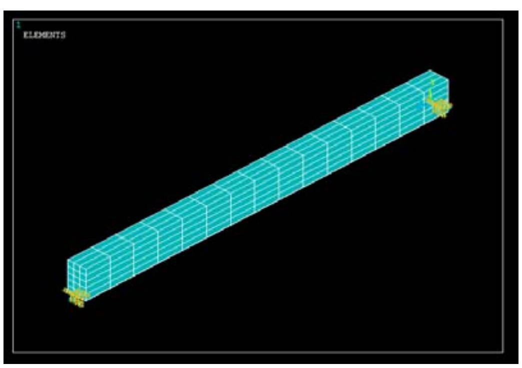



Figure 3. Meshing and load constrained of beam.

Forces on beam are applied on different span for different loading. Point loads applied on span 2L/7, 2L/6and 2L/4, applied load are also three different loads 24KN, 40KN and60KN. Load applies on y direction, so we get the displacement of beam. Loads are on nodes in y direction.

Figure 4. Load on 2L/7 span

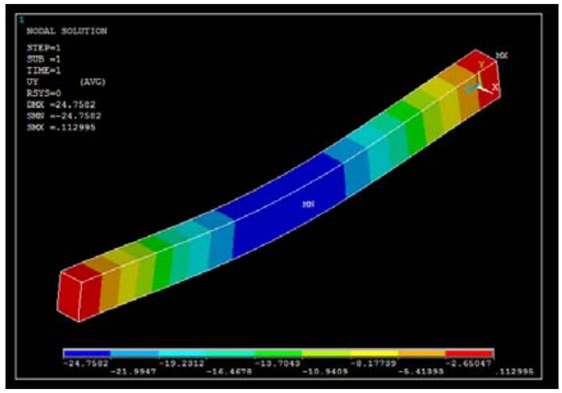
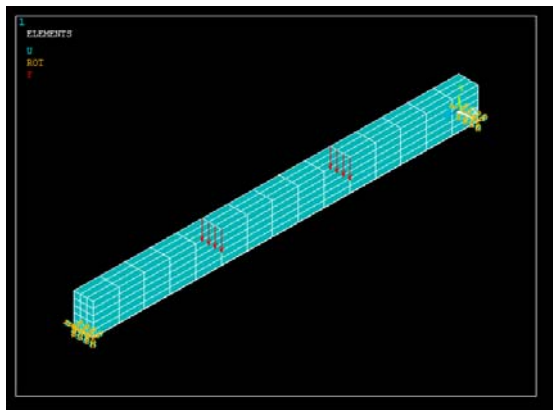



Figure 5. Load on 2L/6 span.




For the different loading condition at each of the three different loading span has been taken. This condition taken for both beam type, one which is not wrapped with CFRP and second one wrapped with CFRP.

Loading span 2L/7, 2L/6and 2L/4 respectively shown in figure 4,5and 6.The FE analysis of this setup gives the different behavior of on three different loads by giving the solution on nonlinear static analysis.

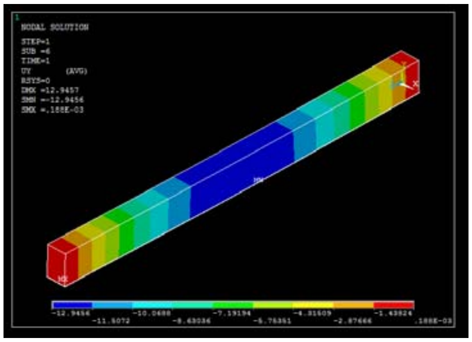


Figure 6. Deflection on 2L/7 span without CFRP

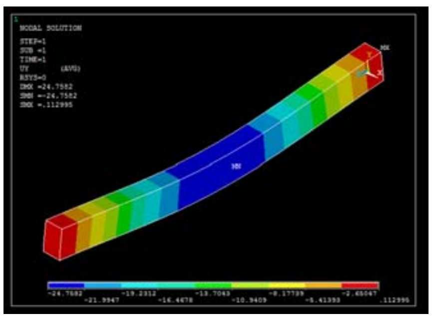


Figure 7. Load on 2L/7 span with CFRP.

Static analysis is carried out for applied load on beam from available options. Point load applied on y direction, so the deflection of beam in Y direction and strain component Of x direction results are taken for discussion. Out of the ANSYS results available the displacement & strain in particular direction only are selected to obtain a proper comparison with two different beam conditions.

### *A. Result*

*For the each of loading span six deflection results carried out to check the behavior of beam.*

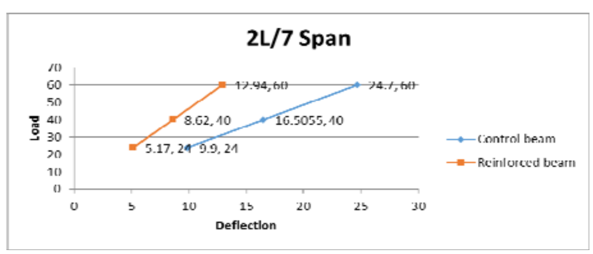
| spans | Type of beam | CFRP layer | Load(KN) | Deflection(mm) |
|---|---|---|---|---|
| 2L/7 | control beam | NO | 24 | 9.9 |
| | | NO | 40 | 16.5055 |
| | | NO | 60 | 24.7 |
| | reinforced beam | 2 | 24 | 5.17 |
| | | 2 | 40 | 8.62 |
| | | 2 | 60 | 12.94 |
| 2L/6 | control beam | NO | 24 | 8.66 |
| | | NO | 40 | 14.43 |
| | | NO | 60 | 21.65 |
| | reinforced beam | 2 | 24 | 4.63 |
| | | 2 | 40 | 7.72 |
| | | 2 | 60 | 11.67 |
| 2L/4 | control beam | NO | 24 | 7.044 |
| | | NO | 40 | 11.74 |
| | | NO | 60 | 17.61 |
| | reinforced beam | 2 | 24 | 3.91 |
| | | 2 | 40 | 6.53 |
| | | 2 | 60 | 9.94 |

Table 3. Beam deflection result

## IV. DISCUSSION

From the result of numerical analysis, it was noted from the load and deflection behavior of CFRP by getting the result of unwrapped (control beam) and wrapped beam (reinforced beam) and the result are plotted on graph for different span.

Figure 8.2L/7 span load- deflection curve.



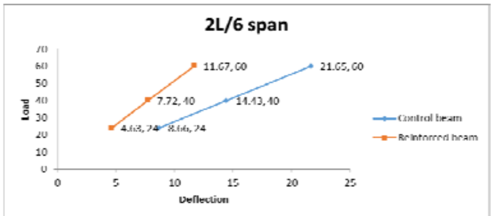



Figure 9.2L/7 span load- deflection curve

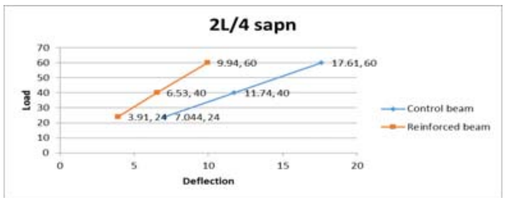



Figure 10. 2L/7 span load- deflection curve.

From the graph the following points:

1) From the result of both the beams variation of deflection at mid-span in three different load are half of other beam deflection.
2) However for all load condition young's modulus for concrete and CFRP are considered same.
3) CFRP wrapped beams gives the 50% increase in strength than the control beam.
4) For all the results the fiber orientation are taken to be [0°, 90°].
5) Stiffness of both beam throughout all the load condition is same.
6) From the graph the effect of different span load gives the same variation result of deflection. Load-deflection graph exponentially increase, which shows the vertical deflection increase with increase in load at same span.

## V. Conclusion

The behavior of the beam is to be checked with the CFRP wrapped at the bottom and without wrapping. These two conditions are analyzed at 3 different loading spans. The unwrapped beam or Control beam (CB) and wrapped beam or reinforced beam (RB) checked at (2L/7), (2L/6), and (2L/4), where L is length of beam. Load on beam for analysis is taken at three steps of 24Kn, 40Kn, and 60Kn. For all loads at same span the increase the deflection with increase of load, but from different span the results shows the small variation in deflection.

In CFRP the orientation is also taking important role for reducing the deflection of the beam. So, Analyzing CFRP wrapping method to structure (beam) on different orientation of the CFRP layer's for its loading condition. Mainly this analysis orientation are taken [0°, 90°] for two layers. From the result of both the beams variation of deflection at mid-span in three different load are half of other beam deflection. CFRP wrapped beams gives the 50% increase in strength than the control beam.

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