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# Mathematical Simulation for Comparison of Unreinforced Concrete and CFRP of I-Beam Using FEM

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***Abstract: In present research we are we analyze the I beam using FEM software Ansys14.5 and comparing Unreinforced concrete and CFRP laminates Reinforced concrete components such as beams and columns are made strong in flexure through the utilization of Fibre reinforced polymer (FRP) composites which are attached in their tension zones. In this study finite element method is used to study the deflection of rectangular concrete I Beam reinforced by FRP laminate composites at the top surface of the beam. In this study the FRP is CFRP. ANSYS software is used for finite element modelling. In this study unreinforced beam and beam reinforced with CFRP are compared on the basis of deformation and stresses. The variables in the finite element modelling are type of FRP and different length of FRP laminates. In this study it is observed that CFRP is provided more strength to the structure as compare to the unreinforced material. Simulation results show that CFRP Laminates provides strength to the I-beam section. Now we conclude with the help of simulative results that there is 50% reduction in deformation for length of 950mm CFRP laminate as compare to unreinforced concrete and 44% reduction in stresses for length of 950mm CFRP laminate as compare to unreinforced concrete. CFRP Provided more strength to the structure (I-Beam) and effective than Unreinforced concrete material in reduction of deformation and stresses.***
***Keywords-: CFRP, FRP, Beam, Unreinforced Material, FEM, ANSYS, etc.***

## I. INTRODUCTION

Fibre reinforcement can provide an alternative to conventional cement concrete in order to improve the efficiency and working conditions on construction sites and in the prefabrication industry. Although fibres most often are used for non-structural applications to control plastic and drying shrinkage, they can also be applied to reduce or in some cases even replace ordinary reinforcement bars. The labour cost makes roughly 40% of the total cost of a concrete building, where a main part is related to the reinforcement work. The reduced labour can in some cases offset the increased material costs when fibres are used as replacement for conventional bars, especially in Norway where the recruitment of construction workers is particularly low. Moreover, the physically hard reinforcement work often leads to health complaints and an early retirement age. Fibres combined with self compacting concrete (SCC) is furthermore a very promising concept which improves the working conditions further, both with respect to efficiency and to health and safety benefits, since the heavy and noisy vibration work is avoided.

As one of the most popular materials used in the world's infrastructure it is important that cement displays exceptional strength and durability because its failure results in high financial costs and the potential loss of millions of lives. To this end several efforts to improve its properties have been and continue to be studied and implemented. The use of fiber reinforcements is one such mean the types of reinforcements currently used include steel, glass cellulose and carbon fibers. The fibers are used individually or in combination. The properties of carbon microfibers (CF) such as their size, thermal stability, high strength, elastic modulus, and apparent chemical inertness make them an especially attractive option. In fact CF reinforced cement based materials have been shown to have improved tensile and flexural properties, low drying shrinkage, high specific heat, low thermal conductivity, high electrical conductivity, high corrosion resistance and weak thermoelectric behaviour. Technological advancements have led to the development of carbon fibers with better properties than the CF; these fibers are referred to as carbon nano fibers (CNF) because of their nano scale dimensions. CNF are smaller in size, have higher strengths and elastic module and therefore show promise as a reinforcement material in cement. Studies on the use of CNF as reinforcement in cement are however limited; work has however been done utilizing carbon nano tubes and has shown mixed results. The maintenance, rehabilitation and upgrading of structural members, are perhaps one of the most crucial problems in civil engineering applications. Moreover, a large number of structures

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constructed in the past using the older design codes in different parts of the world are structurally unsafe according to the new design codes. Since replacement of such deficient elements of structures incurs a huge amount of public money and time, strengthening has become the acceptable way of improving their load carrying capacity and extending their service lives. Infrastructure decay caused by premature deterioration of buildings and structures lead to the investigation of several processes for repairing or strengthening purposes. One of the challenges in strengthening of concrete structures is selection of a strengthening method that will enhance the strength and serviceability of the structure while addressing limitations such as constructability, building operations, and budget. Structural strengthening may be required due to many different situations.

Investigation of the behaviour of FRP retrofitted reinforced concrete structures has in the last decade become a very important research field. In terms of experimental application several studies were performed to study the behaviour of retrofitted beams and how various parameters influence the behaviour. The effect of number of layers of CFRP on the behaviour of a strengthened RC beam was investigated [Aghaei, H.R. (2008)].They tested simply supported beams with different numbers of CFRP layers. The specimens were subjected to dead load and horizontal forces. The results showed that the load carrying capacity increases with an increased number of layers of carbon fibre sheets. The model of RC building shown in plan was developed in ANSYS software.

In this method the cross section is subdivided in to small sub-elements, the deflections are considered constant within each sub-element. The deflections at each sub-element can be traced clearly and hence the gradual spread of yielding can be predicted. The plastic zone method eliminates the need for separate member capacity check, hence this method accepted to provide exact solution. constructions due to structural deficiency, material deterioration, unlooked-for over loadings or physical damage. Premature material deterioration will arise from variety of causes, the foremost common being once the development specifications are profaned or once the ability is exposed to harsher service setting than those expected throughout the design and style stages. Physical damage may also arise from fireplace, explosion – as well as from restraints, each internal and external, against structural movement. Except in extreme cases, most of the structures need restoration to satisfy its purposeful necessities by acceptable repair techniques.

Since 1950s, the development activity in India has been increasing geometrically while not matching increase within the accessibility of quality inputs, in terms of materials and skilled workmen. The gap between the standard planned and also the quality achieved continues to become wider. The factors contributing to damages/distresses in buildings have, thus, become intrinsic right from the development stage. Typically these are hid below external renderings and also the defect takes time to come about. Construction documents contain adequate specifications and directions required to execute quality works. However, they continue to be as papers without achieving the specified level of results, due to lack of understanding of their significance by the field engineers. Standard cube take a look at results are} taken as a measure of quality within the construction. Whereas the factors like technique of putting, compaction and curing of concrete, that have important influence on the standard achieved within the hardened concrete, are given scant attention. Many another times, the standard of concrete as placed and hardened in position has no correlation to the cube take a look at results, which are used for internal control measures. Procedures, necessary or otherwise, for periodic review of buildings and structures and documenting defects, like cracks, excessive deflections, corrosion of reinforcement etc., in logical manner, and recording of structural repairs already administrated, are typically not followed or maintained. In some buildings, only visual review is administrated for making ready maintenance budget estimates and this exercise is usually left to the engineers who have no expertise in such issues.

*A. Fiber reinforced concrete*

Research on fibre reinforced concrete has been conducted since the 1960's. During the 1970s the commercial use of this material began to increase, particularly in Europe, Japan and USA. Common application areas today are concrete, pavements, industrial floors, precast elements and various kinds of repairs. The addition of randomly distributed steel fibres increases the cracking resistance of concrete, i.e. the fracture toughness, ductility, impact resistance, fragmentation and spilling resistance. However, since fibres generally are distributed through the cross section it is not possible to achieve the same area of reinforcement with fibres as with conventional bars. Hence, for normal fibre contents, the concrete exhibits a softening response. Fibres are primarily used as replacement for conventional reinforcement in non-structural applications in order to control early thermal contraction cracking and drying shrinkage cracking. However, the use of fibres for structural applications as part of the overall structural design is continuously increasing. In some types of structures with relatively low reliability levels for structural safety such as slabs on grade, foundations and walls, fibres can replace ordinary reinforcement completely. Furthermore, in load carrying structures in general, fibre reinforcement may be used in combination with conventional or pre-stressed reinforcement. Although economical issues has been the main limiting factor for practical use of SFR, it is presently a more interesting alternative due to lack of skilled concrete workers and need for industrialisation of the construction industry.

## II. LITERATURE

Pampanin et al. 2002 [1] carried out an experiment on six different types of exterior and interior joints designed for gravity loads only. Plane reinforcement was used in the test models. Structural inadequacies, as typical of the Italian construction practice before the introduction of seismic code provisions in the mid- 70‟s were reproduced. The combined use of smooth reinforcing bars with end-hook anchorage as well as lack of any capacity design considerations showed to be a critical source of significantly brittle damage mechanisms as in the case of exterior joints, where additional sources of shear transfer mechanisms cannot develop after first diagonal cracking in the joint. An apparent satisfactory level of deformability as well as ductility, due to the combined effects of slippage phenomena and low column reinforcement ratio, were observed in knee and interior cruciform subassemblies, where no joint degradation occurred and column flexural damage dominated the behaviour. Moreover, the comparison of different anchorage solutions for beam-bars in interior specimens showed a higher deformability due to slippage phenomena, without resulting in flexural strength reduction. When considering the overall seismic behaviour of a frame structure, the implications of the aforementioned flexural damage on the overall seismic behaviour might be significant, with soft storey mechanisms being likely to occur at early stages.

Shiohara et al. 2010 [2] re-examined twenty reinforced concrete interior beam-to-column joint failed in joint shear. The data indicated that joint shear stress had increased in the most specimens, even after apparent joint shear failure starts, while beam moment decreases due to decrease of flexural resistance which is caused by reduction of distance between stress resultants in beam at column face. The cause of the deterioration of story shear is identified to be a degrading of moment resistance of joint, originated from a finite upper limit of anchorage capacity of beam reinforcements through the joint core. To reflect the fact, Hitoshi introduced a new mathematical model and proposed a new approach for the design of beam-to-column joint in seismic zone based on the prediction of the model.

Shiohara et al. 2010 [2] carried out the experiment on twenty interior beam column joints on a one third scale. They investigated the effects of design parameters of joints on lateral capacity and post yielding behaviour. Three major parameters of the test program were (1) amount of longitudinal reinforcement, (2) column-to-beam flexural strength ratio, and (3) column-to-beam depth ratio. The test results indicate that maximum story shear of some specimens fall 5% to 30% short of the story shear calculated from the flexural strength of the beam or the column, although the joints have some margin of the nominal joint shear strength by 0% to 50% compared to the calculated values by a current seismic provision. The extent of insufficiency in the story shear was larger if the flexural strength of the column is equal or nearer to the flexural strength of the beam, and if the depth of the column is larger than that of the beam. This kind of design parameters are common to the existing reinforced concrete buildings and not addressed in many seismic design codes.

Osamu et al 2000 [3]conducted test on RC interior beam-column sub-assemblages using plane and three-dimensional frame specimens. The influence of joint shear input and bond condition of beam bars on frame behaviour after beam yielding was examined, in particular about joint concrete deterioration in large displacement. Following results were derived from two experimental studies. 1) Bond condition of beam bars within joint did not make large influence on energy dissipation of frame, if joint shear deterioration occurred after beam yielding. 2) Joint shear strength was increased by the existence of transverse beams, because they behaved confinement of joint core concrete. 3) The damage of joint core concrete occurred during one way loading up to large displacement made weak in frame performance at following perpendicular loading. 4) If the excess of joint shear strength to beam flexural is enough large, the damage in joint concrete would not make unfavourable effect on frame ductility.

Xiaobing et al. (2013) [4] the experiment was carried out to study the mechanical behavior of square FRP-strengthened concrete columns subjected to concentric and eccentric compression loading. Basing on the study, a numerical analysis model was developed and verified against the test results of square concentrically loaded plain concrete columns and square eccentrically loaded RC Columns. An analytical formula for the increase of maximum compression load for FRP strengthened columns with respect to non strengthened columns was developed and verified by the test results of the square and rectangular RC columns. It was found that the increase of the maximum compression load of the strengthened concrete columns increase linearly with increased amount of FRP sheets used decreased linearly with increased load eccentricity and exponentially with increased concrete compression strength with respect to non-strengthened columns. This implies that FRP wrapping might be most suitable for low strength concrete members.

Al-Salloum et al. (2007a) [5] the study was carried out to see behaviour of FRP strengthened joints with or without mechanical anchorage. Externally bonded FRP sheets can effectively improve the shear strength and ductility of beam column joints but the magnitude of effectiveness depends how the sheets were attached to joints and whether mechanical anchorage was used or not. The effect of two different schemes of rehabilitation was studied in upgrading the joint. In the first scheme, CFRP sheets were epoxy bonded to the joint, beams, and part of the column regions. In the second scheme, however, sheets were epoxy bonded to the joint region only but they were effectively prevented against any possible de-bonding through mechanical anchorages. It was observed that Scheme 1 is an efficient scheme because it upgrades both the joint and the beam. However, due to the absence of any mechanical anchorages in this scheme, at higher stages of loading de-bonding bulging of externally bonded CFRP sheets occurred, which allowed cracks to form and widen under the fibre sheets. Scheme 2 is an economical and effective scheme for joint strengthening, as in this scheme CFRP sheets were applied in such a way that the possibility of de-bonding is eliminated. Moreover, this scheme makes the joint so strong that failure is directed to the beams. The effectiveness of the two above-mentioned schemes of strengthening was also examined through shear distortion hysteretic curves and it was observed that externally bonded CFRP sheets make the joint stiffer against distortion. The results of the present study infer that, for field applications, it is very much necessary to decide judiciously and carefully which scheme is suitable for strengthening a deteriorated or deficient beam-column joint. This is because strengthening of a joint and its adjacent members with CFRP sheets at one place can substantially improve the shear strength and ductility of the joint but at the same time it may also shift the failure mode from the joint to the adjacent member e.g., beam or column or vice versa.

A review of some significant experimental investigations conducted using steel plates is presented to demonstrate some of the structural implications of external plating. Research work into the performance of members strengthened with steel plates was pioneered simultaneously in South Africa and France in the 1960s. Continued development of suitable a adhesives and the increased use of the technique in practicestimulated further research work [ACI Committee 440 (1996)].

The effect of widening the plate whilst maintaining its cross-sectional area constant was studied. It was found that the plated as-cast and the pre-cracked beams gave similar load/deflection curves, demonstrating the effectiveness of external plating for strengthening purposes [Chalioris, C.E.(2007a)].

## III. OBJECTIVE OF THE STUDY

The main objective of this research project is to improve the current knowledge of the mechanical and structural behaviour of fibre reinforced concrete, focusing on practical applications. An analytical study is carried out, and the results are compared with available design rules and with finite element analysis. Further, the connection between casting method and fibre orientation is investigated, since the behaviour of fibre reinforced structures strongly depends on the orientation and distribution of fibres

## IV. SCOPE OF THE STUDY

The first objective was achieved through finite element analyses, which included development of finite element model for the reinforced cement concrete, choice of material model, verification with small-scale laboratory tests, and statistical regression based on the finite element analysis. The finite element model was verified by laboratory model tests, and the results used to analyze the properties of FRC (FIBER REINFORCED CONCRETE) in order to identify an optimum reinforcement design with the aid of statistical analysis.

## V. METHODOLOGY

### *A. Case Study*

An I-Beam subjected to vertical load of intensity, p=100 KN is idealized as linear elastic beam (E, μ) of size 2.45m x 1.95m.

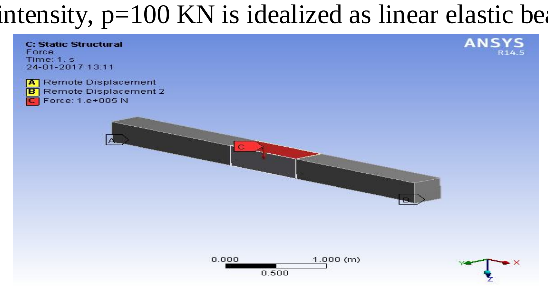


Figure 5.1 Support Condition and loading point of I-Beam section

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*B. Wrapping Pattern of FRP Laminates*

The FRP layers have elastic modulus and poisons ratio (E, μ) and its thickness, 1.5 (mm).

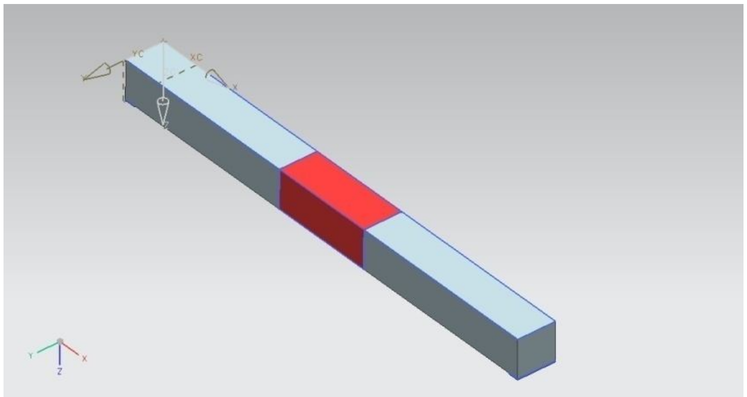

Figure 5.2 Warping Pattern of FRP laminates on the L-Beam section

*C. CAD Model*

First to generate the cad model, it is necessary to get data regarding the geometrical dimensions, element used, properties of material used boundary conditions etc.

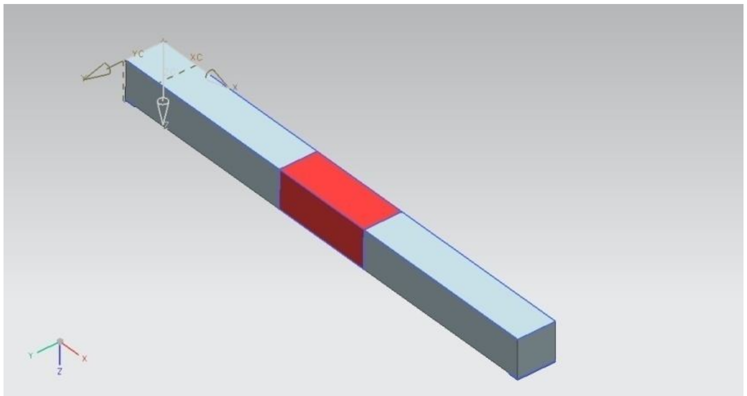

Figure 5.3 Base Model of L-Beam without FRP sheet

*D. Modelling Using ANSYS*

A finite-element computer program, ANSYS has been used to analyze the present problem. ANSYS is general finite-element software for numerically solving a wide variety of structural engineering problems. A 3-D model of the beam system was built using ANSYS. The finite element mesh used for the analysis is shown in Figure 5.4. Beam system have been analyzed using general purpose finite element software ANSYS to investigate deflection pattern.

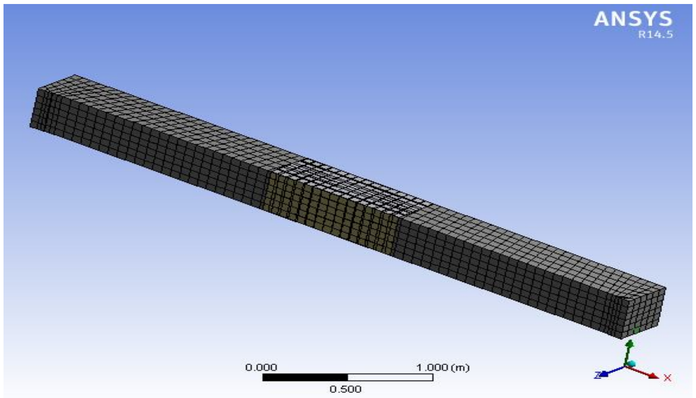


Figure 5.4 Mesh Model of Beam

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*E. Material Used*

Materials used in the analysis are unreinforced cement concrete sleeper, geogrid and soil. All materials used for the system are considered as linear, elastic, isotropic material. Table 5.1 provides the properties of the material which used in this study.

Table 5.1 material properties

| Material used | Modulus of Elasticity (E) | Poisson's Ratio (μ) |
|---|---|---|
| Unreinforced concrete | E= $22.36\times10^{9}$N/$m^2$ | μ=0.23 |
| CFRP Sheet | E=$181\times10^{9}$ N/$m^2$ | μ=0.24 |

## VI. FEM RESULTS

The value of maximum deformation (0.0042007m) or (4.20mm) for reinforced I-Beam Section with CFRP laminates for 950mm length is obtained which is shown in Figure 6.1

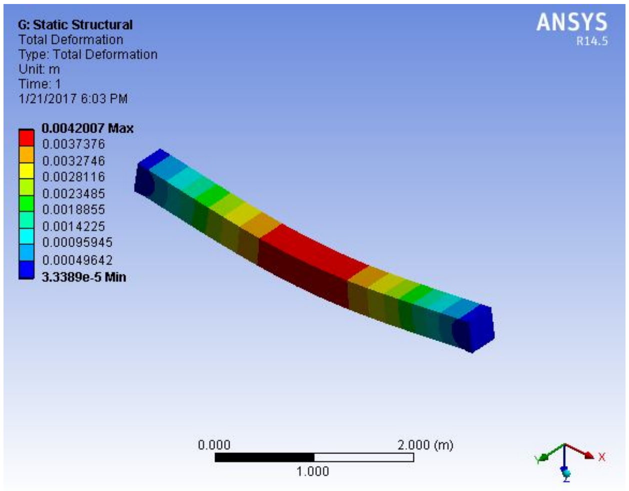


Figure 6.1 Deformation of CFRP Model L-Beam L=950mm

The value of maximum stress(7.67e7pa) for reinforced I-Beam Section with CFRP laminates for 950mm length is obtained which is shown in Figure 6.2

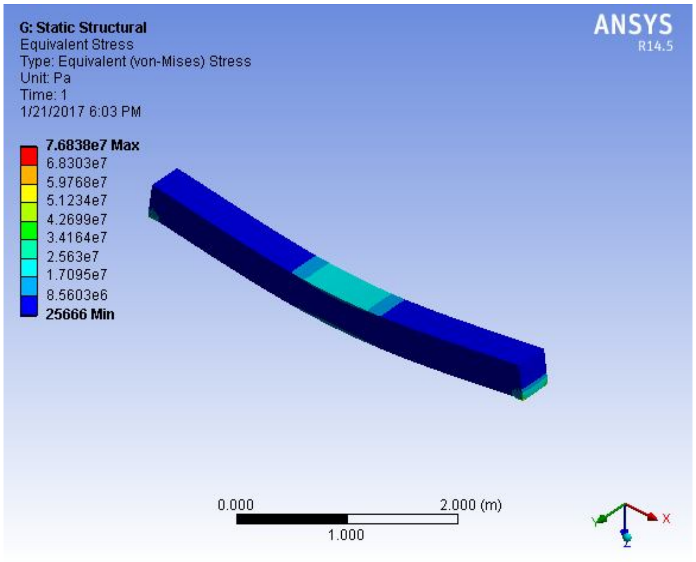


Figure 6.2Stress of CFRP Model I-Beam L=950mm

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The value of maximum strain (0.0060376) for reinforced I-Beam Section with CFRP laminates for 950mm length is obtained which is shown in Figure 6.3

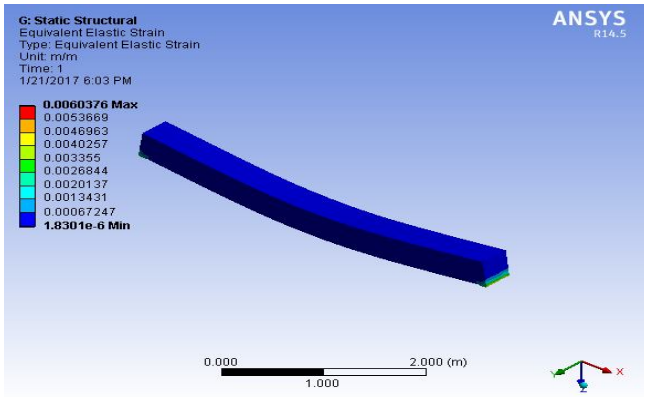


Figure 6.3 Strain of CFRP Model I-Beam L=950mm

Table 6.1 Results of Deformation

| Load (KN) | Results | I-Beam Type | | | | |
|---|---|---|---|---|---|---|
| | Deformation (mm) | Unreinforced | Reinforced With Different warping length L(mm) | | | |
| | | | L=500 | L=650 | L=800 | L=950 |
| 100 | Unreinforced concrete | 8.02 | - | - | | - |
| 100 | CFRP | - | 7.532 | 6.212 | 5.147 | 4.200 |

Table 6.2 Results of Stress

| Load (KN) | Results | L-Beam Type | | | | |
|---|---|---|---|---|---|---|
| | Stress (MPa) | Unreinforced | Reinforced With Different warping length L(mm) | | | |
| | | | L=500 | L=650 | L=800 | L=950 |
| 100 | Unreinforced | 135.52 | - | - | - | - |
| 100 | CFRP | - | 105.23 | 91.45 | 88.54 | 76.03 |

## VII. CONCLUSION

The analytical concrete I-Beam model was generated using a FEM software program ANSYS. In ANSYS software concrete I-Beam this is subjected to loading through horizontal loading which is 100KN.

Following conclusions can be drawn from current study:

There is 50% reduction in deformation for length of 950mm CFRP laminate as compare to unreinforced concrete.

There is 44% reduction in stresses for length of 950mm CFRP laminate as compare to unreinforced concrete.

CFRP provided more strength to the structure (I-Beam) and effective than unreinforced concrete material in reduction of deformation and stresses.

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