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# Retrofitting of the Post-tensioned beam using CFRP wrapping and Ferrocement wrapping system

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***Abstract***

*Three Finite Element (FEM) models have been developed using ANSYS 16 workbench for Post-tensioned prestressed concrete beam, beam retrofitted with Ferrocement, and beam retrofitted with FRP. In this research comparison of two retrofitting systems by formulating excel sheets for generalized solution and validation of results by finite element modeling in ANSYS software is done. This work gives the comparison of total stresses, flexure capacity increase, deflection reduction, crack control, displacement curves, and the check for shear on the same model. Although a great amount of work had been done on retrofitting concrete and prestressed concrete bridge girders, a comparison of these two retrofitting procedures for prestressed beams for residential is really beneficial to design professionals. The results showed that Ferrocement strength was effectively utilized in the section selected herein, which could be addressed through the economy for the amount of Ferrocement and prestressing steel used, thereby increasing the section ductility. The approach produced comparable results to the FEM and can be effectively and conveniently used in the design*

**Keywords —** *ANSYS 16.0 Workbench, CFRP, Ferrocement, Flexure, Post-tensioned beam, Retrofitting.*

## I. INTRODUCTION

Reinforced concrete structures often have to face modification and improvement of their performance during their service life. The main contributing factors are a change in their use, new design standards, deterioration due to corrosion in the steel caused by exposure to an aggressive environment, and accident events such as earthquakes.

In such circumstances, there are two possible solutions: replacement or retrofitting. Full structure replacement might have determinate disadvantages such as high costs for material and labor, a stronger environmental impact, and inconvenience due to interruption of the function of the structure, e.g., traffic problems. When possible, it is often better to repair or upgrade the structure by retrofitting.

Ferrocement is a retrofitting material that can be pretty useful because it can be applied quickly to the surface of the damaged element without the requirement of any special bonding material, and also it requires less skilled labour, as compared to other retrofitting solutions presently existing. The ferrocement construction has the edge over the conventional reinforced concrete material because of its lighter weight, ease of construction, low self-weight, thinner section as compared to RCC & high tensile strength, which makes it a favorable material for prefabrication also.

Objectives of this research are to study of relevant codes for retrofitting of the flexural member, understanding the behavior of wrapping system of retrofitting of the flexural member, analysis of FRP and Ferrocement retrofitting using ANSYS, analysis of Ferrocement retrofitting using Experimental models, and Comparison of FRP and Ferrocement wrapping system for beams.

This study provides important information on the FEM procedure for Ferrocement strengthened prestressed concrete T beams. The results obtained are very helpful to designers and researchers in understanding practical and cost-effective design procedure for flexure and shear strengthening of post-tensioned prestressed concrete T beams with a Ferrocement wrapping system.

## II. LITERATURE REVIEW

O. Rabinovich and Y. Frostig [1] tells a new method of strengthening and upgrading various types of concrete structures is presented. The advantages of the present method over conventional retrofitting methods are discussed. A literature review of existing retrofitted structures along with experimental works and various analytical and design approaches for the strengthened structural member is introduced. The feasibility and effectiveness of the method are discussed. Retrofitting of concrete structures using FRP is possible and feasible, but a satisfactory design approach along with reliable analytical tools are missing.

Y V Ladi and PM Mohite [2] write in their paper about RC beam initially stressed to a prefixed percentage of the ultimate load are retrofitted with ferrocement to improve the performance of RC beam in both shear and flexure, the welded wire mesh is wrapped around the beam in U shape. Experimental work is conducted to evaluate the performance of RC beam retrofitted with ferrocement. The article described load-deflection characteristics and mode of failure. The test results indicate that when the beam is retrofitted with wire mesh in layers at orientations, it significantly increases the load-carrying capacity, first crack load, stiffness but deflection is decreases in both flexural and shear strengthening. After retrofitting, it was observed that reduced crack widths, deflection, and spacing of cracks at the ultimate load. The beams retrofitted with ferrocement at different orientations do not de-bond when loaded to failure. At any given load level, the stiffness is increased significantly because of decreasing deflection of the retrofitted beams because of an increasing percentage of steel.

Asst. Prof. Anumol Raju Asst. Prof. Liji Anna Mathew [3] presented an experimental study on reinforced concrete beams retrofitted with various types of fibers externally, such as various natural and synthetic fibers, polypropylene fibers, glass fibers, coir fibers, carbon fibers, etc. In their experimental investigation, the flexural behavior of reinforced concrete beams externally strengthened by carbon, glass, steel, coir, and polypropylene sheets was studied. The deflection of the beams is minimized due to the full wrapping technique around all four sides of the beam. Initial cracks in the strengthened beams appear at a higher load compared to the beams improved due to the external strengthening of beams. CFRP wrapping was found out to be more effective in improving the flexural strength and ultimate load capacity of beams. Even though the beams retrofitted with CFRP sheets had maximum ultimate load capacity, but the cost of material is too high.

Y.T. Obaidat, Susanne Heyden, Ola Dahlblom [4] state in their paper, they compare a finite element analysis and laboratory tests beams. Beams had rectangular cross-section geometry and were loaded under four-point bending but differed in the length of the carbon fiber reinforced plastic (CFRP) plate. The commercial numerical analysis tool Abaqus was used, and different material models were evaluated with respect to their ability to describe the behavior of the beams. Linear elastic isotropic and orthotropic models were used for the CFRP, and a perfect bond model and a cohesive bond model was used for the concrete–CFRP interface. A plastic-damage model was used for the concrete. The analysis results show good agreement with the experimental data regarding load-displacement response, crack pattern, and de-bonding failure mode when the cohesive bond model is used. The perfect bond model failed to capture the softening behavior of the beams. There is no significant difference between the elastic isotropic and orthotropic models for the CFRP. The behavior of the retrofitted beams is significantly influenced by the length of CFRP. This is clear in experimental results as well as in numerical analysis. The ultimate load increases with the length of the CFRP. Before you begin to format your paper, first write and save the content as a separate text file. Keep your text, and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit the use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you.

## III. RESEARCH METHODOLOGY

For research on post-tensioned beam, the beam specimen used herein is five 12.7 mm diameter bonded prestressing strands with low relaxation are placed. In this research, a T beam of length 8840mm, flange width 2210mm, flange depth 102mm, web width 610mm, web depth 533mm is designed. The longitudinal reinforcement consists of five prestressed bars of 12.7mm diameter with a spacing of 101.66 mm. The value of factored load acting is 110.2N/mm.

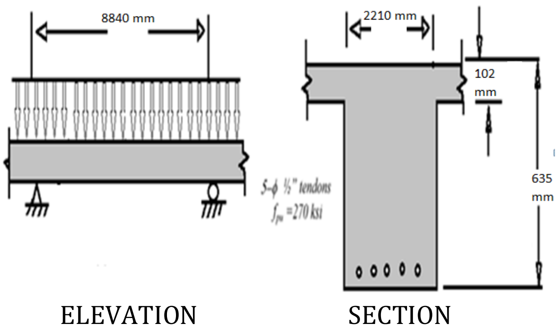


**Fig 1: Post-tensioned Prestressed concrete T beam**

**TABLE 1**
**PROPERTIES OF CONCRETE**

| | |
|---|---|
| Young's Modulus $E_c$ | 24700 N/mm$^2$ |
| Poisson's Ratio | 0.15 |
| Density | 2400 kg/m$^3$ |

**TABLE 2**
**PROPERTIES OF PRESTRESSING STEEL**

| | |
|---|---|
| Diameter of pretsressing strands $d_p$ | 12.7 mm |
| Area $A_p$ | 495 $mm^2$ |
| Grade of Prestressing Steel $f_{pu}$ | 1860 $N/mm^2$ |
| Young's Modulus $E_p$ | $1.96 \times 10^5$ $N/mm^2$ |
| Yield Strength $f_{py}$ | 1586 $N/mm^2$ |
| Poisson's Ratio μ | 0.3 |
| Density | 7850 $kg/m^3$ |

**TABLE 3**
**FERROCEMENT SYSTEM DETAILS**

| | |
|---|---|
| Thickness | 18 mm |
| The diameter of the Mesh wire | 1.4 mm |
| Layers of Mesh | 2 Nos. |
| C/C distance (both Horizontal & Vertical) | 20 mm |
| Spacer bar | 4 mm |
| Cover | 7 mm |

**TABLE 4**
**FERROCEMNT SYSTEM PROPERTIES**

| | |
|---|---|
| Yield Stress | 405 $N/mm^2$ |
| Yield Strain | 0.00286 |
| Ultimate Strength | 502 $N/mm^2$ |
| Ultimate Strain | 0.0329 |

**A numerical method for calculation of Moment of Resistance of both Post-Tensioned beam with and without Ferrocement wrapping system:**

**i. C.G. Calculation (w.r.t. the base):**

$$y = \sum A_i y_i / \sum A_i$$

| | $\bar{y}$ |
|---|---|
| For Post-Tensioned beam | 414.5 mm |
| For Retrofitted beam | 402.1 mm |

### ii. M. I. Calculations:

| | |
|---|---|
| For Post-Tensioned beam | $2.13 \times 10^{10}$ $mm^4$ |
| For Retrofitted beam | $2.39 \times 10^{10}$ $mm^4$ |

### iii. Moment of Resistance:

| | |
|---|---|
| For Post-Tensioned beam | 83161 N-m |
| For Retrofitted beam | 96190 N-m |

## IV. MODEL SIMULATION

Three Finite element 3D models are prepared on ANSYS 16.0 Workbench. The first one is for Post-Tensioned beam, having dimensions as mentioned above is developed. For development, these model material properties are selected as concrete, prestressed steel. Prestressed wires are fixed at one end and applied force on another end. The beam is simply supported. The second model is the same Post-Tensioned beam, along with Ferrocement retrofitting is developed. Herein, Steel mesh is created along with the covering of mortar as a wrapping system. Provided all required contacts, e.g., steel mesh to mortar, mortar to concrete, etc. The third beam is developed with an FRP wrapping system.

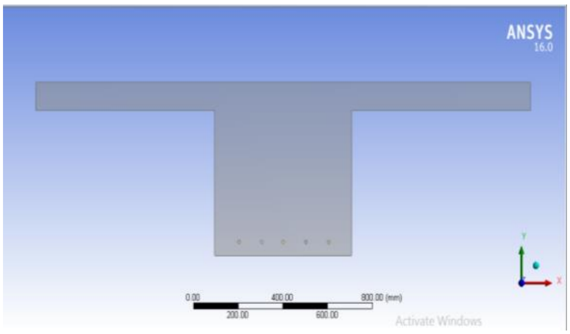


**Fig. 2: Geometry of Post-Tensioned Beam**

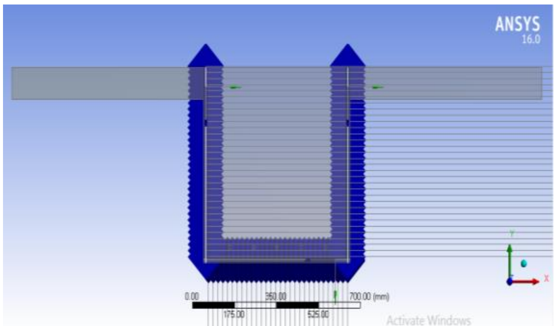


**Fig. 3: Geometry of Post-Tensioned Beam with Ferrocement wrapping system**

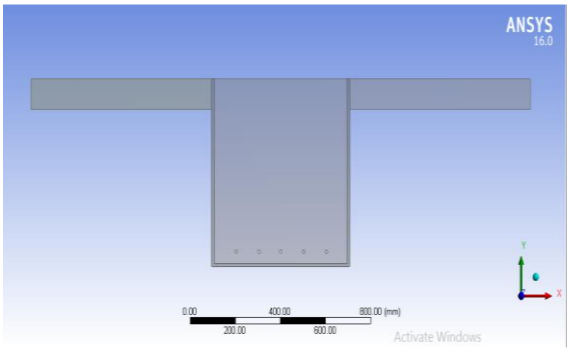


**Fig. 4: Geometry of Post-Tensioned Beam with FRP wrapping system**

## V. RESULT AND DISCUSSION

Ultimate Capacity:

| | |
|---|---|
| For Post-Tensioned beam | 8.51 KN/m |
| For Retrofitted beam | 9.85 KN/m |

**The ultimate Capacity of both beams is calculated using the Moment of resistance of respective beams.**

Following are the results obtained by finite element analysis based on certain parameters as follows:

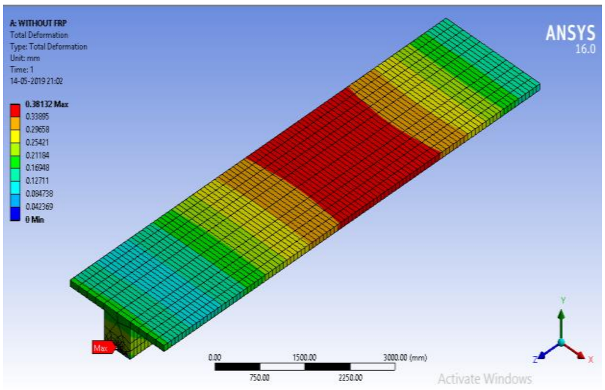


**Fig. 5: Deformation of Post-Tensioned beam**

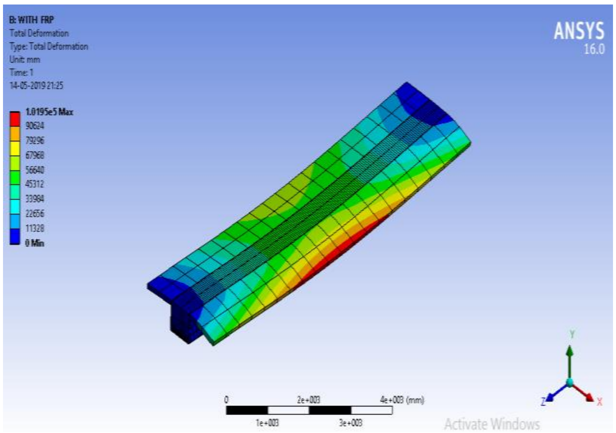


**Fig. 6: Deformation of Post-Tensioned beam with a wrapping system**

## VI. CONSTRUCTION METHOD & EXECUTION

In this type of retrofitting, construction process and execution is the key part. For execution work, we will be needed, skilled laborers. For retrofitting of the beam will connect iron jalis to slab reinforcement with a hook-like structure. Then will cover three sides of the beam with formwork along with required cover spacers on both sides of jali. After constructing formwork around the beam, we will fill those formworks by self-compacting mortar. After 21 days will remove that formwork.

## VII. CONCLUSIONS

1. Flexural strength of ferrocement wrapped beam (thickness 18 mm, two weld mesh jalis of 1.4 mm diameter steel) can be enhanced up to 15.67% . Thus Moment of resistance is also raised by Ferrocement wrapped beam .hence if the utility of building changes or if there are changes in live loads for an existing structure, the required modification can be done using ferrocement wrapping instead of

Carbon fiber wrapping so as to cater for added strength demand from RC section.

2. Similarly, The shear strengthening of the beams at the supports can be done in many ways, here the ferrocement wrapped in flexure is extended to the supports, or it can be done in pieces, i.e., shear wrapping near support and flexure wrapping near mid-span.

3. The displacement in the beam without Ferrocement was 18mm, whereas, on the wrapping of Ferrocement, displacement is reduced to 10 mm. Hence wrapping also helps in reducing deflection, as Ferrocement is fully utilizing its tensile capacity to enhance flexural tension capacity.

4. Total calculated stress and stress obtained by finite element analysis is under limits, and section is safe in flexure and shear. Hence simulation tool is useful to understand the behavior of wrapping, and hence we can head towards the execution of such a solution at the site.

5. As Ferrocement can best be utilized to enhance flexure and shear capacity, this solution is will be economically cheaper than the FRP Wrapping system. And cost saving will be considerable. Also, no special chemicals are needed; construction workers can easily use this technique.

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