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A Study on Post Tensioned T-Beams Strengthened with AFRP Fabric

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Abstract: Reinforced concrete is a widely used versatile material in construction field till now. Post Tensioned structures are not exception to this, to guarantee the stable performance of the structures. In the present work, an attempt is made to study the ultimate load carrying capacity and maximum deflection of post tensioned beam, post tensioned retrofitted beam and post tensioned strengthened beam with AFRP, under two points loading. For this, beams of 1300 mm length, flange width &thickness 300 mm & 75 mm, width and thickness of the web is 180 mm &125 mm depth, were casted and tested for M45 grade concrete and 0.35 water/ cement ratio. Then, the results of experimental method and analytical method were analysed and discussed.
Keywords: Post Tensioned, Strengthening, Retrofitting, Aramid fibre, Epoxy resin.

I. INTRODUCTION

Study shows that, Strengthening of existing structures has become a major part of construction activity in our country. Many civil structures are no longer safe due to increased load specifications in the design codes. Such structures must be strengthened in order to maintain their serviceability. Strengthening refers to the reconstruction or renewal of any part of an existing building to provide better structural capacity like higher strength and ductility than the original. Various strengthening techniques include the use of advanced composite materials like Aramid fiber reinforced polymer (AFRP), Carbon fiber reinforced polymer (CFRP), Ferro cement etc. The crucial regions in post tensioned beams are flexure zone and shear zone. In the present work, the flexure zone is strengthened with AFRP fabric.

The aramid fiber as an externally bonded reinforcement used for increasing flexural strength. Result shows that fully wrapped RC beam gives more torsional strength as compared to controlled beam (Sachin, 2018). The maximum load of Post Tensioned PSC strengthened beam with Natural Sisal Fiber Reinforced Polymer (NSFRP) showed maximum load carrying capacity compared to strengthened beam (Bharath, 2015). FEM modeling is used to study the structural behavior of reinforced concrete beams and bridges strengthened with FRP laminates (Alper, 2001).

II. OBJECTIVES

The main objective of the current work is,

A. To study the ultimate load carrying capacity of the beam.
B. To study the crack pattern and deflection of the beam.

III. MATERIALS USED

The materials used for the present work is:

A. Concrete

For the current study, M45 grade with 0.35 w/c ratio is used. The mix is designed as per IS 10262:2009 and the mix proportion is 1: 1.23: 2.27.

B. Reinforcement

The structural reinforcement of specimen consist of 2 number of 12mm dia at tension reinforcement and 2 No. of 10mm dia and 2 No. of 8mm dia hanger or compression reinforcement. 8mm dia two legged stirrups were provided at 125mm c/c as shear reinforcement.

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C. Aramid fiber reinforced polymer (AFRP)

Aramid Fiber as an external reinforcement is used extensively to deal with the strength requirements related to flexure in structural systems. The manufacturing unit of good quality of fibers is Kevlar. The modulus of elasticity of these fibers are from 75-250Gpa, with an elongation of 1.6-6%. Their Young modulus of elasticity and tensile strength are intermediate between glass and carbon fibers. Their compressive strength is typically around 1/8 of their tensile strength. Post Tensioned beam is externally bonded with Aramid Fiber. Each panel is subjected to equal static loading during the experiment. Fig 1 shows the bidirectional pattern of Aramid fiber.

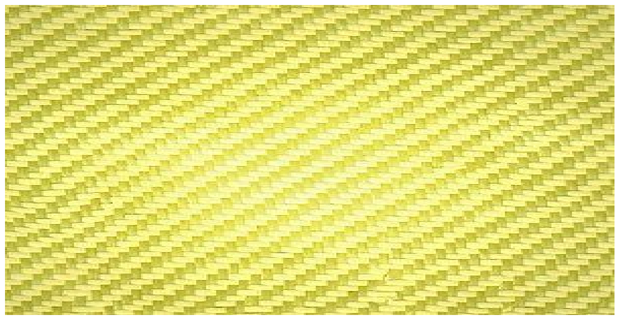

Fig 1: Aramid fiber

IV. EXPERIMENTAL PROGRAM

For the present study three types of beams were casted and tested.

A. Post Tensioned Beams

The experimental study comprises of casting Post-Tensioned T-beams of dimension beams of 1300 mm length, flange width &thickness 300 mm & 75 mm, width and thickness of the web is 180 mm &125 mm depth. The structural reinforcement of specimen consist of 2 number of 12mm dia at tension reinforcement and 2 No. of 10mm dia and 2 No. of 8mm dia hanger or compression reinforcement. 8mm dia two legged stirrups were provided at 125mm c/c as shear reinforcement tendons of 7mm dia were placed at an eccentricity of 40 mm from the bottom surface of the beam. During casting the vibrator was used for compaction of concrete to avoid honey comb formation. After casting the beams were cured for 28 days.

Fig 2:- Casting of Post TensionedT- Beams

B. Post Tensioning Mechanism Of Beams

Once the concrete attains full strength after 28 days of curing, the pre-stressing cable or post tension tendons placed inside plastic pipe duets are pulled tight with the aid of tensioning jack and anchored against outer edges of the specimen with help of wedges and barrel steel plates. A hydraulic post tensioning hand driven jack consisting of a needle gauge is used to apply the load. Needle is inserted into tendon and pre-stressed to the required force is the basic principle behind it. Two mild steel plates of dimension 100 mm x 80 mm x 10 mm were used as end bearing plates at both the ends of the beam. Two holes were driven in each end bearing plates to accommodate the post-tensioning wires or tendons. The Wedges and Barrels were inserted at the end of steel bearing plates

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to avoid the relaxation of pre-stressed tendons. The tendons were anchored at one end of the beam and pre-stressing is applied at other end through jack needle. Pre-stressing force of 90kN is applied in hydraulic jack to pull the pre-stressing wire.

Figure.3. Post-tensioning of beams

C. Strengthening of T-beams with AFRP fabric

Before the bonding of AFRP, the beam surface should be cleaned. Both the epoxy resin and hardener are mixed for five minutes in order to get the uniform mix as bonding agent. The AFRP fabric is cut to the required form. As in case of strengthening, after the beam is air dried, epoxy resin is applied on beam surface and AFRP fabric is placed on it. With help of rollers the fabric is pressed to remove the entrapped air or else it may lead to early failure. After strengthening, the beams are cured for three to four days. The corrosion of steel or deterioration of concrete must be solved before application of epoxy resin. Figure 4 shows the application of epoxy and aramid fibre to strengthen the beam.

Fig 4: Application of Epoxy and Aramid fibre

D. Experimental Setup

The beams are subjected to two point loading under the loading frame of 500 kN capacity and all beams were tested under static loading as shown in figure 5. The load is applied at an interval of 10kN till the failure of the specimen. The maximum load at which the beam fails is considered as ultimate load. For every incremental load of 10kN, the corresponding deformations were measured using LVDT's placed at right loading point, left loading point and at the mid span of the beam. The results were tabulated and discussed. Figure 6 shows the deflected shape of the beam.

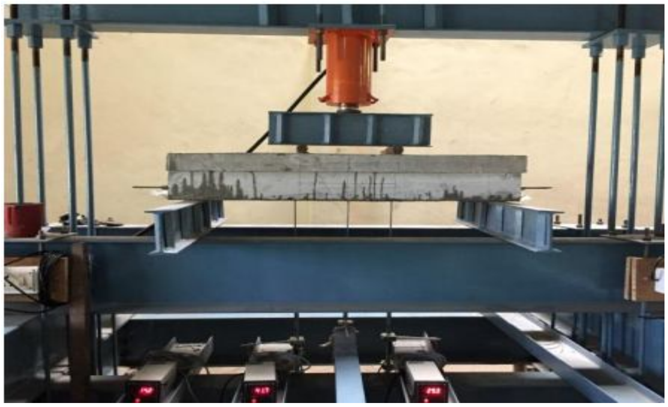
Fig 5: Test setup for Post Tensioned T Beam


Fig 6:- Deflected shape of Post Tensioned Beam

V. ANALYTICAL METHOD

The software used to carry out the analytical method is Ansys Workbench 14.5, which enables to simulate tests or working conditions and to test in virtual environment before manufacturing prototypes of products.

A. Modelling of The Beam

The first step is to generate the computer graphical model of the given component which will represent the original component. Same considerations have been considered during the modelling of the component such as; material properties, loading and boundary conditions. Figure 7 shows the modelling of Post Tensioned (PT) beam strengthened with AFRP fabric. The results were tabulated and discussed and the deflected shape of the beam model is as shown in figure 8.

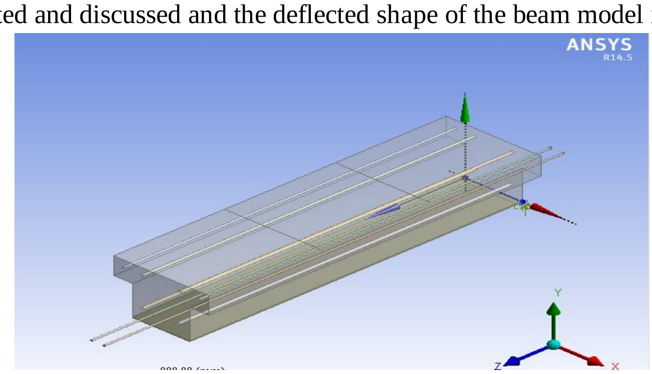

Fig 7:- Post Tensioned T Beam strengthened with AFRP

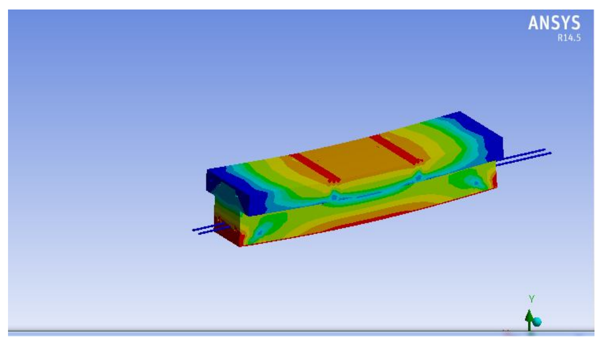

Fig 8:- Deflected shape by analytical method

VI. RESULTS AND DISCUSSIONS

The results obtained were discussed for different beams and the results were tabulated and the same is presented here

A. Experimental Results

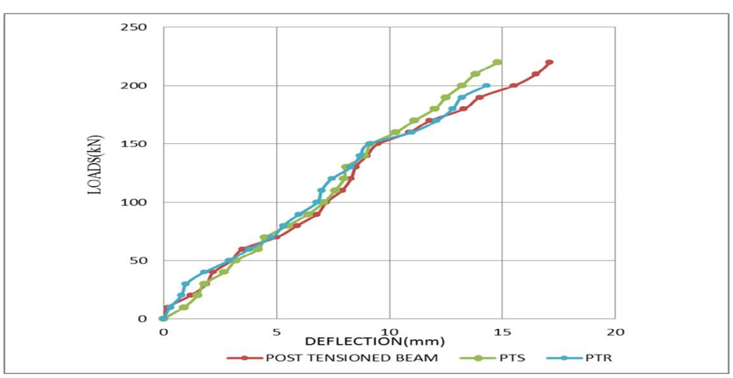

Fig 9:- Load v/s Deflection curve for different types of PT-beams

Figure 9 shows load v/s deflection curve for different types of beams used in the experimental work. From the above graph it is observed that, the deflection of Post Tensioned Strengthened beam and retrofitted beam with AFRP is reduced by 8% and 4% respectively when compared to Post Tensioned Beam. It can also be observed that, Post Tensioned Strengthened beam shows less deflection when compared to other beams. This may be because of AFRP fabric used at the bottom of the beam for full length.

B. Analytical Results

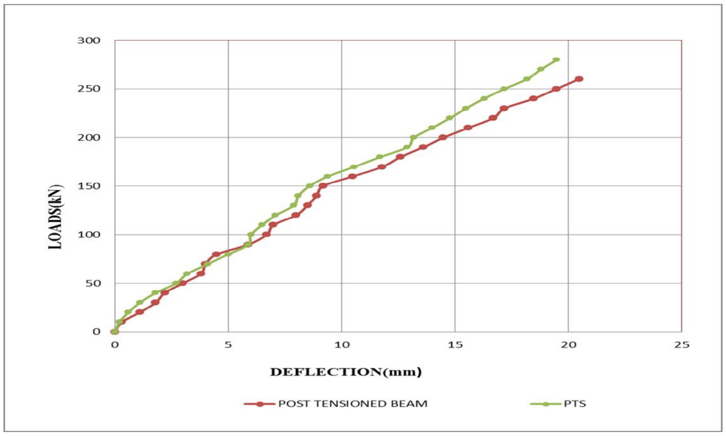

Fig 10:- Load v/s Deflection curve for different types of PT-beams

Figure 10 shows load v/s deflection curve for different types of beams used in the analytical work. From the above graph it is observed that, the deflection of Post Tensioned Strengthened beam with AFRP is reduced by 9% when compared to Post Tensioned Beam. This shows that even in analytical method the Post Tensioned Beam Strengthened with AFRP performs better compared to Post Tensioned beam. Same trend of result is observed even in experimental method. That is, the Post Tensioned Beam Strengthened with AFRP performs better when compared to Post Tensioned beam. Also when compared with the experimental results, the deflection of post tensioned strengthen beam by analytical is reduced by 1% with more load carrying capacity. This may be because of the Analytical method results are more accurate when compared to experimental method.

C. Comparison of Ultimate Loads by Experimental & Analytical Method

The ultimate load carrying capacity of the beams used for the experimental and analytical works is compared here. It is observed that, the load carrying capacity by experimental method of Post Tensioned (PT) beam is 250kN, PT beam strengthened with AFRP is 270kN, PT Beam Retrofitted with AFRP is 260kN. And the load carrying capacity by analytical method of PT beam is 260kN and that of PT beam strengthened with AFRP is 280kN. Here it can be observed that, analytical method gives more accurate values when compared to manual or experimental method. And overall PT beam strengthened with AFRP performed better in both experimental and analytical methods i.e, maximum load carrying capacity and minimum deflection when compared to other beams. This may be because of AFRP fabric used at the bottom of the beam for full length. Figure 11 shows the Comparison of loads with different types of PT-beams.

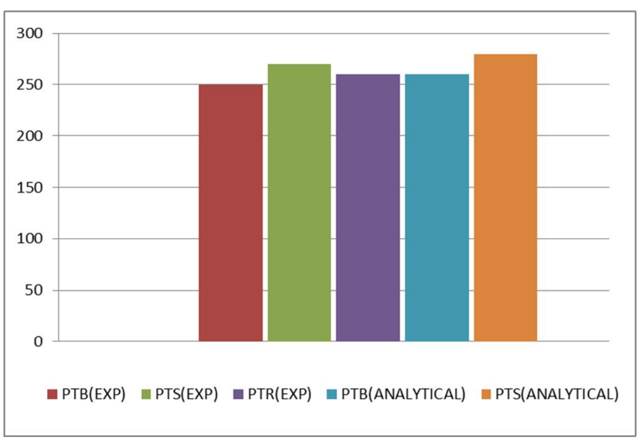

Fig 11:- Comparison of loads with different types of PT-beams

VII. CONCLUSIONS

Based upon the observations made from the experimental and analytical study, the following conclusions were drawn.

A. Experimental method:

1) The deflection of Post Tensioned Strengthened beam and retrofitted beam with AFRP is reduced by 8% and 4% respectively when compared to Post Tensioned Beams.

2) The ultimate load carrying capacity of Post Tensioned Strengthened beam and retrofitted beam with AFRP is increased by 10% and 5% respectively when compared to Post Tensioned beam.

B. Analytical method:

1) The deflection of Post Tensioned Strengthened beam with AFRP is reduced by 5% when compared to Post Tensioned beam.

2) The ultimate load carrying capacity of Post Tensioned Strengthened beam is increased by 10% when compared to the Post Tensioned Beam.

C. In both the cases i.e, in Experimental and Analytical methods, the performance of Post Tensioned Strengthened beam showed better results with more load carrying capacity and less deflection when compared to other beams.

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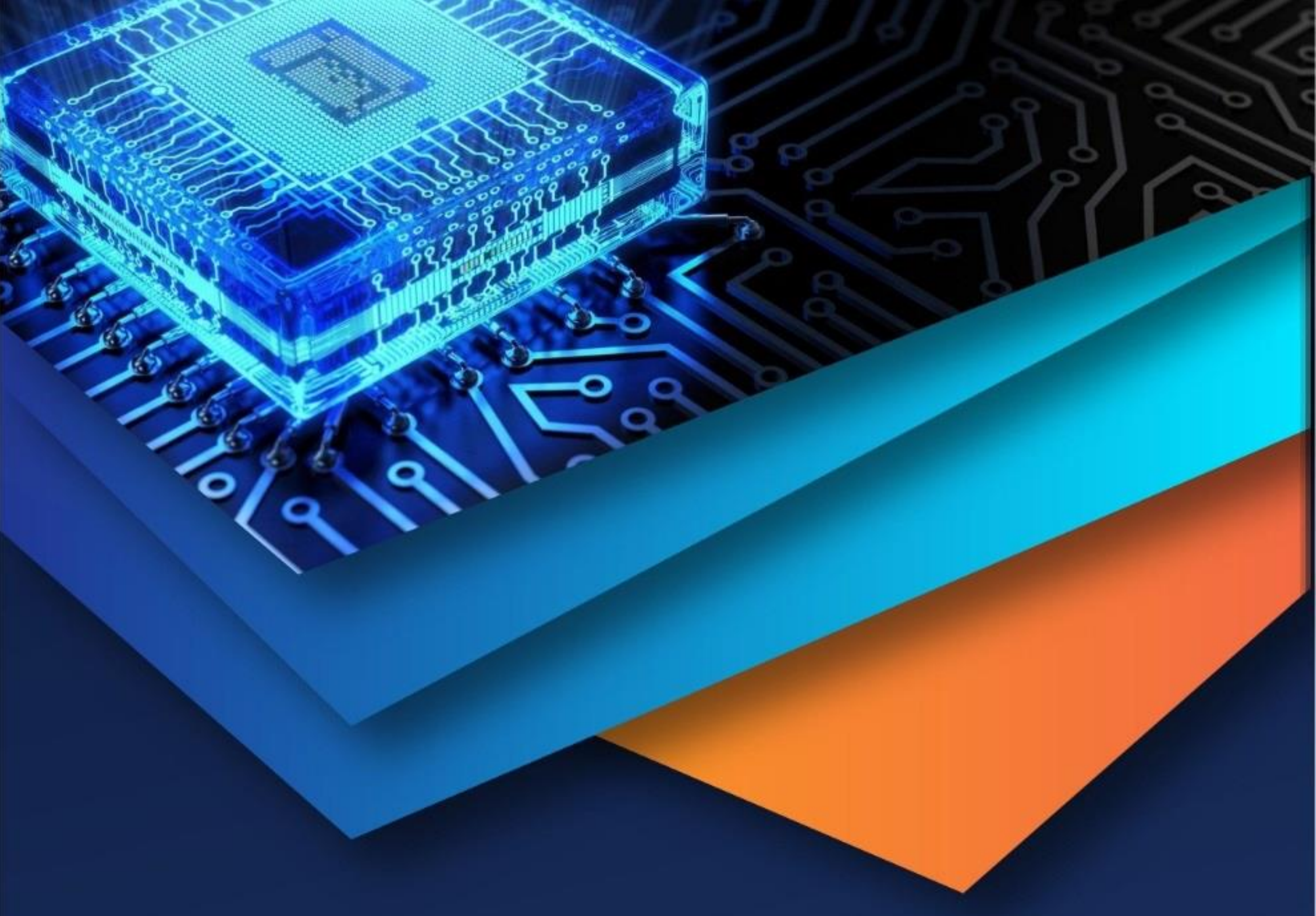

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