FLEXURAL BEHAVIOURAL STUDY ON RC BEAM WITH EXTERNALLY BONDED ARAMID FIBER REINFORCED POLYMER

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Abstract

This paper presents the flexural behaviour of Aramid fiber reinforced polymer (AFRP) strengthened reinforced concrete (RC) beams of M_{25} grade of concrete. The experimental program included strengthening and testing of simply supported rectangular cross section beam of size 100mm x 150mm x 1200 mm strengthened with Aramid fiber polymer sheets. Total twenty specimens were tested out of which two beam specimens were tested as control beams and remaining for various damage degrees (i.e. 0%, 70%, 80%, 90%, and 100%). The effects of strengthening on load carrying capacity and effect of damage degree are discussed in detail. The results indicate that the load carrying capacity of beams was significantly increased as the number of layer increased. The validation of the experimental results was done by using ANSYS software. In order to study the flexural behaviour of the beam, the specimens were only subjected to two point loading mechanism only. The beams were wrapped with AFRP sheets in single layer and double layers along the length at the bottom face of the beam. The present work includes Effect of damage degree of the beam and effect of number of layers. Thus it is a feasible method for strengthening and retrofitting of RC beams.

Keywords: *AFRP, Strengthened beams, Flexural behaviour, damaged beams, ANSYS.*

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1. INTRODUCTION

Fiber reinforced polymers (FRP) have been used for many years in the automotive and aerospace industries. In construction industry they can be used for cladding or for structural elements in a highly aggressive environment. Now a day's building are found to be damaged because of change in the function of building, exposure to environmental conditions and due to use of older codal provisions. Today deterioration of RC structure is one of the major problems in civil industry. Mostly large number of buildings are constructed as per older design codes in different parts of the world, thus are structurally unsafe according to present design codes, since replacement of such deteriorated structure takes plenty of money and time. Nowadays, it is necessary to find repair techniques suitable in terms of low costs and fast processing time.[1,2] Much of our current infrastructure is constructed of concrete. As time passes, deterioration and change of use requirements facilitate the need for new structures. Demolition of existing and construction of new structures is a costly, time consuming and resource intensive operation.[3] Externally bonded FRP sheet can be used to increase as flexural strength of reinforced concrete beams. Reinforced concrete beams externally reinforced with fibre reinforced polymer sheets using finite element method adopted by ANSYS. The accuracy of the finite element model is checked with help of comparison its results with the experimental results. The load-deflection curves obtained from the finite element analysis holds good with the experimental results.[4] Experimental studies conducted by Balsamo A., Nardone F.[5] investigated on the Flexural strengthening of concrete beams with FRP. Tajari A.R.et.al. [6] focused on Flexural behaviour of reinforced concrete beams strengthened by Carbon Fiber Reinforced Polymer sheets. Fathelbad F.A. et.al.[7] Focused on finite element modelling of strengthened simple beams using fiber reinforced polymer techniques.

1.1 Aramid Fiber

Aramid Fiber is also known as keveler fiber. Aramid fiber is also high strength, tough and highly oriented organic fiber derived from polyamide incorporating into an aromatic ring structure. Keveler is used in bullets resistance jacket. This fiber is quite abrasive and under repeated loading they can abrade against each other by weakening the sheets. Aramid fiber is a family of synthetic products characterized by strength some five times stronger than steel on an equal weight basis and heat-resistance and high tensile strength. Physical properties of Aramid fiber are given in Table 1.

Table 1 Properties of Aramid fiber sheet

Properties	**Values**
Tensile Strength (MPa)	3039
Modulus of Elasticity (GPa)	127
Weight of the sheet per m^2 (gsm)	300
Density (g/cm^3)	1450
Dry fabric thickness (mm)	0.4

2. EXPERIMENTAL PROGRAM

The experimental program consisted of casting reinforced concrete beams, with various degree of damaging, number of layer of applying the AFRP sheets and testing them under two point loading on a Universal Testing Machine of capacity 600 kN.

2.1 Details of the Beam Specimen

The experimental work consisted of a total twenty rectangular beams designed as under reinforced concrete. All beams were of the same size 100 mm x 150 mm x 1200 mm of F_e 500, 2Nos-8 mm diameter bars were used for flexural reinforcement at the bottom of each beam, 2Nos-8 mm at the top of each beam and 6 mm diameter stirrups spaced 150 mm c/c for shear reinforcement. The reinforcement details of beam used for experiment has illustrated in the Fig. 1. The casting of beams was made as per IS code specification using M_{25} grade concrete with 20 mm maximum size of coarse aggregate, locally available sand and 53 grade ordinary Portland cement. These beams were cured for 28 days in pure water and were tested under two-point loading on a Universal Testing Machine of capacity 600 kN.

2.2 Preparation of Test Specimen

The description of test specimens is summarized in Table 2. The tension surfaces of the beams were cleaned using polish paper to ensure a good bond between the AFRP strip and concrete surface. Each of these beams was externally bonded with AFRP strips and epoxy at the tension face of the beam as per the procedure given by the manufacturer.

Table 2 Description of test specimens

Specimen ID	**Beam ID**	**Aramid fiber reinforced Polymer strip**	
		Length (mm)	**No. of Layer**
Control beam	CB	NA	NA
Single layer 0% damaged 100mm width	SLA	850	1
Double layer 0% damaged 100mm width	DLA	850	2
Single layer 70% damaged 100mm width	SLB	850	1
Double layer 70% damaged 100mm width	DLB	850	2
Single layer 80% damaged 100mm width	SLC	850	1
Double layer 80% damaged 100mm width	DLC	850	2
Single layer 90% damaged 100mm width	SLD	850	1
Double layer 90% damaged 100mm width	DLD	850	2
Single layer 100% damaged 100mm width	SLE	850	1
Double layer 100% damaged 100mm width	DLE	850	2

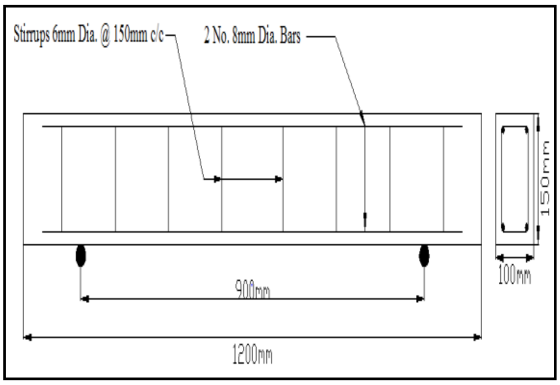

Fig. 1 Reinforcement details of beam with stirrups

2.3 Test Setup

All specimens were tested under two point loading. The load was applied through Universal Testing Machine of capacity 600 kN. They were statically tested for failure at equal 2 kN increment of load. During loading the mid span deflection was measured using dial gauge having a least count of 0.01 mm. Deflections and the applied load were recorded at every load increment. Cracks formed on the faces of the beams were marked and identified. All beam specimens were loaded and simply supported as shown in fig. 2

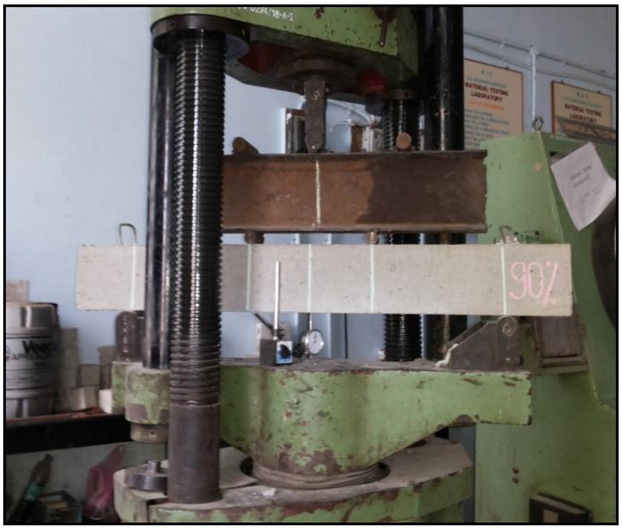

Fig.2 Test Setup

2.4 Crack Pattern

In this the comparison of crack pattern was done of control beam and wrapped beam. It was seen that flexural and shear crack pattern in both the beams was same. The flexural cracks develop in vertical direction at pure bending and shear cracks are developed in inclined pattern at shear zone nearer to support. The number of cracks and crack width gets reduced after application of AFRP sheet. The crack pattern of control beam has been shown in fig.3.

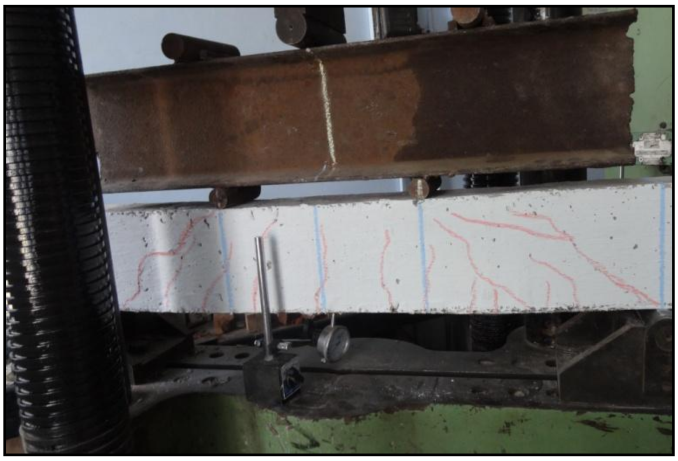

Fig.3 flexural and Shear crack Pattern for control beam

3. FINITE ELEMENT MODELING

Concrete is a nonlinear behaviour material during loading, it is modeled in ANSYS Version 14.0 (Workbench) to conduct analysis.

3.1 Concrete

An eight noded element solid 65 is used to model the concrete. The solid 65 element is capable of plastic deformation, crushing and cracking as shown in Fig. 4

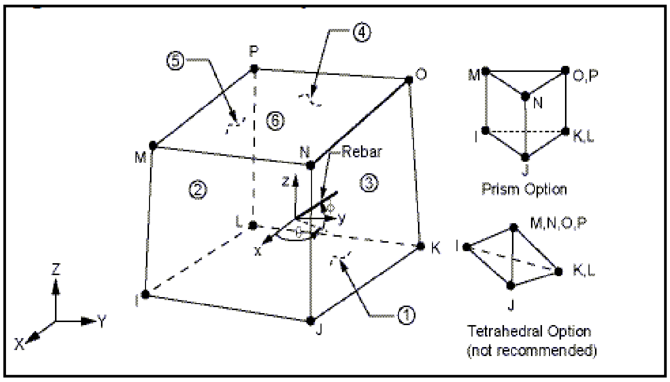

Fig. 4 Solid65 element geometry

3.2 Steel Reinforcement

Link 8 element was used to model steel reinforcement with two nodes element. Link 8 element is also capable of plastic deformation, the geometry as shown fig.5.

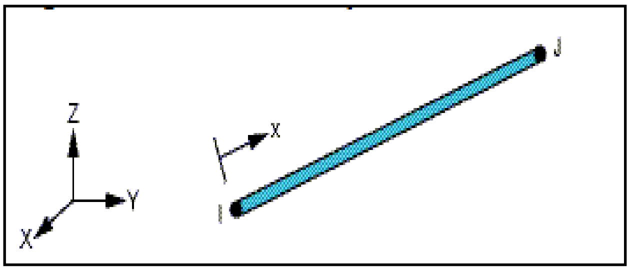

Fig. 5 Link8 element geometry

3.3 Steel Plate

A Solid 45 element was used to model steel plates. Steel plates were added at support and loading locations in the finite element models, to avoid stress concentration problem. The steel plates were assumed to be linear elastic material. The geometry of a Solid 45 element is as shown in fig. 6

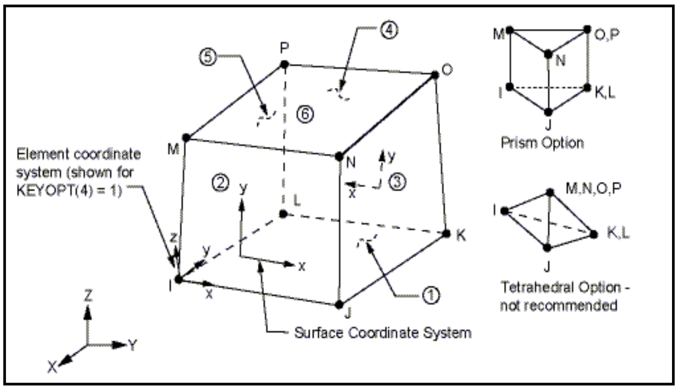

Fig. 6 Solid45 element geometry

3.4 Fiber Reinforced Polymer Sheet

A solid 45 element was used to model FRP composites as shown in fig.6. The reinforcing material is in the form of Aramid fibers, which are stiffer and stronger than the matrix. Linear elastic properties of FRP composites are assumed.

3.5 Modeling of Reinforced Concrete Control Beam

A full beam was used for modeling by taking advantage of the loadings and symmetry of the beam. Meshed model of control beam and steel reinforcement of beam has shown in fig.7 and fig.8.

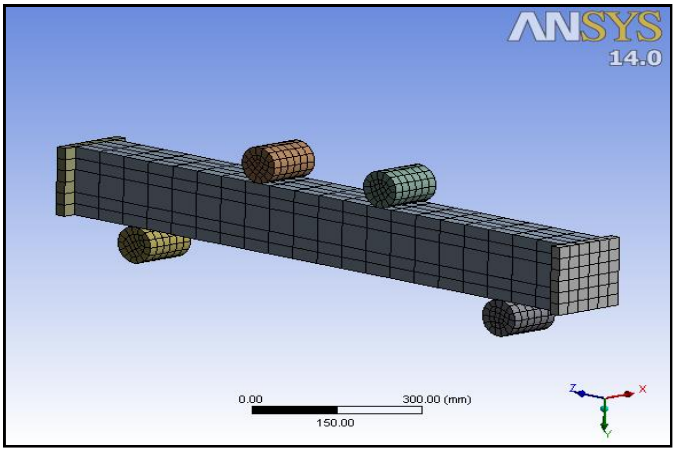

Fig. 7 Meshed Model of control beam

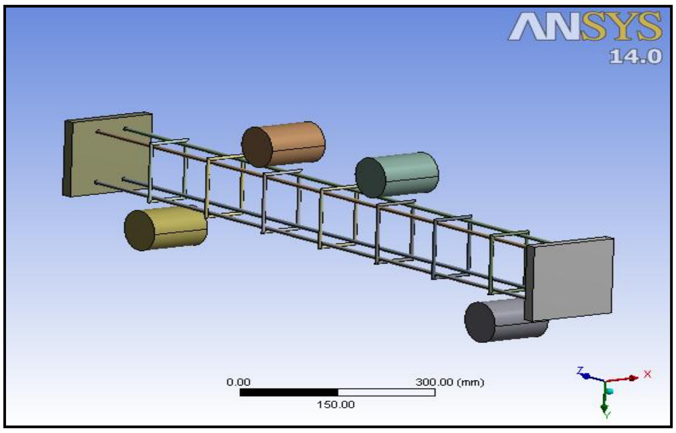

Fig. 8 FEA Modeling of steel Reinforcement beam

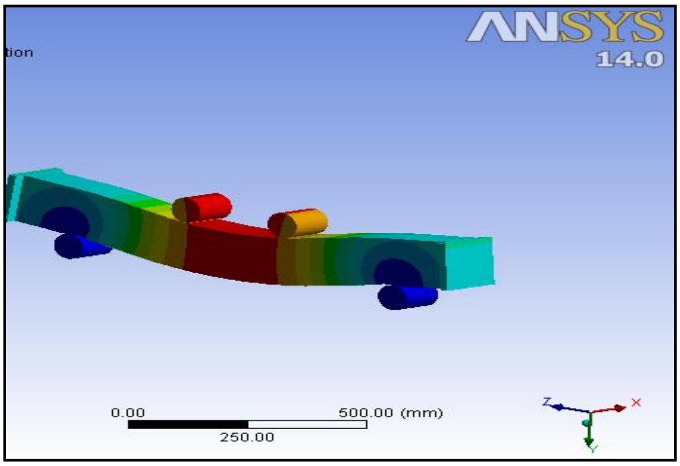

Fig. 9 Deformed Model of wrapped beam

4. RESULTS AND DISCUSSIONS

All strengthened specimens exhibited limited deformation and cracks before yielding of reinforcement. The initial cracks were initiated at a load of 22 kN and progressed towards upward direction from bottom of beam. The validation of experimental results of two beam specimens was done with help of ANSYS software from fig.15 and fig.16.

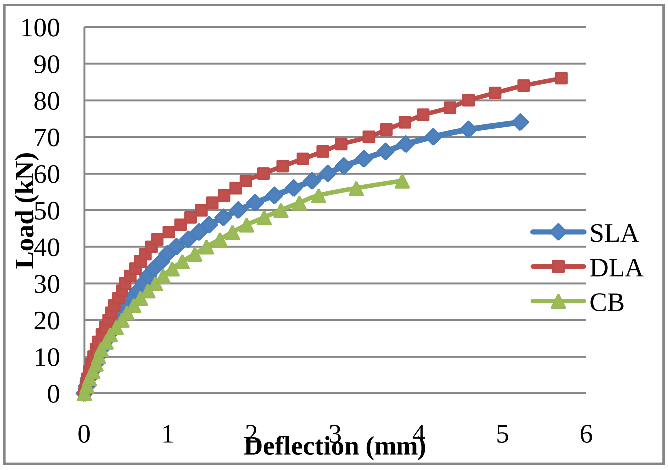

Fig. 10 Load versus deflection curve for comparison of CB, SLA, DLA

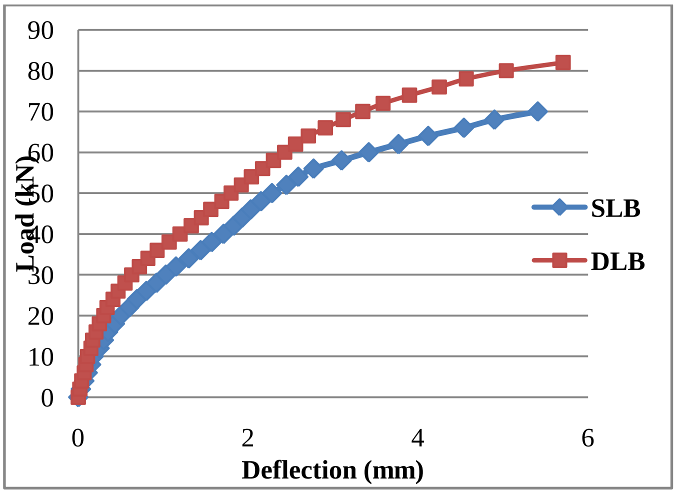

Fig. 11 Load versus deflection curve for comparison of SLB, DLB

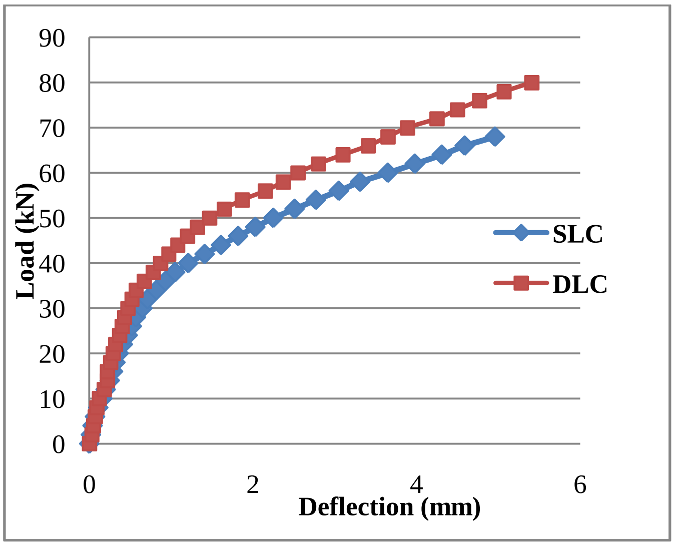

Fig. 12 Load versus deflection curve for comparison of SLC, DLC

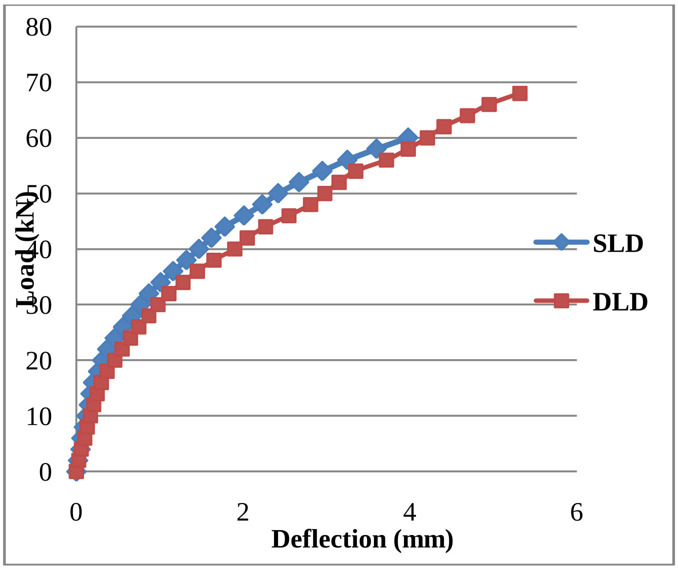

Fig. 13 Load versus deflection curve for comparison of SLD, DLD

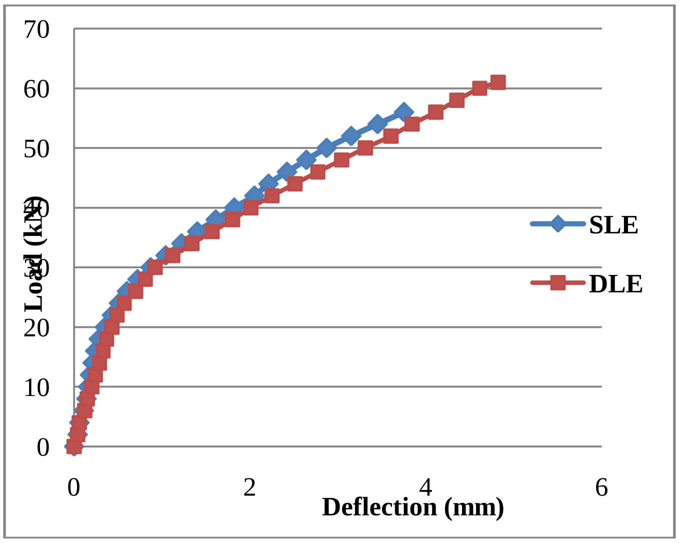

Fig. 14 Load versus deflection curve for comparison of SLE, DLE

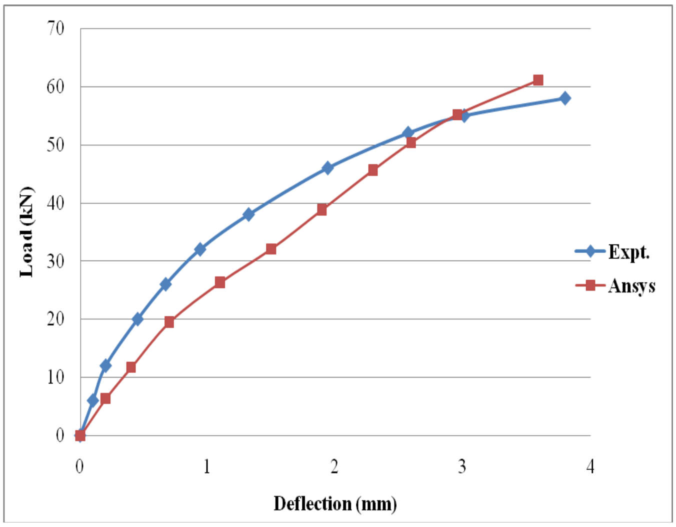

Fig. 15 Load versus deflection curve for Experimental and Ansys for Control Beam.

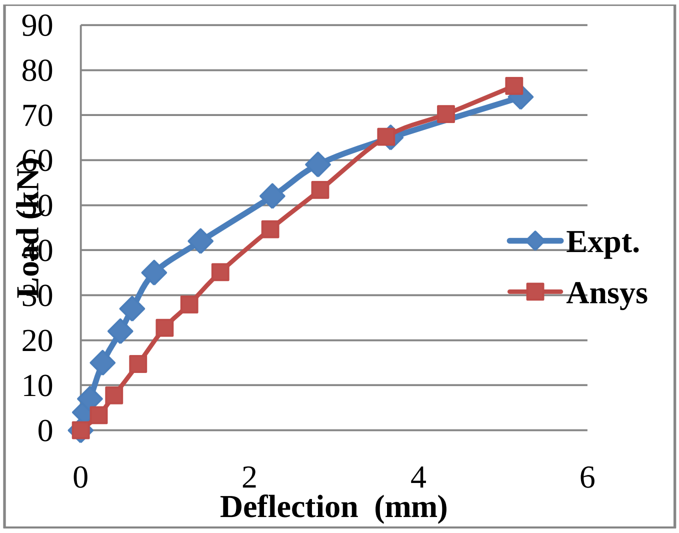

Fig. 16 Load versus deflection curve for experimental and Ansys for wrapped beam

5. CONCLUSIONS

Based on experimental results following conclusions are drawn.

1. The ultimate load carrying capacity for 0% damage degree beams are increased after strengthening with single layer and double layer of 100 mm width AFRP strip is 27.59% and 48.27% respectively compared with control beam.
2. Ultimate load carrying capacity in beams is found to be increasing with increase in layer of AFRP strip.
3. With increase in degree of damage, deflection at ultimate load is found to be decreasing by applying AFRP strip.
4. 0%, 70% and 80% damaged degree beams showed higher performance in terms of load carrying capacity, while 90% and 100% damage degree beams did not show appreciable increase in load carrying capacity.

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