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Finite Element Analysis of a Reinforced Concrete Beam by Retrofitting with Different Thermoplastic Polymer Composites using Ansys

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***Abstract*: The service life of Reinforced concrete structures is getting reduced day by day. This is due to deterioration of reinforced structural components such as beams, columns, walls, Floors etc. These components are getting damaged due to various factors such as massive loads, fires, earthquakes, errors in design, Chemical attack etc. These structural components can be strengthened by using retrofitting techniques. This paper deals with the finite element analysis of a RC beam retrofitted with different thermoplastic polymer composite sheets carried out using Ansys18.2 software. RC beams with different thermoplastic sheets were modelled using Ansys software. First RC beam was bonded with HDPE polymer sheet, second with Polypropylene polymer sheet and third with Nylon6 polymer sheet. Bonding at bottom, both sides and bottom+both sides were made. The performances of the above retrofitted beams are then compared with the reinforced beam and the results were presented in this paper.**

Keywords: Ansys 18.2 software, Thermoplastic polymer composite sheets, HDPE, Polypropylene, Nylon6, Retrofitting.

INTRODUCTION

Reinforced concrete (RC) structures damaged due to various reasons and in most of the cases damage occurred in the form of cracks, delamination, dusting, concrete spalling etc. Many of the existing lifeline structures were analysed, designed and detailed as per the recommendations of then prevalent codes. Such structures often do not qualify for current seismic requirements. Therefore, repair and restoration has become an important challenge for the reinforced concrete structures in recent years. Repair techniques should be suitable in terms of low cost. Polymer composites bonding technique is a structural strengthening technology in response to the urgent need for repair and strengthening of reinforced concrete structures. A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that when combined produce a material with characteristics different from the individual components. Typical engineered composite materials include reinforced plastics, ceramic composites, metal composites, composite building materials such as cements, concrete etc. The polymer matrix composites can be used to increase the fatigue resistance, durability, lifespan and flexural resistance.

Repairing RCC structures by externally bonded thermoplastic polymer composites consists sticking of polymer sheets at the tensile portion of the beam. The main aim of the retrofitting is to strengthen the damaged structures for the safety and protection of the structures. Therefore, the existing damaged structures be retrofitted to improve their performance and to avoid large scale damage to life and property.

This study focuses on a finite element modelling to simulate the behaviour of RC beams retrofitted with different Thermo plastic polymer composites.

RETROFITTING OF POLYMER SHEETS

Externally bonded thermoplastic sheets can be used for strengthening of RC members in flexure, shear. Here the following different wrapping systems of externally bonded thermoplastic sheets are used to improve the strength of RC beams: (a) bonding thermoplastic sheets to the bottom side of the beam; (b) bonding thermoplastic sheets on both sides of the beam and (c) bonding thermoplastic sheets to the bottom+both sides of the beam.

GEOMETRY

The geometry of the beam as reported by P. Polu Raju (2017) was used for this study. The control beam dimensions, and the reinforcement details are shown in fig.1.

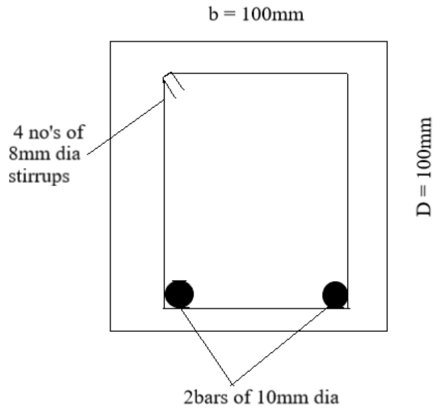

Fig.1: Reinforcement Details

ANSYS MODEL

The finite element analysis adopted by ANSYS Work Bench version 18.2 was used. Concrete was modelled using solid 65

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elements. Link 8- 3D spar element was used to model all the reinforcement details. Also, solid 45 were used to model the thermo plastic polymer sheets(fig.2). Table 1 shows the element types for working model.

Table 1
Element Types for Model

Material Type	Elements
Concrete	Solid65
Steel bars	Link180
Polymer sheets	Solid45

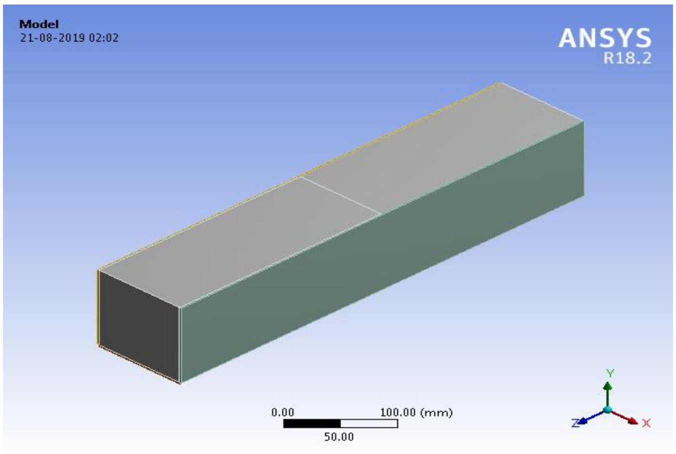

Fig. 2: Ansys Structural Model

Table 2
Description of specimen

Specifications	Details of RCC beam
Grade of Concrete	M30
Grade of Steel	Fe415
Dimensions of Beam	500mm×100mm×100mm
Area of Steel	10mm Ø bars (2)
Cover	20mm

MATERIAL PROPERTIES

1. *Concrete*

For concrete, ANSYS requires material properties as follows:

Elastic modulus (E_c)
Ultimate uniaxial compressive strength (f'_c)
Ultimate uniaxial tensile strength (modulus of rupture, f_{cr})
Poisson's ratio (μ)
Shear transfer coefficient (β_t)
Compressive uniaxial stress-strain relationship for concrete
The modulus of elasticity was based on the equation, $Ec = 5000\sqrt{f_{ck}}$
Where f_{ck} is the characteristic compressive strength of concrete.
Properties of concrete are shown in table3.

Table 3
Properties of concrete

Linear Isotropic	
Youngs Modulus, E_C	27117 Mpa
Poisson's Ratio, μ	0.2

Table 4
Concrete Material Data

Constant	Meaning	Value
1	Shear transfer coefficients for an open crack	0.3
2	Shear transfer coefficients for a closed crack	1
3	Uniaxial tensile cracking stress	3.83
4	Uniaxial crushing stress	22.4

The ANSYS program requires the uniaxial stress-strain relationship for concrete in compression. Values are shown in table5.

Table 5
Compressive uniaxial stress-strain values

Multilinear Isotropic	
Strain	**Stress Mpa**
0.000222	6.02
0.000275	7.414
0.0005	13.015
0.001	22.661
0.0012	25.275
0.0014	27.217
0.0016	28.569
0.0018	29.42
0.002	29.865
0.0035	30

2. *Steel*

Grade 415 steel reinforcing bars were used for the study. Linear isotropic and bilinear isotropic properties for the steel reinforcement used in this FEM study are given in table 6.

Table 6
Properties of Steel

Linear isotropic	
Youngs Modulus, E_C	$2*10^5$ Mpa
Poisson's Ratio, μ	0.3
Bilinear isotropic	
Yield Stress	420 Mpa
Tangent Modulus	20 Mpa

3. *Thermoplastic polymer composites*

Data needed for the thermoplastic polymer composites in the FEM analysis of this model are as follows.

- Thickness of the sheet.
- Density
- Elastic Modulus
- Poisson's Ratio

Table7
Properties of thermoplastic polymer sheets

Properties	HDPE	Polypropylene	Nylon6
Density, kg/m^3	950	910	1130
Elastic Modulus, E_C GPa	1.86	1.36	2.95
Poisson's Ratio, μ	0.45	0.42	0.3

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ANSYS SOLUTION

Point load at the centre and simply supported boundary conditions are assigned to the beam then the deformation shape and crack pattern are obtained from Ansys18.2 workbench as follows.

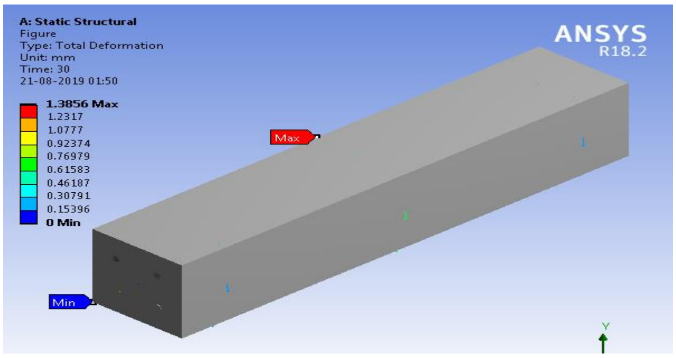

Fig.3: Deformation of RC beam

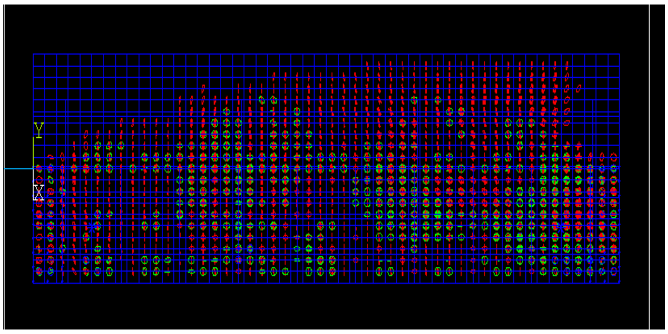

Fig.4: Crack pattern of RC beam

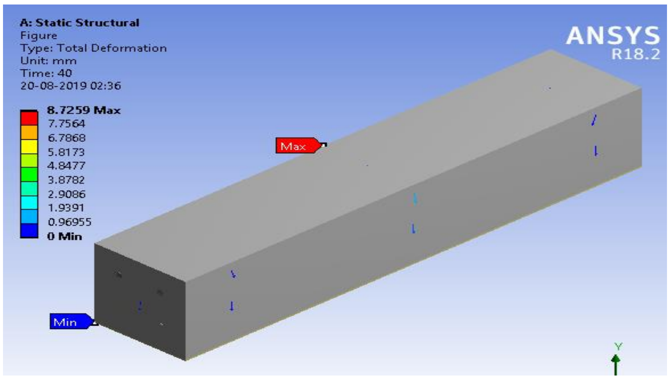

Fig.5: Deformation of RC beam bonded with HDPE sheet at bottom side

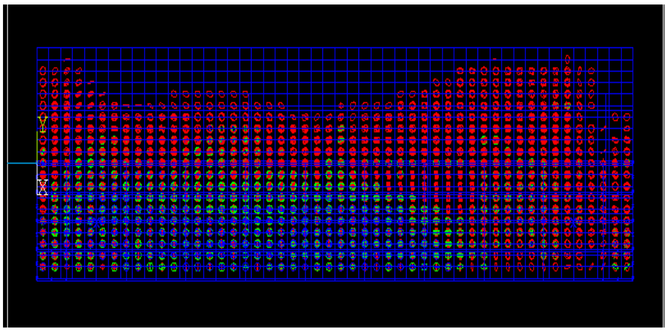

Fig.6: Crack pattern of RC beam bonded with HDPE sheet at bottom side

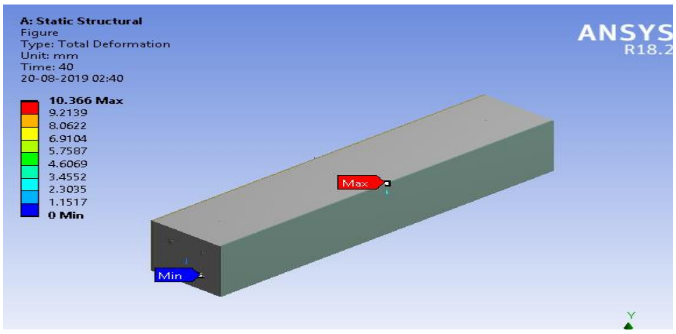

Fig.7: Deformation of RC beam bonded with HDPE Sheet at both sides

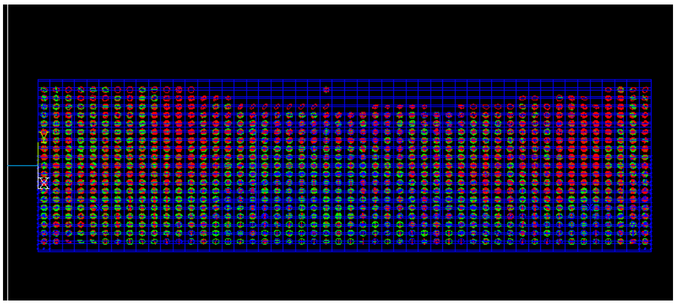

Fig.8: Crack pattern of RC beam bonded with HDPE Sheet at both sides

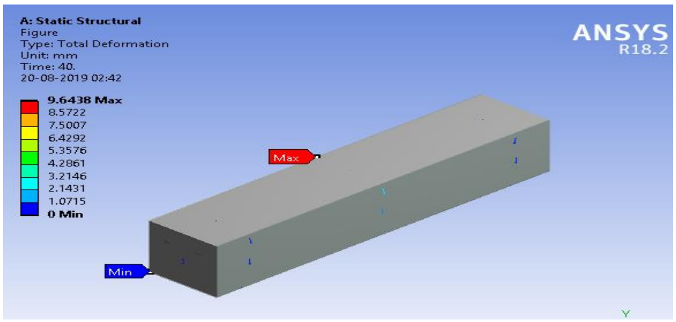

Fig.9: Deformation of RC beam bonded with HDPE Sheets at bottom + both sides

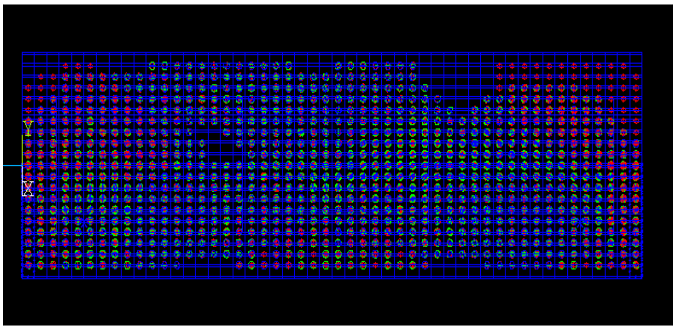

Fig.10: Crack pattern of RC beam bonded with HDPE at bottom+both sides

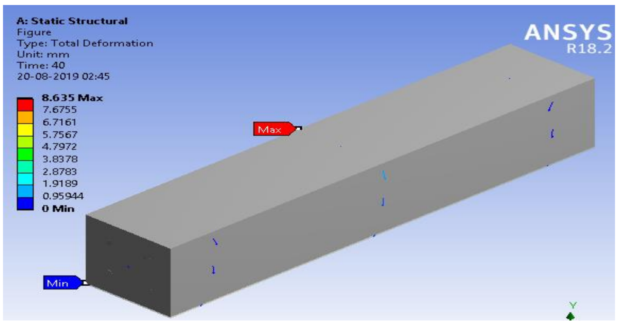

Fig.11: Deformation of RC beam bonded with Polypropylene sheet at bottom side

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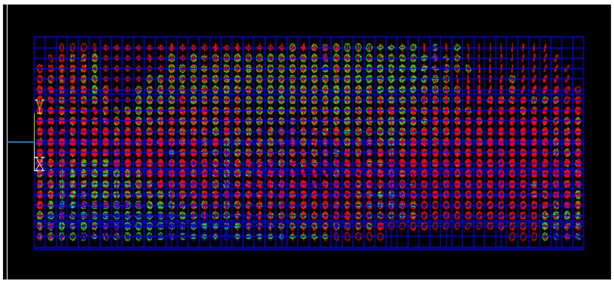

Fig.12: Crack pattern of RC beam bonded with Polypropylene sheet at bottom side

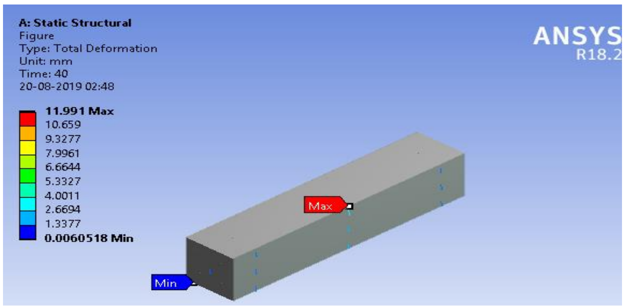

Fig.13: Deformation of RC beam bonded with Polypropylene sheet on both sides

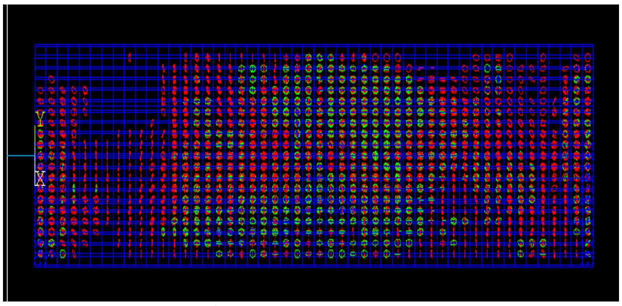

Fig.14: Crack pattern of RC beam bonded with Polypropylene sheet on both sides

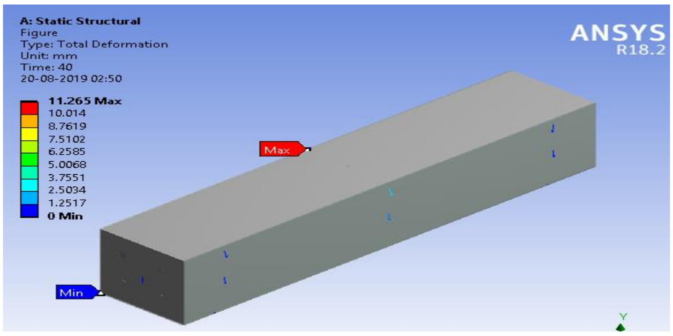

Fig.15: Deformation of RC Beam bonded with Polypropylene sheets on bottom side & both sides

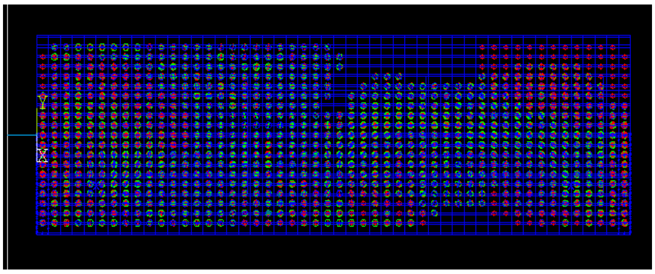

Fig.16: Crack pattern of RC Beam bonded with Polypropylene sheets on bottom side + both side

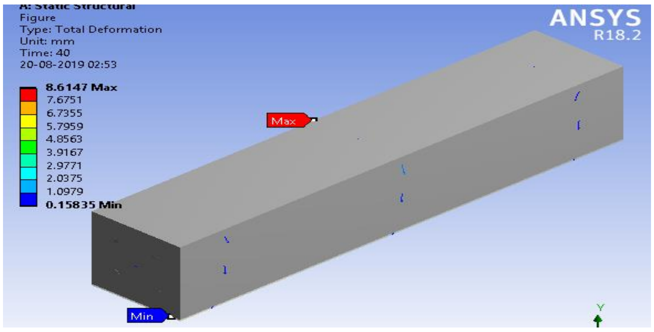

Fig.17: Deformation of RC Beam bonded with Nylon6 sheet on bottom side

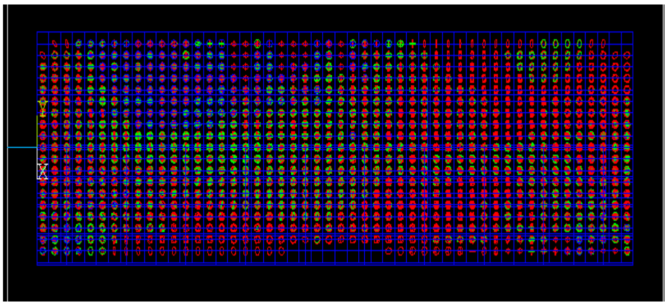

Fig.18: Crack pattern of RC Beam bonded with Nylon6 sheet on bottom side

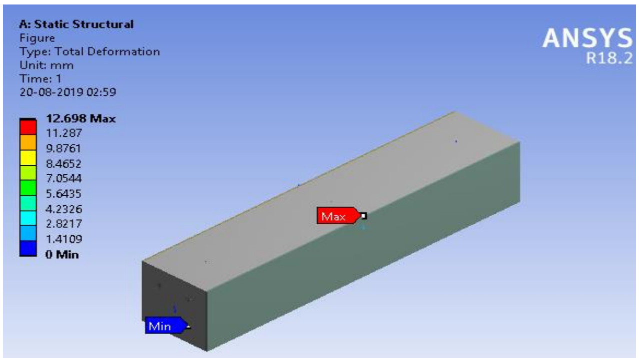

Fig.19: Deformation of RC Beam bonded with Nylon6 sheet on both sides

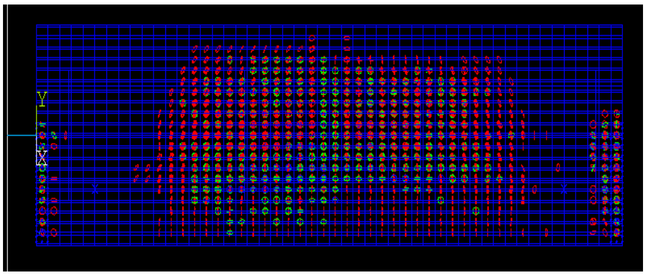

Fig.20: Crack pattern of RC Beam bonded with Nylon6 sheet on both sides

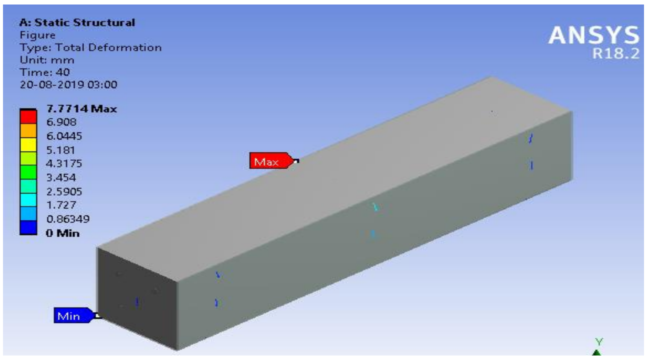

Fig.21: Deformation of RC Beam bonded with Nylon6 sheets on bottom side & both sides

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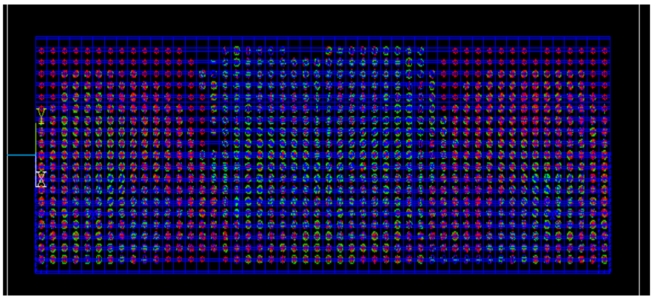


Fig.22: Crack pattern of RC Beam bonded with Nylon6 sheets on bottom side & both sides

RESULTS

Table 8 shows load and deflection at failure of control beam and beams with different combinations of thermoplastic polymer sheets.

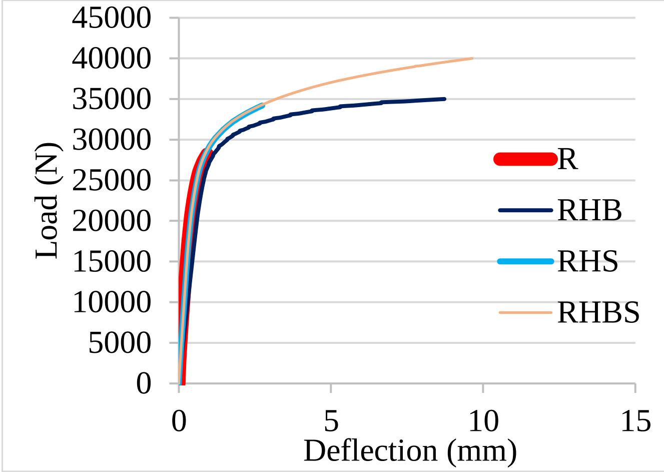
Table 8

Specimen	Plastic sheet thickness (mm)	Load at failure (kN)	Deflection at failure (mm)
Control Beam	0	28.2	0.93
HDPE sheet at bottom	2	35	8.79
HDPE sheet at both sides	2	34.2	2.73
HDPE sheet at bottom+ both sides	2	40	9.64
Polypropylene at bottom	2	30.7	1.66
Polypropylene at both sides	2	34.2	2.98
Polypropylene at bottom+ both sides	2	35	3.52
Nylon6 at bottom	2	31.1	1.9
Nylon6 at both sides	2	34.2	2.43
Nylon6 at bottom+ both sides	2	35.2	2.9

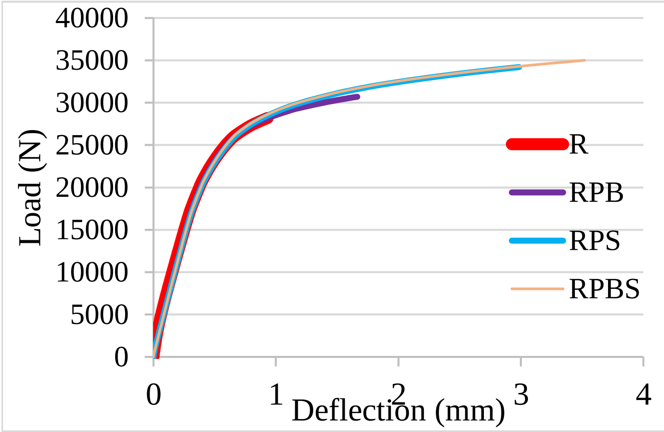
LOAD DEFLECTION GRAPHS

Reinforced concrete beam fails at 28.2 kN at a deflection of 0.93mm. RC beam fails at 26.2 kN when designed manually. So, the results we got in Ansys is nearly equal to the manual analysis. Load deflection curve is linear up to 3-10 kN. Within this load first cracking occur. The graph changes its nature after first cracking i.e. its slope is changed continuously. This is due to change in crack depth due to load increment.

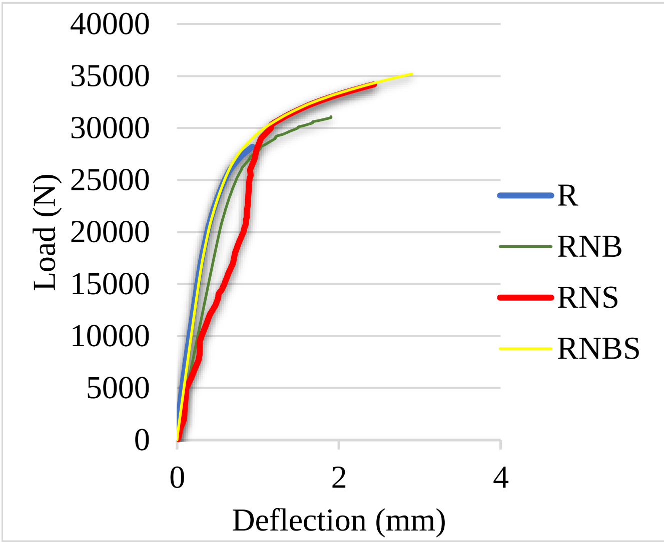
The load-deflection graphs for the beams from control beam to polymer retrofitted beams are plotted as follows



Graph1: load deflection graph of RC beam comparing with HDPE sheet bonded at bottom, sides, bottom+both sides.



Graph2: load deflection graph of RC beam comparing with Polypropylene sheet bonded at bottom, sides, bottom+both sides.



Graph3: load deflection graph of RC beam comparing with Nylon6 sheet bonded at bottom, sides, bottom+both sides.

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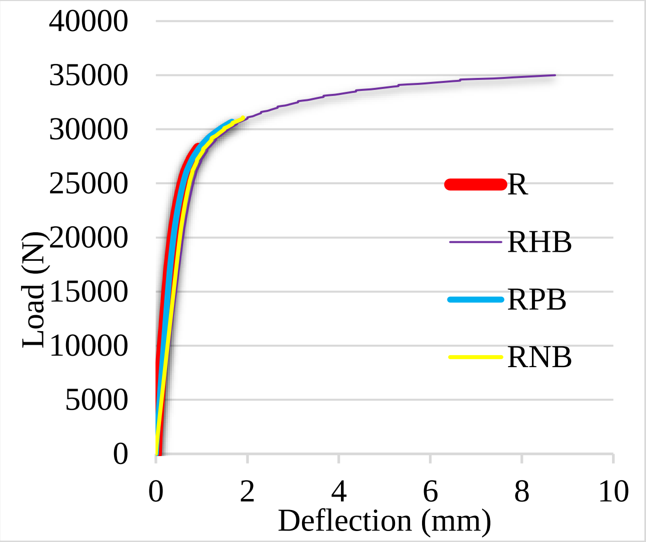
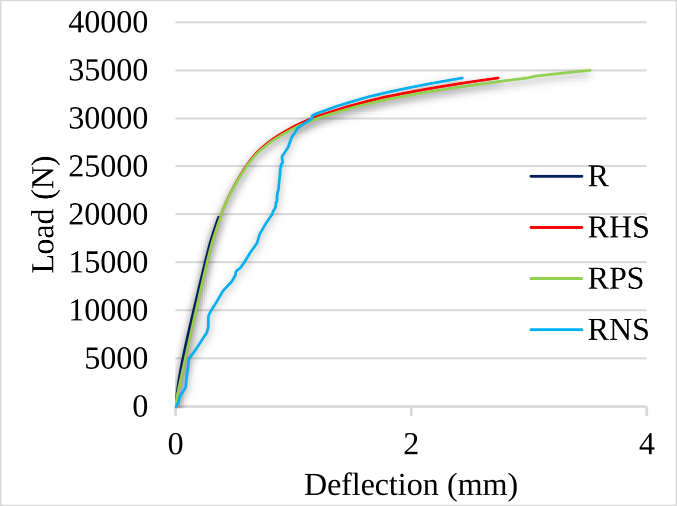
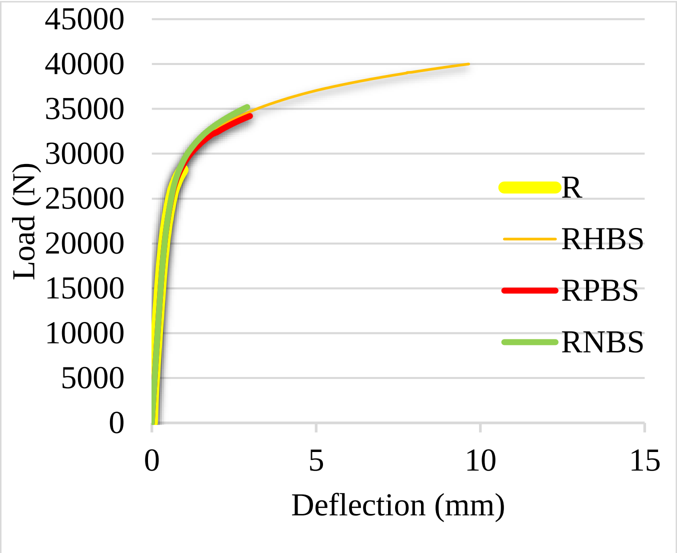


Graph4: load deflection graph of RC beam comparing with HDPE, Polypropylene, Nylon6 sheets bonded at bottom.



Graph5: load deflection graph of RC beam comparing with HDPE, Polypropylene, Nylon6 sheets bonded at both sides.



Graph6: load deflection graph of RC beam comparing with HDPE, Polypropylene, Nylon6 sheets bonded at bottom+both sides.

CONCLUSIONS

The main objective of the project is to study the effect of HDPE, PP, NYLON6 sheets on retrofitting and to find out the best wrapping technique among the nine models. Also, to study the performance of the beam when Polymer sheets provide in layers

From the results of the present study, the following conclusions were made:

1. RC beam retrofitted with thermoplastic sheet has more load carrying capacity than control beam.
2. When RC beam bonded with HDPE sheet at bottom the load carrying capacity is increased by 24.11%.
3. When RC beam bonded with HDPE sheet along both sides the load carrying capacity is increased by 21.27%.
4. When RC beam bonded with HDPE sheet at bottom + both sides the load carrying capacity is increased by 41.8%.
5. When bonded with Polypropylene sheet at bottom load carrying capacity is increased by 8.86%.
6. When bonded with Polypropylene sheet at both sides load carrying capacity is increased by 21.27%.
7. When bonded with Polypropylene sheet at bottom + both sides load carrying capacity is increased by 24.11%.
8. When RC beam bonded with Nylon6 sheet at bottom the load carrying capacity is increased by 10.28%.
9. When RC beam bonded with Nylon6 sheet at both sides the load carrying capacity is increased by 21.27%.
10. When RC beam bonded with Nylon6 sheet at bottom + both sides the load carrying capacity is increased by 24.82%.
11. HDPE sheet when bonded at bottom + both sides have taken more load when compared to Polypropylene and Nylon6 sheets.
12. HDPE sheet when bonded at bottom have more load carrying capacity when compared to Polypropylene and Nylon6 sheets.
13. It can be concluded that the strength of RC beam is increased by retrofitting with thermoplastic polymer sheets.

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