International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Strengthening of RC Beam Using Wire Mesh–Epoxy Composite

Anju Mary Ealias[1], Binu P[2]

[1]PG Student, Sree Narayana Gurukulam College of Engineering, Kadayiruppu, Kerala, India

[2]Associate Professor, Sree Narayana Gurukulam College of Engineering, Kadayiruppu, Kerala, India

Abstract: ***Repair and strengthening of RC beam is now becoming more and more important in the field of structural strengthening. In this thesis work, investigate the flexural behaviour of reinforced concrete beams strengthened with a new type of strengthening material, namely wire mesh-epoxy composite. An analytical study conduct using ANSYS 16.2 on plain concrete beam is externally bonded with wire mesh–epoxy composite using different layers of wire mesh and different size of wire mesh. The flexural performance of the beam specimens bonded with wire mesh layers will compare with the beam specimens bonded with fibre reinforced polymer (FRP) sheet. The mid-span deflection, crack pattern and load deflection behaviour of the tested beams will record and compare.***

Keywords: Wire mesh, Epoxy, FRP, Flexural, RC Beam

1. Introduction

The infrastructure development is an inevitable component of industrial growth as it provide good service and comfort to the user and need of strengthening and retrofitting to bring back to originally intended position is significant.. Deterioration of concrete structures is one of the major problems of the construction industry today.. Now a days modern techniques are evolved and applied for effective strengthening and retrofitting methods.

The aim of this thesis is to study the behaviour of large-scale RC beams strengthened using the wire mesh-epoxy composite. The development of the wire mesh-epoxy composite requires a clear understanding of the behaviour of strengthened RC beams at different loading stages. The type of strengthening material significantly affects the behaviour of the strengthened beam. Therefore, the work focus to investigate the effectiveness of the wire mesh-epoxy composite for strengthening RC structural elements, which helps for further development and making it more practically acceptable. The effect of wire mesh-epoxy composite on load carrying capacity and cracking behaviour is investigate and compared with the glass fibre reinforced polymer (GFRP) and hybrid wire mesh-epoxy-glass fibre composite.

Wire meshes are used commonly with concrete shown in fig 1. Fabric is quick and easy to lay, and once in position is not readily displaced by workmen when laying the concrete, as in often the case when rods are used. Mesh stays wherever put and has excellent adherence to concrete, also reduces reinforcement consumption thereby economy can also be achieved.

2. Literature Review

[1]S. S. Mohite, Dr. M. M. Awati and R. A. Patil(2014) conducted study on flexural behaviour of R.C. beams with side bonded G.F.R.P. laminates. They found that the load carrying capacity for the M20 grade concrete beams is increased by 50 % after strengthened with full U wrapping of GFRP compared with the reference beam.

[2]Ismail M.I., Qeshta, PayamShafigh and MohdZamin Jumaat (2015) reviewed flexural behaviour of RC beams strengthened with wire mesh-epoxy composite. They concluded as the wire mesh-epoxy composite significantly enhanced the yield strength of beam specimens. An increase of yield load of up to 47% over the control specimen was achieved.

[3]Ismail M.I. Qeshta, Payam Shafigh, Mohd Zamin Jumaat, Aziz Ibrahim Abdulla, Zainah Ibrahim and Ubagaram Johnson Alengaram (2014) carried out work on the use of wire mesh–epoxy composite for enhancing the flexural performance of concrete beams. The use of wire mesh–epoxy composite constitutes a new technique to significantly enhance the performance of concrete in flexure. All specimens bonded with wire mesh exhibited an increase in first crack load. This increase is associated with the increase in the number of wire mesh layers.

3. Scope

Structural rehabilitation and strengthening have recently gained considerable attention in the civil engineering field. Reinforced concrete (RC) structures need to be upgraded to meet current design requirements and overcome the problems of deterioration. For this purpose, steel plates bonded to the soffits of beams using epoxy were initially adopted. The use of steel plates was later found to have some long-term problems (e.g. corrosion) and difficulties in handling long plates on site. These problems initiated the idea of using an alternative material that has a large strength to weight ratio and good durability properties. The use of fibre reinforced polymer (FRP) materials and wire mesh-epoxy composites for flexural strengthening have gained widespread popularity in the structural retrofitting of RC structures.

4. Objectives

- To conduct a FE analysis using ANSYS to strengthen the flexural behavior of RC beams.
- To study the effectiveness of wire mesh- epoxy composite to increase the flexural strength of RC beams.
- To compare the performance of wire mesh- epoxy composite with GFRP sheet- epoxy composite in terms of flexural behavior of RC beams.

5. Methodology

a) Literature survey.
b) Adopting a suitable geometry as per the requirements.
c) Modeling of the RC beam using ANSYS 16.2-workbench
- RC beam without any strengthening material.
- RC beam with wire mesh-epoxy composite.

d) Use different sizes of wire mesh
e) Use different layers of wire mesh
f) RC beam with GFRP sheet-epoxy composite.
- Comparative study of strengthened beams.
- Interpretation of results.

6. Finite Element Analysis

6.1 General

Finite element analysis of beams strengthened with wire mesh epoxy composite was done using the software ANSYS 16.2 workbench. The analysis was carried out to find the ultimate load, maximum deflection, first crack point, crack pattern, load – deflection curve etc.

6.2 Geometry of Beam Specimens

Length of the beam = 1000 mm
Width of the beam = 150 mm
Depth of the beam = 200 mm

The support condition provided for beam is roller supports on both sides which is on 130 mm from edges of beam. The force applied on the top mid-span of the beam. The material of the beam is concrete and reinforcement inside it is structural steel. Properties of concrete and structural steel input as which is used for experimental study (Appendix A). Use solid-65 for getting the crack pattern in Ansys Workbench. Analyse the beam as static structure. The loading conditions and the total deformation corresponding to 90 kN is used to compare with experimental study.

6.3 Control Beam

Control beam is used to compare the results with the beam having strengthening materials. The loading and support conditions for strengthened beams are being kept same as the control specimen.

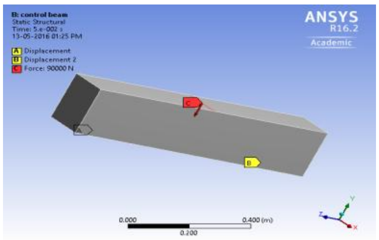

Figure 8: Loading Diagram of Control Beam

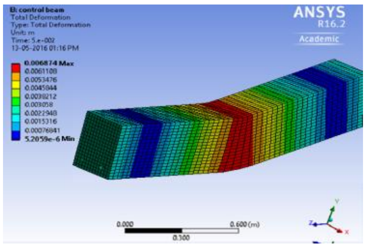

Figure 9: Total Deformation Diagram of Control Beam

Total Deformation corresponding to 90 kN = 6.87 mm

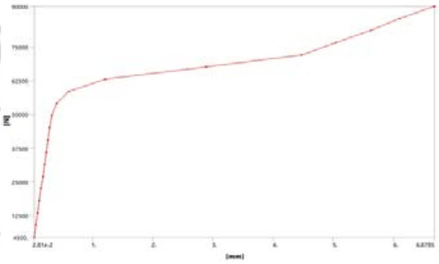

Figure 10: Load-Deformation Diagram of Control Beam

Ultimate load of control beam = 90 kN

Deformation corresponding to ultimate load =6.87 mm

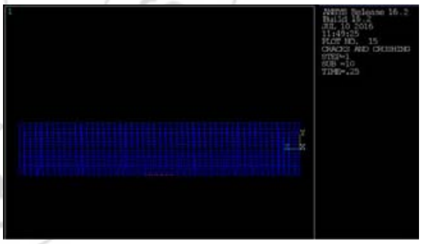

Figure 11: First Crack Point of Control Beam

Time for first crack on control beam = 0.025
The load corresponding to first crack = 0.025 X 9 = 22.5 kN

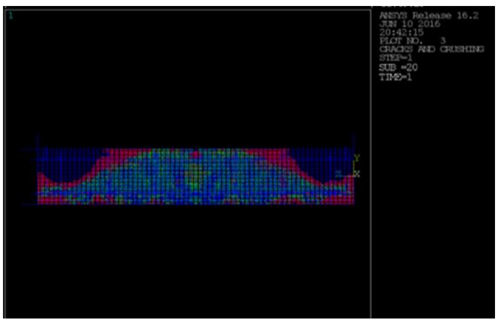

Figure 12: Crack Pattern of Control Beam

6.4 Beam Strengthened With Wiremesh Epoxy Composite

For the beam with wire mesh epoxy composite, the support condition and loading conditions are same as control beam. The only difference is the wire mesh epoxy composite is provided on the bottom phase of the beam. For numerical analysis the epoxy is given as a thin layer having 1 mm thick. Wiremesh is provided as a single wire on longitudinal and transverse direction with its original diameter, then it pattern into proper dimension. Boolean operation is used to make it as a single unit. Then the epoxy layer and wiremesh bonded into the concrete beam. The properties of wire mesh and epoxy resin is given below which is used for experimental study.

Table 3: Properties of Wire Mesh

Material Property	*Values*
Density	8.0 g/cm^3
Poison's ratio	0.3
Tensile Strength	620.5 Mpa
Yield Strength	275.8 Mpa
Modulus of Rigidity	70.3 Mpa
Modulus of Elasticity	187.5 MPa

Table 4: Properties of Epoxy Resin & Hardener

Property	*Araldite AW 106*	*Hardener HV 953*	*Mix*
Viscosity at 25^{0}C (pas)	30 - 50	20 - 35	30 - 45
Specific Gravity (gm/cc)	1.15	0.95	1.05
Colour (visual)	neutral	Brownish yellow	Pale yellow
Life (min)	-	-	100

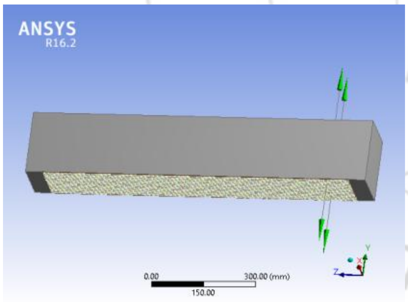

Figure 13: Geometry of Beam with Wiremesh Epoxy Composite

6.4.1 Beam Strengthened With 1 Layer 3 mm Wiremesh - Epoxy Composite

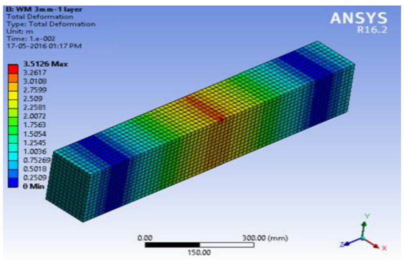

Figure 14: Total Deformation Diagram of Beam with 1 Layer 3mm WireMesh

Total Deformation corresponding to 90 kN = 3.51 mm

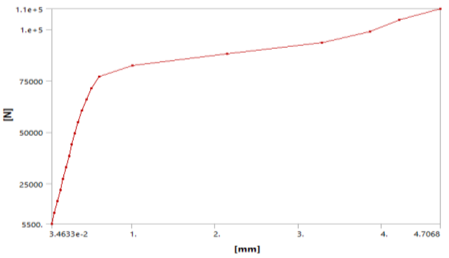

Figure 15: Load-Deformation Diagram of Beam with 1 Layer 3mm WireMesh

Ultimate load of beam with 1 layer 3 mm wiremesh= 110 k

Deformation corresponding to ultimate load =4.70 mm

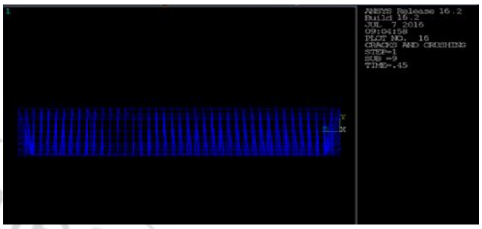

Figure 16: First Crack Point of Beam with 1 Layer 3 mm WireMesh

Time for first crack on beam with 1 layer 3 mm wiremesh = 0.45

The load corresponding to first crack = 0.45 X 110 = 49.5 kN

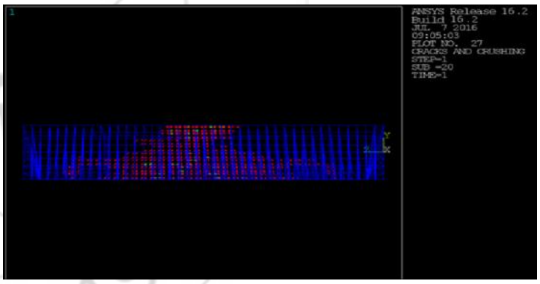

Figure 17: Crack Pattern of Beam with 1 Layer 3 mm WireMesh

6.4.2 Beam Strengthened With 1 Layer 4 mm Wiremesh - Epoxy Composite

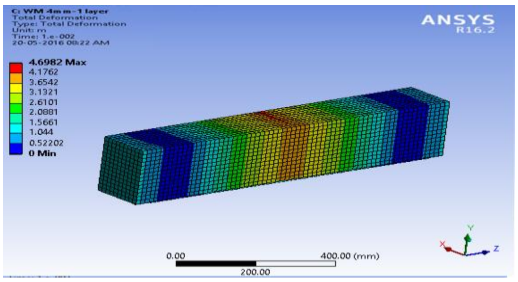

Figure 18: Total Deformation Diagram of Beam with 1 Layer 4mm WireMesh

Total Deformation corresponding to 90 kN = 4.69 mm

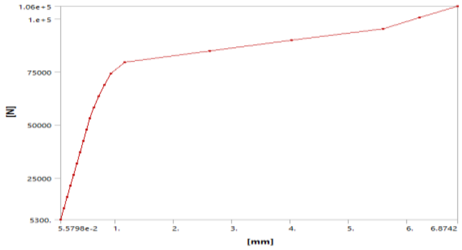

Figure 19: Load-Deformation Diagram of Beam with 1 Layer 4mm WireMesh

Ultimate load of beam with 1 layer 4 mm wiremesh = 106 k

Deformation corresponding to ultimate load = 6.87 mm

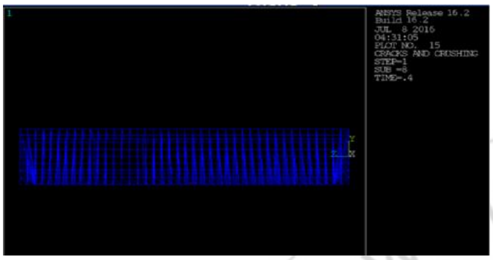

Figure 20: First Crack Point of Beam with 1 Layer 4 mm WireMesh

Time for first crack on beam with 1 layer 4 mm wiremesh = 0.4

The load corresponding to first crack = 0.4 X 106 = 42.4 kN

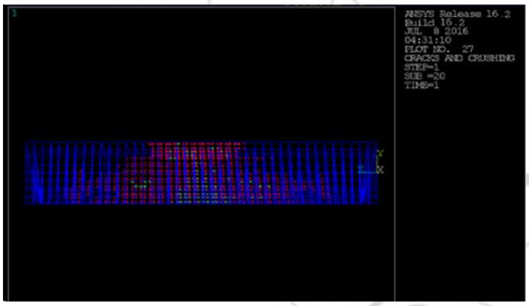

Figure 21: Crack Pattern of Beam with 1 Layer 4 mm WireMesh

6.4.3 Beam Strengthened With 1 Layer 5 mm Wiremesh - Epoxy Composite

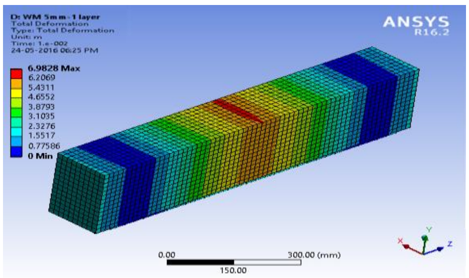

Figure 22: Total Deformation Diagram of Beam with 1 Layer 5mm WireMesh

Total Deformation corresponding to 90 kN = 6.98 mm

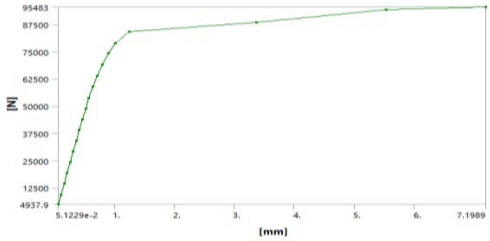

Figure 23: Load-Deformation Diagram of Beam with 1 Layer 5mm WireMesh

Ultimate load of beam with 1 layer 5 mm wiremesh = 95.48 k
Deformation corresponding to ultimate load = 7.19 mm

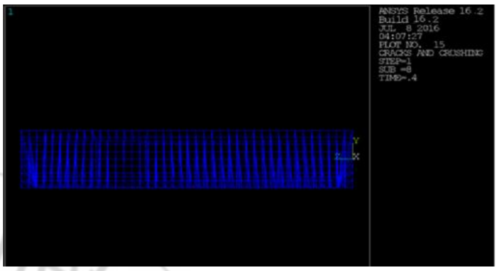

Figure 24: First Crack Point of Beam with 1 Layer 5 mm WireMesh

Time for first crack on beam with 1 layer 5 mm wiremesh = 0.4
The load corresponding to first crack = 0.4 X 95.48= 38.19 kN

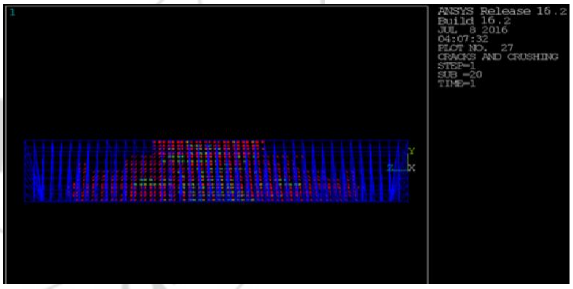

Figure 25: Crack Pattern of Beam with 1 Layer 5 mm WireMesh

6.4.4 Beam Strengthened With 2 Layer 4 mm Wiremesh - Epoxy Composite

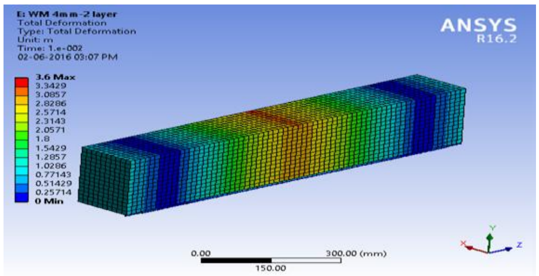

Figure 26: Total Deformation Diagram of Beam with 2 Layer 4mm WireMesh

Total Deformation corresponding to 90 kN = 3.60 mm

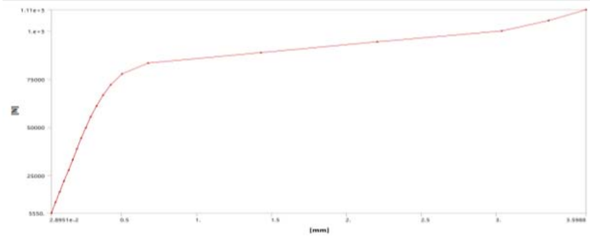

Figure 27: Load-Deformation Diagram of Beam with 2 Layer 4mm WireMesh

Ultimate load of beam with 2 layer 4 mm wiremesh = 111.0 k
Deformation corresponding to ultimate load = 3.59 mm

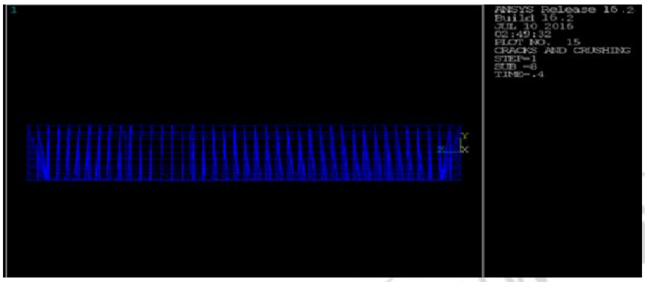

Figure 28: First Crack Point of Beam with 2 Layer 4 mm WireMesh

Time for first crack on beam with 2 layer 4 mm wiremesh = 0.4
The load corresponding to first crack = 0.4 X 111 = 44.4 kN

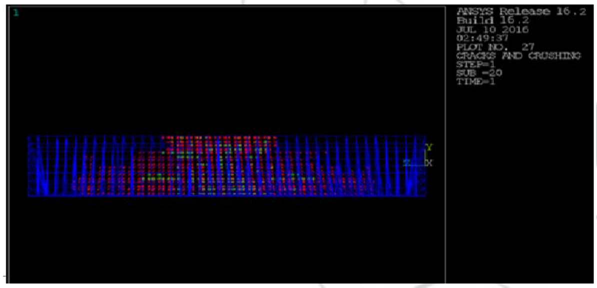

Figure 29: Crack Pattern of Beam with 2 Layer 4 mm WireMesh

6.4.5 Beam Strengthened With 3 Layer 4 mm Wiremesh - Epoxy Composite

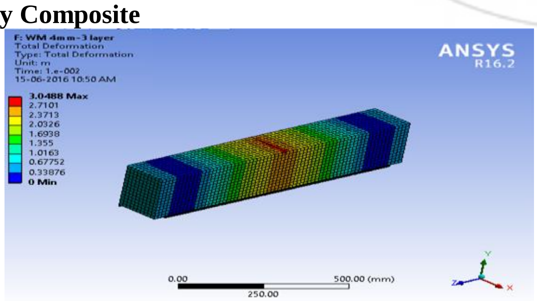

Figure 30: Total Deformation Diagram of Beam with 3 Layer 4mm WireMesh

Total Deformation corresponding to 90 kN = 3.04 mm

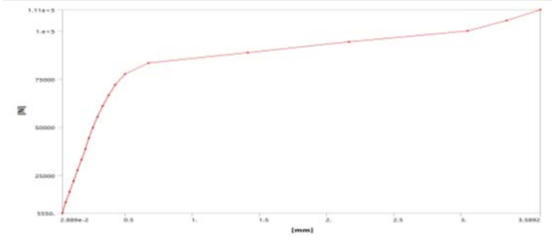

Figure 31: Load-Deformation Diagram of Beam with 3 Layer 4mm WireMesh

Ultimate load of beam with 3 layer 4 mm wiremesh= 111.0 k
Deformation corresponding to ultimate load = 3.58 mm

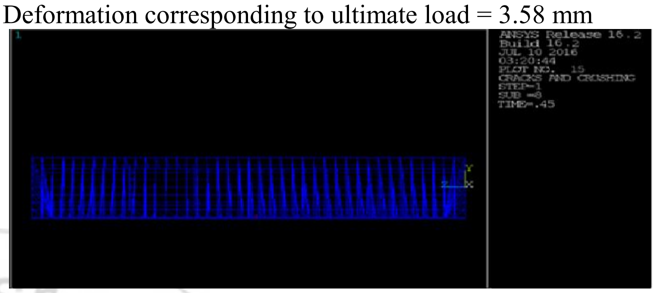

Figure 32: First Crack Point of Beam with 3 Layer 4 mm WireMesh

Time for first crack on beam with 3 layer 4 mm wiremesh = 0.45
The load corresponding to first crack = 0.45 X 111= 49.95 kN

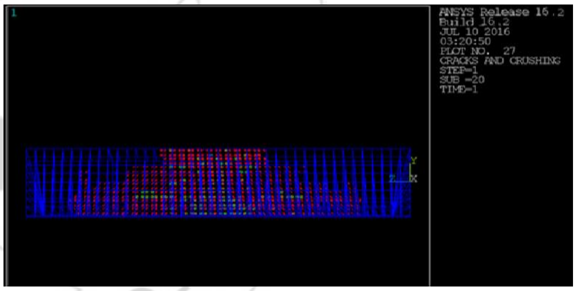

Figure 33: Crack Pattern of Beam with 3 Layer 4 mm WireMesh

6.5 Beam Strengthened With Frp Epoxy Composite

For the beam with GFRP epoxy composite, the support condition and loading conditions are same as control beam. Provide a layer of FRP on soffit of the beam with a layer of epoxy. Material properties of GFRP given below.

Table 5: Properties of GFRP

Material Property	*Values*
Density	1.45 g/cm^3
Poison's ratio	0.46
Tensile Strength	786.4 Mpa
Yield Strength	350.5 Mpa
Modulus of Rigidity	132.8 Mpa
Modulus of Elasticity	205.7 MPa

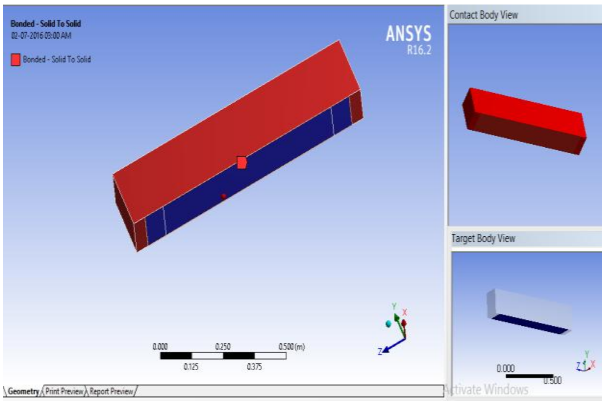

Figure 34: Bonding Between Beam and FRP

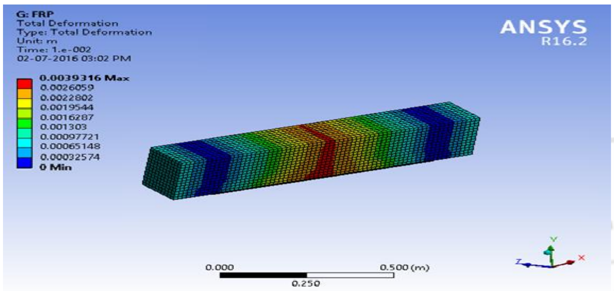

Figure 35: Total Deformation Diagram of Beam with FRP

Total Deformation corresponding to 90 kN = 3.93 mm

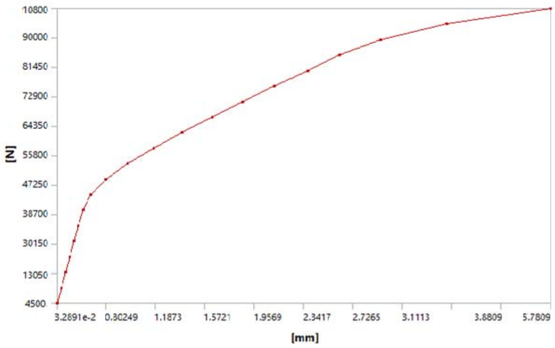

Figure 36: Load-Deformation Diagram of Beam with FRP

Ultimate load of beam with FRP = 108.0 kN

Deformation corresponding to ultimate load=5.78 mm

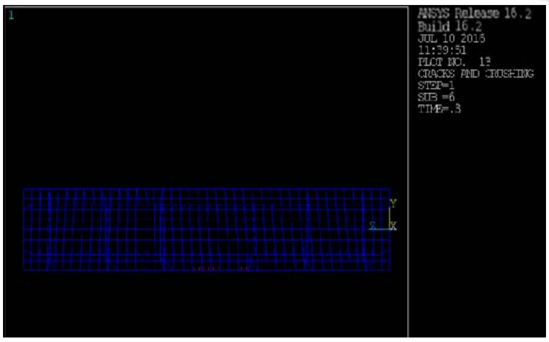

Figure 37: First Crack Point of Beam with FRP

Time for first crack on beam with FRP = 0.30

The load corresponding to first crack = 0.30 X 108 = 32.4 kN

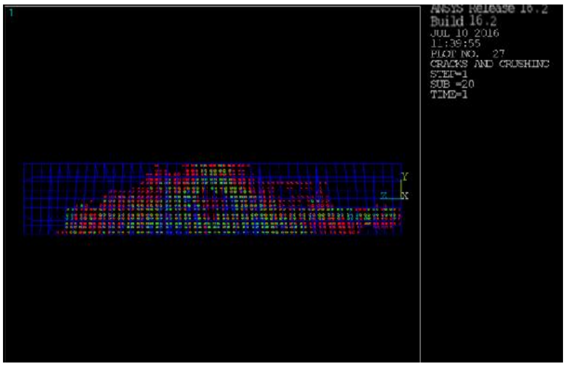

Figure 38: Crack Pattern of Beam with FRP

6.6 Results from Numerical Analysis

The results observed from numerical analysis is given below

Table 6: Results from Numerical Analysis

Type	Deflection at 90 kN (mm)	Ultimate load (kN)	Deflection at ultimate load (mm)	First crack load (kN)
Control beam	6.87	90	6.87	22.5
1 layer 3mm WM	3.51	110	4.70	49.5
1 layer 4mm WM	4.69	106	6.87	42.4
1 layer 5mm WM	6.98	95.4	7.19	38.1
2 layer 4mm WM	3.60	111	3.59	44.4
3 layer 4mm WM	3.04	111	3.58	49.9
GFRP	3.93	108	5.78	32.4

Table 7: Flexural Strength of Beam from Numerical Analysis results

Type	Flexural strength (N/mm^2)
Control beam	16.65
3 mm WM- 1 Layer	20.35
4 mm WM- 1 Layer	19.96
5 mm WM- 1 Layer	17.66
4 mm WM- 2 Layer	20.53
4 mm WM- 3 Layer	20.53
GFRP	19.98

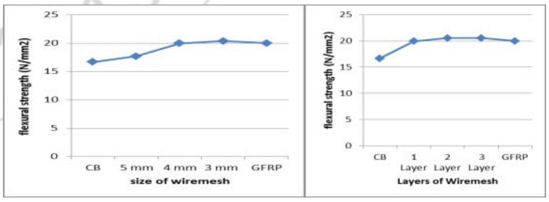

Figure 39: Flexural Strength of Beam from Numerical Analysis results

The deflection of beam strengthened with wire mesh epoxy composite is found to be reduced as compared with control beam. The ultimate load and first crack load were improved in all cases irrespective of layers and spacing of wire mesh. And the flexural strength improves by the usage of wire mesh epoxy composite.

7. Conclusions

In this study, the beam strengthened with wiremesh epoxy composite is compared with control specimen and beam with GFRP. The beams with different layers of wiremesh and spacing of wiremesh were analysed. Total deformation, load-deflection curve, ultimate load, first crack load and crack patterns of each case was observed.

Based on results from numerical study for the beams strengthened in flexure with wire mesh, the following conclusions are drawn:

- The flexural strength of beam strengthened with wire mesh epoxy composite is increased when compared with control beam.
- The flexural strength found to be increasing when the spacing of wire mesh reduces and the numbers of layers of wire mesh increases.
- The ultimate load of strengthened beam increases with decreasing the spacing of wire mesh and increasing the number of layers of wire mesh.
- The first crack load increases with decreasing the spacing of wire mesh and increasing the number of layers of wire mesh. But the more significant increase identified when the number of layers increases.
- The deflection, ultimate load and first crack load of beam strengthened with GFRP are approximately equal to that of the beam strengthened with wire mesh epoxy composite, so wire mesh can be accepted as strengthening material for structural members.

It can be concluded that even though both methods (1 layer 3mm wiremesh and 3 layer 4mm wiremesh) enhances flexural strength, decreasing size of wiremesh is found to be more economical than increasing layers of wiremesh and the later consumes more epoxy which is not cost effective.

References

[1] S. S. Mohite, Dr. M. M. Awati and R. A. Patil ,"Flexural Behaviour of R.C. Beams With Side Bonded G.F.R.P. Laminates", *International Journal of Emerging Technology And Advanced Engineering*, Volume 4, Issue 8, August 2014.

[2] Ismail M.I., Qeshta, PayamShafigh and MohdZaminJumaat, "Flexural Behaviour of RC Beams Strengthened With Wire Mesh-Epoxy Composite", *Construction and Building Materials*- 79 ,Pp: 104–114, January 2015.

[3] Ismail M.I. Qeshta, PayamShafigh, MohdZaminJumaat, Aziz Ibrahim Abdulla, Zainah Ibrahim and Ubagaram Johnson Alengaram, "The Use of Wire Mesh–Epoxy Composite For Enhancing The Flexural Performance Of Concrete Beams", *Materials and Design*- 60, Pp: 250–259, April 2014.

[4] Maher A. Adam, Mohamed Said, Ahmed A. Mahmoud and Ali S. Shanour, "Analytical And Experimental Flexural Behaviour of Concrete Beams Reinforced With Glass Fiber Reinforced Polymers Bars", *Construction and Building Materials*- 84, Pp: 354–366, March 2015.

[5] J.A.O. Barros, S.J.E. Dias & J.L.T. Lima, "Analytical And Numerical Analysis of The Behaviour of RC Beams Flexural Strengthened With CFRP", *Fourth International Conference on FRP Composites in Civil Engineering*, Pp:22-24, July 2008.

Author Profile

Anju Mary Ealias received B.Tech in civil engineering under CUSAT University and M.Tech in structural engineering & construction management from MG University.

Binu P, Associate Professor, Sree Narayana Gurukulam College of Engineering, Kadayiruppu, Kerala. She received B.Tech degree in Civil Engg from N.S.S.College of Engineering Palghat, and M.Tech (Computer Aided Structural analysis and Design) from CUSAT and currently pursuing Ph D at CUSAT. She has published book on Basics of Civil Engineering bearing ISBN No. 978-93-5254-842-2. She is a member of ISTE & ICI.