ISSN: 0974-5823 Vol. 7 No. 3 March, 2022

International Journal of Mechanical Engineering

Carbon Fabric Reinforced Cementitious Matrix for Flexural Strengthening of Reinforced Concrete Beams

Lekshmi Priya A N[1] & Harshana S[2]

[1]Assistant Professor, Department of Civil Engineering, Younus College of Engineering and Technology, Vadakkevila P.O., Kollam, Kerala.

[2]M.Tech Student, Department of Civil Engineering, Younus College of Engineering and Technology, Vadakkevila P.O., Kollam, Kerala.

Abstract: Due to several limitations on the use of Fiber Reinforced Polymers (FRP) on retrofitting structural members leaded to the implementation of Fabric Reinforced Cementitious Matrix (FRCM) on structural members for retrofitting. This FRCM consist of a grid or fiber mesh which is embedded in a cementitious bonding material. In this study the conventional Finite Element Method using ANSYS is used to study the static behavior of Reinforced Concrete beams strengthened with Carbon Fabric Reinforced Cementitious Matrix. A comparative study is conducted by providing fully U-wrapped Carbon Fabric Reinforced Cementitious Matrix on Reinforced Concrete beam and also by providing U-wrap strips of Carbon FRCM of varying width on Reinforced Concrete beams. It was observed that highest load carrying capacity is obtained for reinforced concrete beam strengthened with fully U-wrapped Carbon FRCM, whereas the least load carrying capacity is obtained for RC beams strengthened with 50mm wide U-wrap strips of Carbon FRCM. This proves that it is efficient to use Carbon Fabric Reinforced Cementitious Matrix as a strengthening technique in Reinforced Concrete beams, also, the most efficient scheme of Carbon Fabric Reinforced Cementitious Matrix wrapping on Reinforced Concrete beams is by providing full U-wrap.

Keywords: Fabric Reinforced Cementitious Matrix, Fiber Reinforced Polymer, ANSYS.

1. Introduction

Over the last few decades, Fiber Reinforced Polymer (FRP) composites have been successfully used for the upgradation and repairing of deficient structural members. Apart from several advantages of FRP such as light weight, corrosion resistance, ease of application, etc FRP loses its bond connection to the concrete surface by the exposure of adhesive such as epoxy resin when exposed to higher levels of temperature. As a consequence, a new set of materials were developed for the strengthening of deficient of structural members. These materials were formerly known as Textile Reinforced Mortar (TRM) and later came to known as Fabric Reinforced Cementitious Matrix. These composites consist of two components namely reinforcement mesh and a bonding agent. Reinforcement mesh can be made of different type of materials such as polyparaphenylene-benzobisoxazole (PBO), carbon, Aramid, or glass whereas the bonding agent can be a cement-based mortar.

The focus of the present work is to apply Carbon FRCM composites for the improvisation and extension of life span of Reinforced Concrete beams from different structural aspects. A numerical investigation was conducted to validate the use of Carbon FRCM composite in addressing its serviceability and ultimate loading state.

1.1. Carbon Fiber Fabric

The fibers are extremely stiff, strong, and light, and they are used in many activities to create excellent building materials. Carbon fiber material are available as raw building blocks, including yarns, uni-directional, weaves, braids, and several others, which are successively used to create composite parts.

The properties of a carbon fiber part are near to that of steel and the weight is near to that of plastic. Thus, the strength to weight ratio (as well as stiffness to weight ratio) of a carbon fiber part is much higher than either steel or plastic. Several advantages of carbon fibers are high tensile strength, flexibility, corrosion resistance, light weight, low coefficient of thermal expansion, low thermal conductivity, exceptional durability, dampens sound etc. Apart from the advantages there are also certain disadvantages such as high cost, time consuming manufacture, fragile.

2. Objectives

The objectives of the present study are:

(1) To study the efficacy of Reinforced Concrete beams strengthened with Carbon Fabric Reinforced Cementitious Matrix. (2) To compare the behavior of Reinforced Concrete beams strengthened in flexure with fully U-wrapped Carbon Fabric Reinforced Cementitious Matrix and with U-wrap strips of Carbon Fabric Reinforced Cementitious Matrix at varying width. (3) To find out the most efficient scheme of Carbon Fabric Reinforced Cementitious Matrix wrapping.

3. Non-Linear Static Finite Element Analysis

Numerical analysis of Reinforced Concrete beams was conducted by providing Carbon Fabric Reinforced Cementitious Matrix in different schemes.

3.1. Analysis of fully U-wrapped Carbon FRCM

A numerical analysis of reinforced concrete beam strengthened with fully U-wrapped Carbon Fabric Reinforced Cementitious Matrix was conducted by using ANSYS Workbench 18.1. The analysis included modelling of specimen in ANSYS workbench 18.1, followed by meshing and then analyzing.

From the analysis of Reinforced Concrete beams strengthened with fully U-wrapped Carbon Fabric Reinforced Cementitious Matrix, Ultimate load carrying capacity obtained as 198.12kN and corresponding deformation obtained is 55.316 mm. The maximum load at which the specimen fails is obtained as 197.680kN and corresponding deformation is 57.816mm.

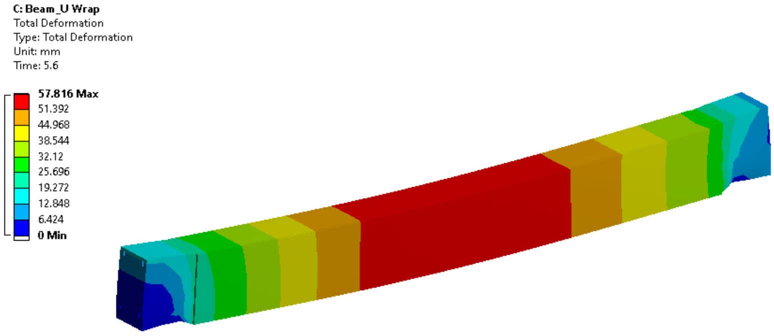

Fig.1. Deformation of fully U-wrapped Carbon FRCM beam

3.2. Analysis of Carbon FRCM beam with 50mm wide strips

A numerical analysis of reinforced concrete beam strengthened with 50mm wide U-wrap strips of Carbon Fabric Reinforced Cementitious Matrix was conducted by using ANSYS Workbench 18.1. The analysis included modelling of specimen in ANSYS workbench 18.1, followed by meshing and then analyzing.

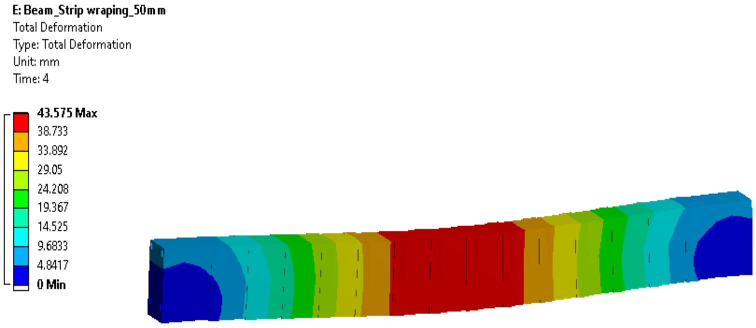

Fig.2. Deformation of Carbon FRCM beam with 50 mm wide U-wrap strips

3.3. Analysis of Carbon FRCM beam with 50mm wide strips

A numerical analysis of reinforced concrete beam strengthened with 50mm wide U-wrap strips of Carbon Fabric Reinforced Cementitious Matrix was conducted by using ANSYS Workbench 18.1. The analysis included modelling of specimen in ANSYS workbench 18.1, followed by meshing and then analyzing.

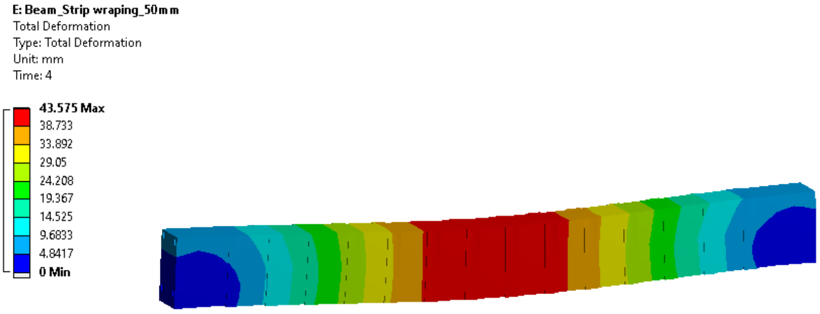

Fig.3. Deformation of Carbon FRCM beam with 50 mm wide U-wrap strips

From the analysis of Reinforced Concrete beams strengthened with 50mm wide U-wrap strips of Carbon Fabric Reinforced Cementitious Matrix, ultimate load carrying capacity obtained as 142.147kN and corresponding deformation obtained is 40.097 mm. The maximum load at which the specimen fails is obtained as 142.058kN and corresponding deformation is 43.575mm.

3.4. Analysis of Carbon FRCM beam with 75mm wide strips

A numerical analysis of reinforced concrete beam strengthened with 75mm wide U-wrap strips of Carbon Fabric Reinforced Cementitious Matrix was conducted by using ANSYS Workbench 18.1. The analysis included modelling of specimen in ANSYS workbench 18.1, followed by meshing and then analyzing.

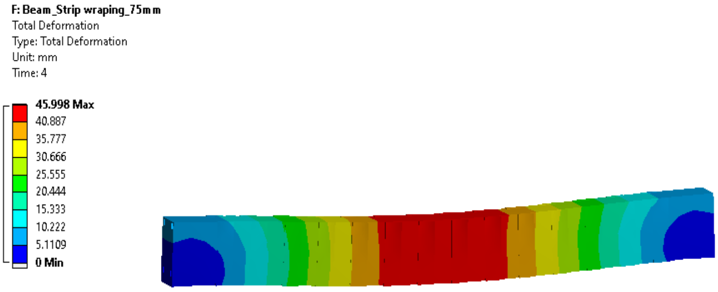

Fig.4. Deformation of beam with 75 mm wide strips of Carbon FRCM

From the analysis of Reinforced Concrete beams strengthened with 75mm wide U-wrap strips of Carbon Fabric Reinforced Cementitious Matrix, ultimate load carrying capacity obtained as 158.638kN and corresponding deformation obtained is 36.612 mm. The maximum load at which the specimen fails is obtained as 155.965kN and corresponding deformation is 45.998 mm.

3.5. Analysis of Carbon FRCM beam with 100mm wide strips

A numerical analysis of reinforced concrete beam strengthened with 100mm wide U-wrap strips of Carbon Fabric Reinforced Cementitious Matrix was conducted by using ANSYS Workbench 18.1. The analysis included modelling of specimen in ANSYS workbench 18.1, followed by meshing and then analyzing.

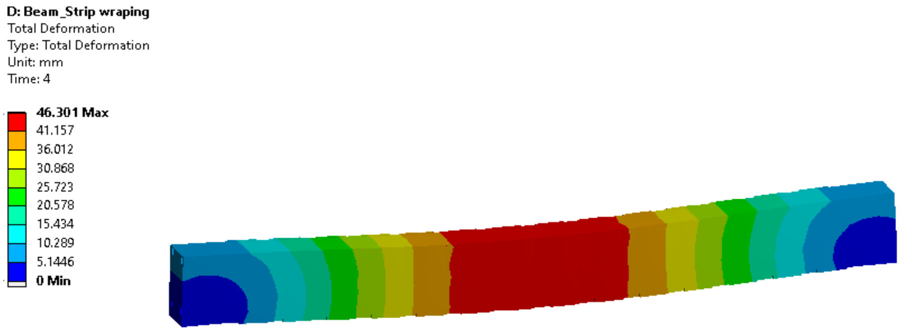

Fig.5. Deformation of beam with 100mm wide U-wrap strips of Carbon FRCM

From the analysis of Reinforced Concrete beams strengthened with 100mm wide U-wrap strips of Carbon Fabric Reinforced Cementitious Matrix, ultimate load carrying capacity obtained as 171.919kN and corresponding deformation obtained is 37.339mm. The maximum load at which the specimen fails is obtained as 169.128kN and corresponding deformation is 46.301 mm.

4. Results and Discussions

The conventional Finite Element Method using ANSYS is used to study the static behavior of Reinforced Concrete beams strengthened with Carbon Fabric Reinforced Cementitious Matrix. A comparative study is conducted by providing fully U-wrapped Carbon Fabric Reinforced Cementitious Matrix on Reinforced Concrete beam and also by providing U-wrap strips of Carbon FRCM of varying width on Reinforced Concrete beams.

Table 1. Comparison of results

Specimen Carbon FRCM	Ultimate load (kN)	Deformation at ultimate load (mm)	Failure load (kN)	Deformation at failure load (mm)
Fully U-wrap	198.12	55.316	197.680	57.816
50 mm wide U-wrap strips	142.147	40.097	142.058	43.575
75 mm wide U-wrap strips	158.638	36.612	155.965	45.998
100 mm wide U-wrap strips	171.919	37.339	169.128	46.301

4.1. Load vs deformation graph

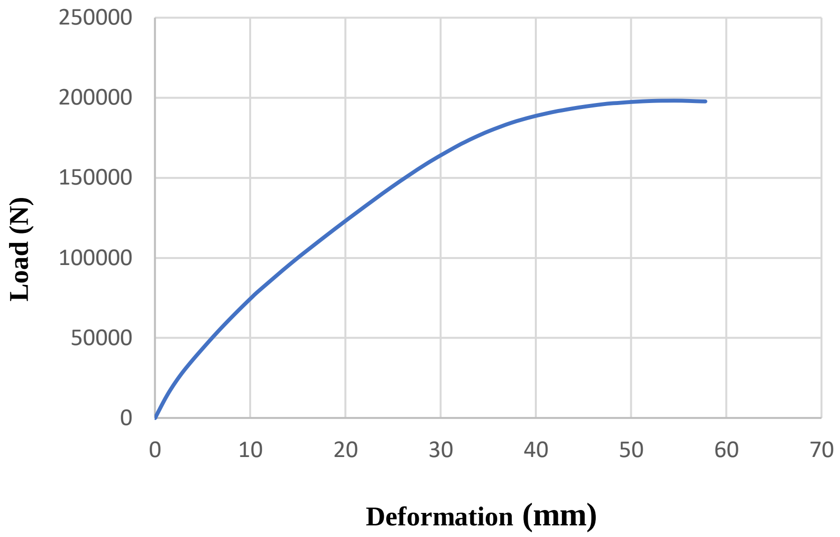

Fig.6. Load-deformation graph of fully U-wrapped Carbon FRCM beam

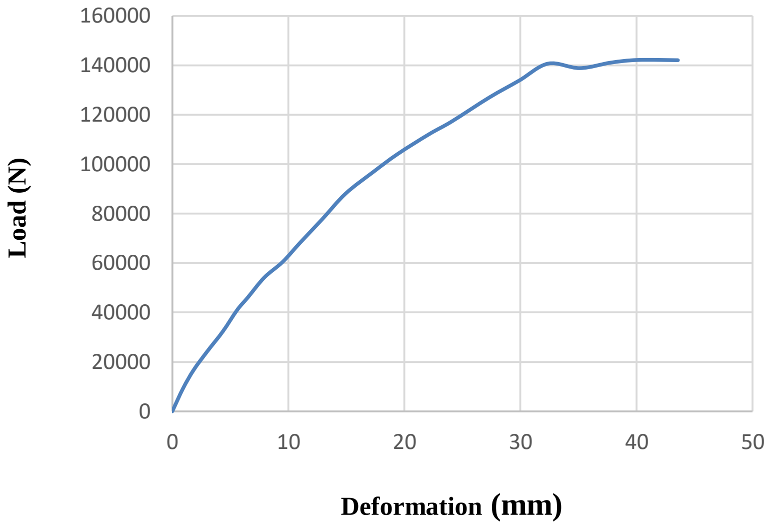

Fig.7. Load-deformation graph of beam with 50mm wide U-wrap strips of Carbon FRCM

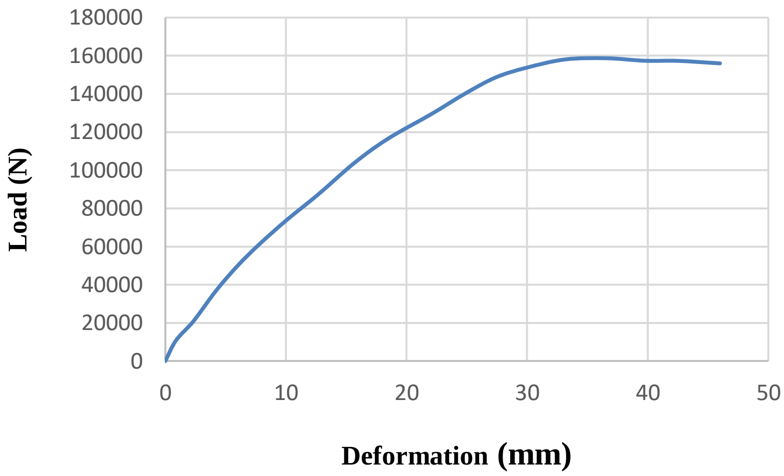

Fig.8. Load-deformation graph of beam with 75mm wide U-wrap strips of Carbon FRCM

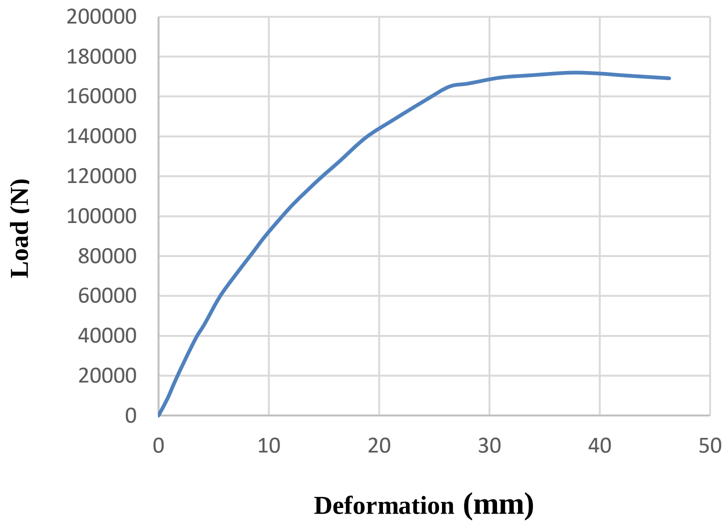

Fig.9. Load-deformation graph of beam with 100mm wide U-wrap strips of Carbon FRCM

From the above results, it is observed that highest load carrying capacity is obtained for reinforced concrete beam strengthened with fully U-wrapped Carbon FRCM, whereas the least load carrying capacity is obtained for RC beams strengthened with 50mm wide U-wrap strips of Carbon FRCM.

5. Conclusion

The conventional Finite Element Method using ANSYS was used to study the static behavior of Reinforced Concrete beams strengthened with Carbon Fabric Reinforced Cementitious Matrix. A comparative study was conducted by providing fully U-wrapped Carbon Fabric Reinforced Cementitious Matrix on Reinforced Concrete beam and also by providing U-wrap strips of Carbon FRCM of varying width on Reinforced Concrete beams.

From the analysis of Reinforced Concrete beams strengthened with fully U-wrapped Carbon Fabric Reinforced Cementitious Matrix, Ultimate load carrying capacity obtained as 198.12kN and corresponding deformation obtained is 55.316 mm. The maximum load at which the specimen fails is obtained as 197.680kN and corresponding deformation is 57.816mm.

From the analysis of Reinforced Concrete beams strengthened with 50mm wide U-wrap strips of Carbon Fabric Reinforced Cementitious Matrix, ultimate load carrying capacity obtained as 142.147kN and corresponding deformation obtained is 40.097 mm. The maximum load at which the specimen fails is obtained as 142.058kN and corresponding deformation is 43.575mm.

From the analysis of Reinforced Concrete beams strengthened with 75mm wide U-wrap strips of Carbon Fabric Reinforced Cementitious Matrix, ultimate load carrying capacity obtained as 158.638kN and corresponding deformation obtained is 36.612 mm. The maximum load at which the specimen fails is obtained as 155.965kN and corresponding deformation is 45.998 mm.

From the analysis of Reinforced Concrete beams strengthened with 100mm wide U-wrap strips of Carbon Fabric Reinforced Cementitious Matrix, ultimate load carrying capacity obtained as 171.919kN and corresponding deformation obtained is 37.339mm. The maximum load at which the specimen fails is obtained as 169.128kN and corresponding deformation is 46.301 mm.

By comparing the above results, it is observed that highest load carrying capacity is obtained for reinforced concrete beam strengthened with fully U-wrapped Carbon FRCM, whereas the least load carrying capacity is obtained for RC beams strengthened with 50mm wide U-wrap strips of Carbon FRCM. This proves that it is efficient to use Carbon Fabric Reinforced Cementitious Matrix as a strengthening technique in Reinforced Concrete beams, also, the most efficient scheme of Carbon Fabric Reinforced Cementitious Matrix wrapping on Reinforced Concrete beams is by providing full U-wrap.

References

[1] A. Younis, U. Ebead, K.C. Shrestha, “Different FRCM systems for shear strengthening of reinforced concrete beams”, (2017).

[2] Abdulla Jabr, Amr El-Ragaby and Faouzi Ghrib, “Effect of the Fiber Type and Axial Stiffness of FRCM on the Flexural Strengthening of RC Beams”, (2017).

[3] C. Escrig, L. Gil, E. Bernat-Maso, “Experimental comparison of reinforced concrete beams strengthened against bending with different types of cementitious-matrix composite materials”, (2017).

[4] Dr Luke Bisby, Dr Tim Stratford, Joanna Smith & Sarah Halpin, “Comparative performance of fiber reinforced polymer and fiber reinforced cementitious mortar strengthening systems in elevated temperature service environments”, (2019).

[5] M. Elghazy, A. El Refai, U. Ebead, A. Nanni, "Effect of corrosion damage on the flexural performance of RC beams strengthened with FRCM composites", (2017).

[6] Saman Babaeidarabad, Giovanni Loreto, Antonio Nanni, "Flexural Strengthening of RC Beams with Externally Bonded Fabric-Reinforced- Cementitious-Matrix (FRCM)", (2018).

[7] S.M. Raoof, L.N. Koutas, D.A. Bournas, "Textile-reinforced mortar (TRM) versus fiber-reinforced polymers (FRP) in flexural strengthening of RC beams", (2017).

[8] U. Ebead, K.C. Shrestha, M.S. Afzal, A. El Refai, A. Nanni, "Effectiveness of Fabric- Reinforced Cementitious Matrix in Strengthening Reinforced Concrete Beams", (2017).

[9] Usama Ebead, Hossam Eldin El-Sherif, "Near surface embedded FRCM for flexural strengthening of Reinforced Concrete Beams", (2019).

[10] Z.C. Tetta, L.N. Koutas, D.A. Bournas, "Textile-reinforced mortar (TRM) versus fiber-reinforced polymers (FRP) in shear strengthening of concrete beams", (2015).