INTERNATIONAL JOURNAL OF SUSTAINABLE CONSTRUCTION ENGINEERING AND TECHNOLOGY
VOL. 14 NO. 1 (2023) 76-84

© Universiti Tun Hussein Onn Malaysia Publisher's Office

IJSCET

http://publisher.uthm.edu.my/ojs/index.php/ijscet

ISSN : 2180-3242 e-ISSN : 2600-7959

International Journal of Sustainable Construction Engineering and Technology

Numerical Studies on Flexural Behaviour of Carbon Fiber Reinforced Polymer-Wrapped Reinforced Concrete Beam

J.Geetha[1], R.Padmapriya[1*]

[1]Faculty of Building and Environment,
Sathyabama Institute of Science and Technology, INDIA

*Corresponding Author

DOI: https://doi.org/10.30880/ijscet.2023.14.01.009
Received 08 August 2022; Accepted 12 January 2023; Available online 14 February 2023

Abstract: Construction faults and poor maintenance of concrete buildings become crucial as a result of heavy loading. Fibre reinforced polymer increases load bearing capacity, improves ductility, and decreases degradation damages. The researchers are looking for new and novel ways to strengthen beams since traditional techniques of reinforcement have limits that must be addressed. Due to its better qualities, the technology of wrapping a Reinforced Concrete (RC) beam with composite material has become popular and widely employed in structural applications. FRP has a lower labour cost and is a simple technique to reinforce buildings for a more effective solution. The experimental and analytical work was done for both conventional and CFRP strengthening with various intervals, such as CFRP wrapped with a 100mm interval, CFRP wrapped with a 200mm interval, and CFRP wrapped without an interval, with improved results in deformation and stress analysis. All of the experimental data were compared to the calculated analytical values. When CFRP is used on a beam, it enhances its strength, load bearing capability, and ductility.

Keywords: Flexural behaviour, reinforced polymer, reinforced concrete, stress analysis

1. Introduction

Because of its excellent strength-to-weight ratio and corrosion resistance, fibre reinforced polymer composites have found widespread use in civil engineering. The CFRP wrapping technique may be used to enhance or retrofit existing concrete buildings to withstand greater design loads and repair deterioration-related damage. In the previous two decades, there has been a significant growth in the quantity and types of CFRP-based strengthening applications, as well as various experimental [1]. The design requirement for reinforcing flexure beams using FRP is addressed in a number of code rules [2-4]. To estimate the internal stresses and pressures in different materials, information regarding the distribution of strains throughout the full cross section of a flexural beam is required. If the internal forces are understood and developed, a design equation can be created to describe the behaviour of a reinforced concrete beam. The unified design technique utilised in the design of RC beams [5] is also used to design the reinforced flexure beam, with the strain compatibility approach and ductility monitoring.

Zhao et al. (2020) investigated the tensile characteristics of SFCB and their bonding performance in concrete in an experimental study. In comparison to SFCB with ribbed steel core and FRP wrapping, test findings revealed that SFCB with round steel core and FRP wrapping had better tensile behaviour. The rule of mixtures may be utilised to characterise the tensile behaviour of SFCB, according to the authors. SFCB's stress–strain curve has a bilinear tendency. The diameter and surface treatment of SFCB have an impact on bond strength.

Steel Fibres are employed in most water holding structures, according to Sattainathan Sharma A et al. (2019). This demonstrates that varying the volume percentage of steel fibres improves the ductility of RC beams. When compared to

---

*Corresponding author: padmapriya.civil@sathyabama.ac.in

Crimped GFRP beams, Steel Fibre beams with Glass Fibre overlay have higher flexural strength and deflection than normal beams.

In comparison to steel, FRP materials offer a higher last strength and a smaller thickness. When these characteristics are combined, fibre composites can have a more grounded/heavier proportion than steel plate. FRP is inherently easier to connect and maintain than steel because of its reduced weight [8]. Experimental studies of the flexural behaviour of fibre-reinforced concrete beam specimens using CFRP as tensile reinforcement are done in this work to cover these gaps in the literature [9]. The combined use of CFRP wrapped fibres as reinforcement in concrete structural components might be regarded an unique technology for improving durability and cracking resistance. The flexural behaviour of concrete beams reinforced with CFRP wrapped fibre must be examined experimentally and numerically in order to create design recommendations for practical applications, which inspired the research described in this work. The numerical analysis involved creating models of the tested beam specimens in the general-purpose finite-element programme ABAQUS and comparing them to test findings.

2. Experimental Work-Results and Discussions

Flexure-beam testing on enhanced reinforced concrete beams was part of the experimental programme. Control experiments were also carried out on non-strengthened beams. The beams were statically tested until they failed [10]. Load–deflection curves for various beam types, load–strain at top and bottom reinforcements, and load–strain at the CFRP wrapping surface were among the experimental results. In addition, failure mechanisms were anticipated and addressed in light of the experimental findings. The experimental work-results are given and discussed in the following subsections. Table 2 summarises the experimental results of wrapped CFRP beams and compares them to control unwrapped specimens [11].

2.1 Failure Mode

After 28 days of curing, the beams were tested to two-point loading. Below the two-point loading supports and mid-point, three LVDTs were installed. Three deflection values were recorded for every 4 kN. The conventional beam's first crack load was 65.3 kN, whereas the completely wrapped (without interval) beam was 140 kN, the 200mm interval CFRP wrapped beam was 110 kN, and the 100mm interval wrapped CFRP beam was 95 kN, all of which were higher than the conventional beam's first crack load of 65.3 kN.

Fig. 1 - First crack on conventional beam

Fig. 2 - Cracks on the sides of CFRP fully wrapped beam

This was because the fully wrapped (without interval) beam bridged the hair cracks and delayed the initial crack load, and the fully wrapped (without interval) beam ultimate load was larger than the 100mm and 200mm interval beams.

Fig. 3 - First crack on CFRP wrapped beam with 200 mm interval

This clearly demonstrates that adding a 200mm interval beam to concrete has no impact on strength development. Hair fractures occurred at the bottom of the beam and transversely towards the top as the stress rose. The load bearing capability increases when the interval separation is lowered. Figure 5 shows a comparison of the first fracture load and ultimate load for the beams.

Fig. 4 - First crack on CFRP wrapped beam with 100 mm interval

When compared to other beams, CFRP wrapped beams with a 100 mm interval have a lower load bearing capability than other, more typical beams. The capacity of the 100mm interval beam grew less. A bar chart is given to demonstrate the evident outcome of the initial fracture developing on other beams and the final load attained on the beams [12].

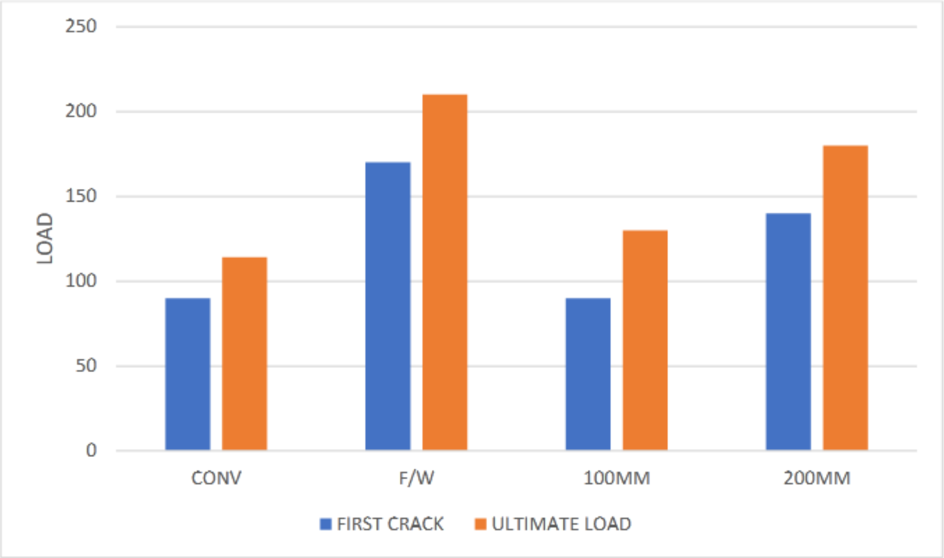

Fig. 5 - Comparisons of first crack load and ultimate load

2.2 Experimental Result

Table 1 - Outcomes result for experimental

SI.No	Specimen Designation	Ultimate Load (KN)	Deflection(mm)
1	Conventional Beam	114	2.4
2	Fully wrapped (W/o Intervals)	210	6.2
3	WB-1-100mm Interval	130	4.2
4	WB-2-200mm Interval	180	5.3

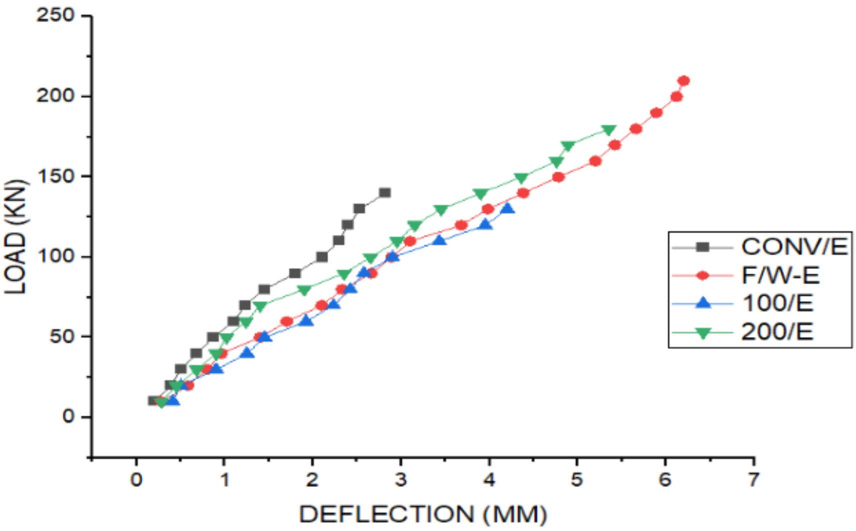

Fig. 6 - Load vs deflection curve for all beams (experimental result)

2.3 Numerical Analysis Results

For the parametric investigation, numerical analysis is carried out. The stress profile of a traditional RC beam covered with CFRP Figures 7 through 10 illustrate an RC beam with no interval, a 100mm interval, and a 200 CFRP wrapped interval. The rays are seen to be The load–deflection values determined using Ansys findings [13] are shown in Table 2.

Table 2 - Outcomes result for numerical

SI.No	Specimen Designation	Ultimate Load (KN)	Deflection(mm)
1	Conventional Beam	120	2.7
2	Fully wrapped (W/o Intervals)	230	4.7
3	WB-1-100mm Interval	120	3.9
4	WB-2-200mm Interval	160	3.5

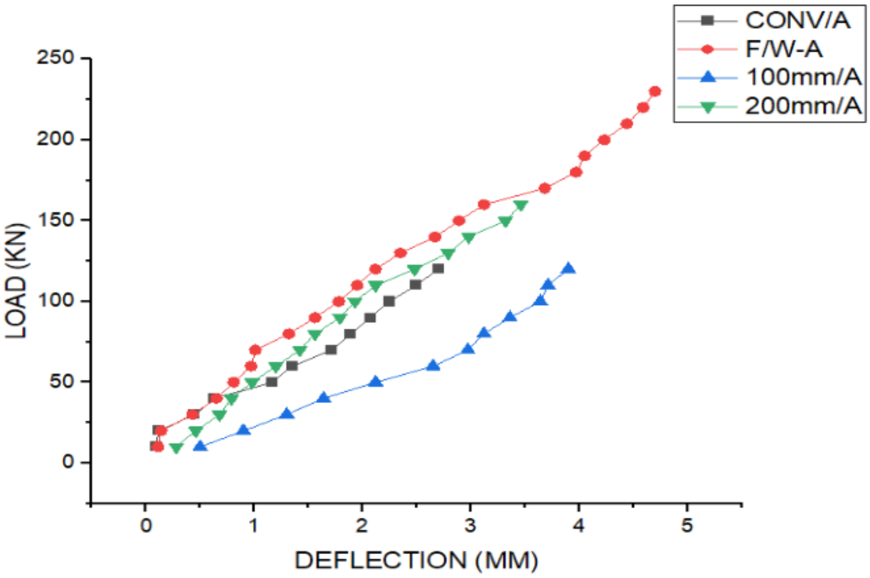

Fig. 6 (a) - Load vs deflection curve for all beams (numerical result)

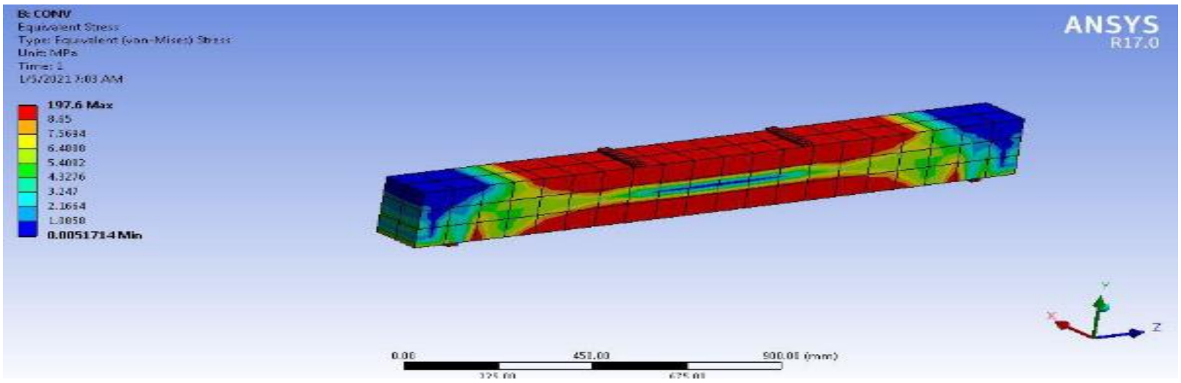

Fig. 7 - Conventional beam – stress contour

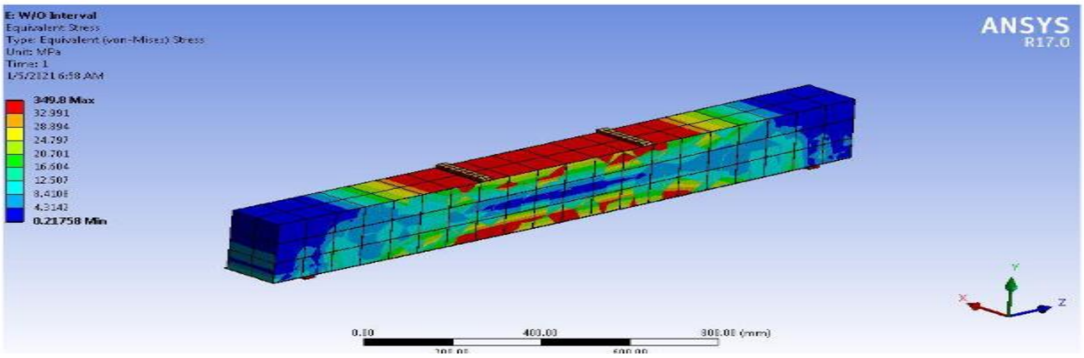

Fig. 8 - CFRP wrapped without interval – stress contour

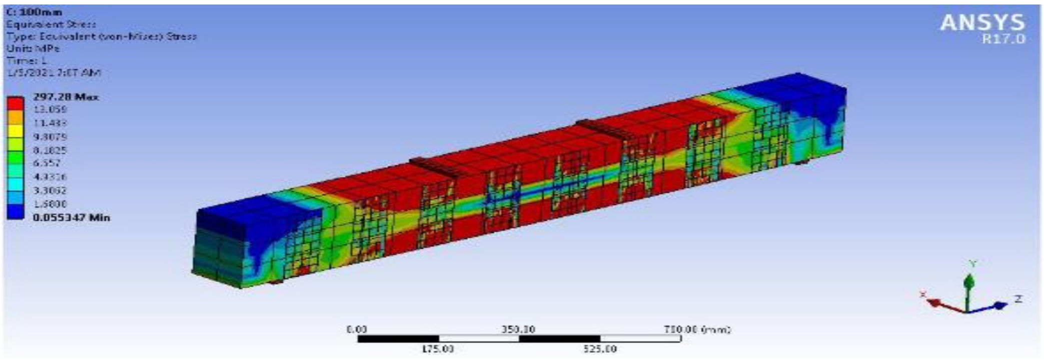

Fig. 9 - CFRP wrapped 100mm interval – stress contour

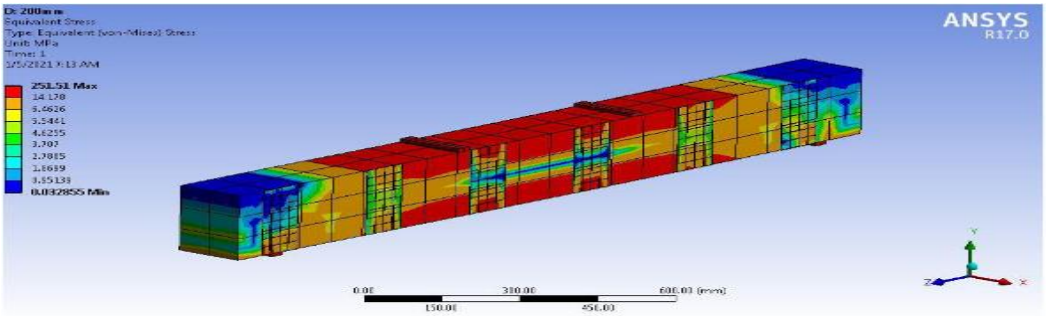

Fig. 10 - CFRP wrapped 200mm interval – stress contour

3. Comparison of Experimental Results with Analytical Results

The load–deflection curves computed using ANSYS and empirically for varied interval wrapping of CFRP are shown in Figures 11,12,13, and 14. The experimental findings were compared to the Ansys Finite Element Analysis results. The Ansys Finite Element Analysis findings were found to be less consistent with the experimental data [14].

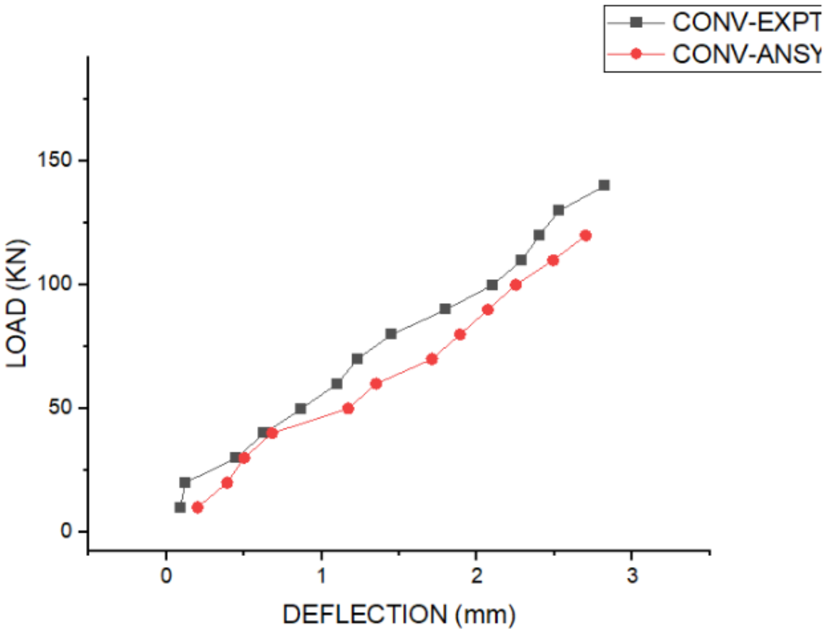

Fig. 11 - (conventional beam)

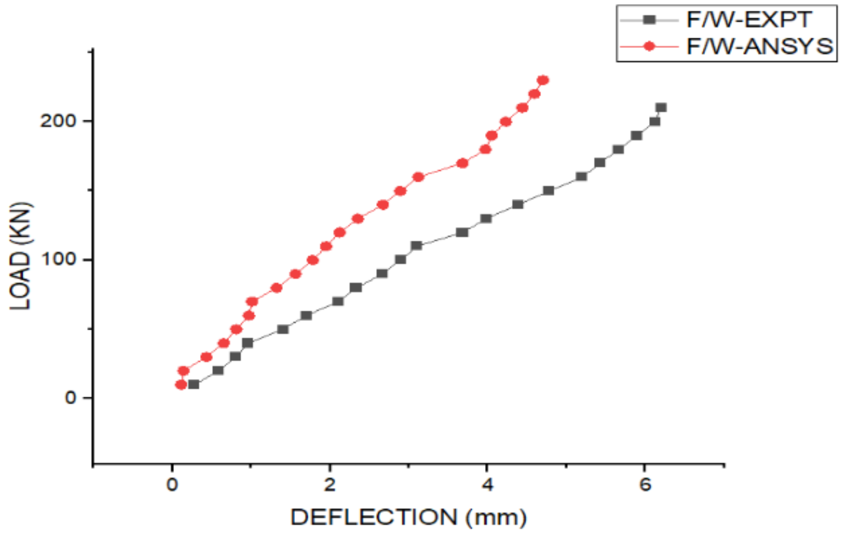

Fig. 12 - CFRP wrapped without interval

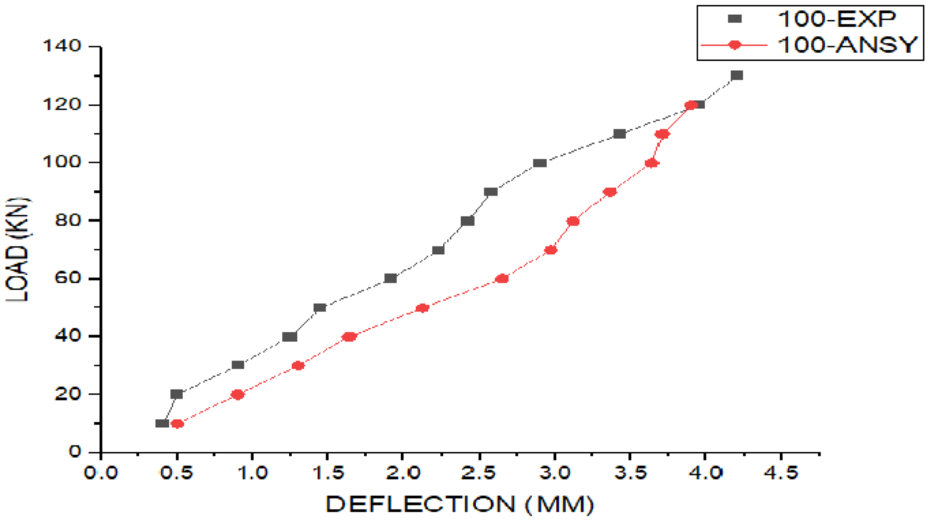

Fig. 13 - (CFRP wrapped beam with 100 mm interval)

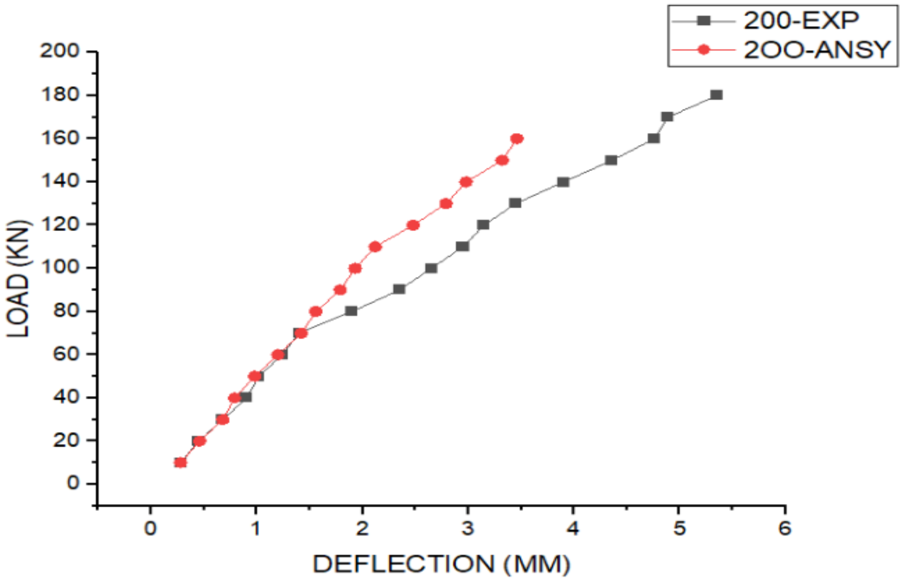

Fig. 14 - (CFRP wrapped beam with 200 mm interval)

4. Conclusions

The flexural behaviour of fibre-reinforced concrete beams with conventional and CFRP strengthening with various intervals, such as CFRP wrapped with 100mm interval and CFRP wrapped with 200mm spacing, is studied experimentally and numerically in this study. The following are the results drawn from the experimental and numerical investigations provided in this study.

1. Flexural fractures were discovered in the beams after a two-point stress test. According to the findings, the application of CFRP improved both ways, increasing the flexural capacity of the beam and helping to boost stiffness under service loads. It also aids in the reduction of deflection in both directions.
2. Future experimental work is needed to understand the behaviour of RC beams with FRP through design, building, instrumentation, and testing of beams, as well as future work to make recommended adjustments to account for the nature of FRP reinforcements in present design requirements.
3. It demonstrates that CFRP may effectively increase the load-bearing capacity, cracking, and stiffness of concrete beams.
4. It has been determined from this study that CFRP strengthening is one of the most cost-effective strategies for reducing flexural failure of the beam. The load bearing capability rose when the interval wrapping separation was lowered.
5. The resulting figure demonstrates an increase in load bearing capability due to the use of CFRP.
6. Additional study is needed in this area in order to generate design standards.

Acknowledgement

The authors would like to thank Faculty of Building and Environment, Sathyabama Institute of Science and Technology, India for allowing to conduct this research.

References

Abed, F., C. Oucif, Y. Awera, H. H. Mhanna, and H. Alkhraisha. 2020. “FE Modeling SFCB Reinforced Beams Can Be Very Useful in Marine Environment Where Chloride Induced Corrosion of Reinforcing Bars Form a Severe Threat to Durability of RCC Structures. Of Concrete Beams and Columns Reinforced with FRP Composites.” Defence Technology. doi:10.1016/j.dt.2020.02.015.

Cheng Chen, Yancai Yang, Jinbo Yu, Jinming Yu, Haizheng Tan, Lili Sui, Yingwu Zhou 2020 “Eco-friendly and mechanically reliable alternative to synthetic FRP in externally bonded strengthening of RC beams: Natural FRP”.Vol.241.No.112081.pp.112081.

Essam S. Khalifa, Sherif H. Al-tersawy. 2013. Experimental and analytical investigation for enhancement of flexural beams using multilayer wraps. Composites: Part B 45 (2013) 1432–1440.

Fei Peng, Weichen Xue 2018 “Design approach for flexural capacity of concrete T-beams with bonded prestressed and non prestressed FRP.

Fei Peng, Weichen Xue 2018 “Design approach for flexural capacity of concrete T-beams with bonded prestressed and non prestressed FRP

Guo, Q., Q. Chen, Y. Xing, Y. Xu, and Y. Zhu. 2020. “Experimental Study of Friction Resistance between Steel and Concrete in Prefabricated Composite Beam with High-Strength Frictional Bolt.” Hindawi Advances in Materials Science and Engineering 13. doi:10.1155/2020/1292513.

Rafid Saeed Atea 2017 “Torsional behaviour of reinforced concrete T- beams strengthened with CFRP strips”.Vol.03, No.02.pp.110-117

Raghunathapandian, B. Palani, D. Elango 2020 “Flexural Strengthening of RC Tee Beams using Ferrocement”. Vol.08., No.05 pp.4505-4509

Sattainathan Sharma A , Sadhana , Shoban Prabhu , Solomon Sachin Samson Supriya. (2019) “Ductility Behaviour of Steel Fibre Reinforced Concrete Beam Strengthened with GFRP Laminates”. Vol.06, No.03. pp.6530-6539.

Sivaramakrishnan Subbaram & Chinnaraju Komarasamy 2021: Experimental and numerical studies on the flexural behavior of fibre reinforced concrete beams with innovative hybrid FRP-wrapped steel bars, Journal of Asian Architecture and Building Engineering, DOI: 10.1080/13467581.2020.1870983.

Sun, Z., L. Fu, D. Feng, A. R. Vatuloka, Y. Wei, G. Wu, and B. Steel. 2019. “Experimental Study on the Flexural Behavior of Concrete Beams Reinforced with Bundled Hybrid steel/FRP Bars.” Engineering Structures 197: 109443. doi:10.1016/j. engstruct.2019.109443

Xu, J., P. Zhu, Z. John, and W. Qu. 2019. “Fatigue Flexural Analysis of Concrete Beams Reinforced with Hybrid GFRP and Steel Bars.” Engineering Structures 199: 109635. doi:10.1016/j.engstruct.2019.109635.

Zhao, D., J. Pan, Y. Zhou, L. Sui, and Z. Ye. 2020. “New Types of steel-FRP Composite Bar with Round Steel Bar Inner Core: Mechanical Properties and Bonding Performances in Concrete.” Construction and Building Materials 242: 118062. doi:10.1016/j.conbuildmat.2020.118062.

Zhou, Y., B. Zheng, L. Sui, F. Xing, P. Li, and H. Sun. 2019. “Effects of External Confinement on Steel Reinforcement Corrosion Products Monitored by X-ray Microcomputer Tomography.” Construction and Building Materials 222: 531–543. doi:10.1016/j.conbuildmat.2019.06.119.