Journal of Advances and Scholarly Researches in Allied Education
Vol. 21, Issue No. 3, April-2024, ISSN 2230-7540

Development of Approaches for Strengthening and Retrofitting of Concrete Beams Using Structural Steel

Mr. Nikhil Hanmant Bagal[1*], Dr. V. S. Kshirsagar[2], Prof.Pooja B. Ronge[3],

Prof. Basavaraj M. Malagimani[4], Dr. Manik G. Deshmukh[5]

[1] Post-Graduate Student, Dept. of Civil Engineering, SVERI's College of Engineering, Pandharpur, Maharashtra

[2] Associate Professor, SVERI's College of Engineering, Pandharpur, Maharashtra

[3,4] Assistant Professor, SVERI's College of Engineering, Pandharpur, Maharashtra

[5] Associate Professor, SVERI's College of Engineering, Pandharpur, Maharashtra

Email id - mgdeshmukh@coe.sveri.ac.in

Abstract - In structural analysis, the term 'frame' typically refers to a robust structure comprising various elements such as slabs, beams, columns, and footings. These components are cast together to create a monolithic construction, effectively functioning as a single integral unit. The frame is subject to various forces, which are transferred through its different components. Additionally, changes in facility usage or the introduction of additional live loads can exert further stresses on the structure. Consequently, it is imperative that the elements of the frame possess sufficient strength to withstand these loads.

In this study, we focus on the development of approaches for strengthening and retrofitting concrete beams using structural steel elements. Specifically, our investigation involves the analysis of beams under different load combinations to enhance their integrity performance. To achieve this, angles and steel plates are utilized for reinforcement. We conduct numerical analysis through finite element modeling using ANSYS Workbench. Multiple beam models are created within the ANSYS platform, allowing us to study and compare various outcomes, including total deformation. This comprehensive approach aims to contribute to the advancement of methods for enhancing the structural resilience of concrete beams in real-world applications.

Keywords: ANSYS Workbench, Finite element model, Frame, loads, Total Deformation.

---------------------------------x---------------------------------

INTRODUCTION

Retrofitting of beams refers to the process of strengthening or repairing existing beams in a structure to increase their load-carrying capacity and improve their overall performance. This process can involve various techniques, including the addition of steel plates, epoxy bonding, or carbon fiber wrapping. There are several reasons why retrofitting beams may be necessary, such as changes in the building code, deterioration of the beams due to age or environmental factors, or an increase in the loads the beams need to support. Retrofitting can be a cost-effective alternative to replacing the entire structure or individual beams. The specific approach to retrofitting beams will depend on the condition and requirements of the structure. It is important to consult with a structural engineer or other qualified professional to determine the most appropriate retrofitting method for a given situation.

The project has a primary objective of designing and assessing various methods for strengthening Reinforced Concrete (RCC) beams using structural steel, with a focus on both strengthening and retrofitting aspects. The first goal involves developing diverse approaches for enhancing the loadbearing capacity of RCC beams through the integration of structural steel, considering factors such as beam dimensions, steel placement, and load distribution. Subsequently, the project aims to comprehensively analyze the performance of these strengthened beams under different loading conditions, employing advanced analytical techniques to assess structural integrity and deformation behavior.

In addition to strengthening, the project seeks to address the retrofitting of partially damaged RCC beams. The second objective focuses on devising effective retrofitting strategies using structural steel for beams that have sustained partial damage or deterioration. This involves considering scenarios of localized damage and deterioration and formulating guidelines for selecting appropriate retrofitting techniques based on the extent of the damage. The subsequent step involves evaluating the performance of retrofitted beams through numerical simulations and experimental investigations, quantifying improvements in load-carrying capacity, flexural strength, and overall structural behavior. The project's outcomes extend beyond technical aspects. It aims to contribute to the field of structural engineering by generating comprehensive design guidelines, there by facilitating the practical implementation of various strengthening and retrofitting techniques. Furthermore, the project evaluates the economic feasibility of these approaches, considering material costs, labor requirements, and potential reductions in maintenance expenses. The durability and sustainability of strengthened and retrofitted beams are also assessed, considering factors such as corrosion, fatigue, and environmental influences on structural steel components.

OBJECTIVES

1. To design different approaches of RCC beam strengthening using structural steel.
2. To analyze the performance of beam strengthened with structural steel.
3. To design different approaches for retrofitting of RCC beam using structural steel for partially damaged beams.
4. To analyze the performance of beam retrofitted with Structural Steel for partially damaged beams.

RESULTS AND DISCUSSION

1. Introduction

To understand the behaviour of Normal specimen and strengthened specimens under different loading conditions Such as simply supported beam and fixed beam tested for two-point bending cantilever beam tested for combined torsion and bending, the column is tested for combined vertical and lateral load and the single bay frame is tested for different loading conditions and deformation and stress-induced in each specimen is measured at regular interval of time and graph of deformations v/s time and stress v/s time is plotted.

Fig. 1.1 shows the plot of comparison between deformation calculated by analytical method and by ANSYS Workbench 15.0 for Beam 1

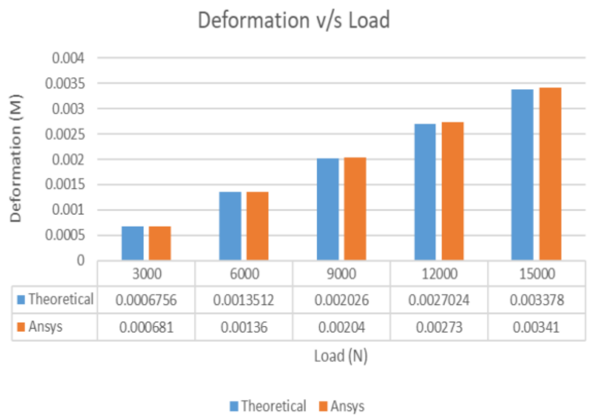

Figure 1.1 comparison between analytical and ANSYS deformation calculation.

Fig. 1.2 shows the plot of comparison between Stress calculated by analytical method and by ANSYS Workbench 15.0 for Beam 1.

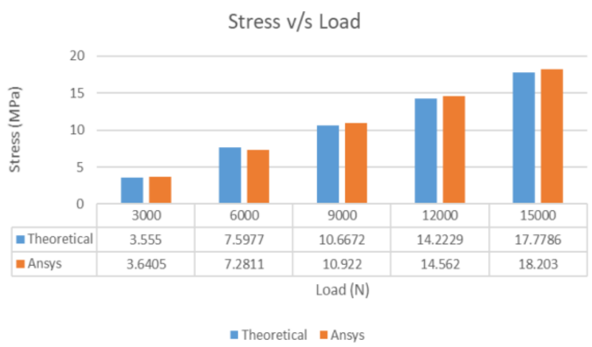

Figure 1.2 comparison between analytical and ANSYS stress calculation.

2. To design different approaches of RCC beam strengthening using structural steel.

Strengthening an RCC (Reinforced Concrete) beam using structural steel can be necessary for various reasons, such as increasing load-carrying capacity, addressing structural deficiencies, or retrofitting for seismic considerations. There are several approaches to achieve this, each with its own advantages and disadvantages. Here are different approaches for RCC beam strengthening using structural steel:

External Steel Plates/Sheets (FRP or Steel): Carbon Fiber Reinforced Polymer (CFRP) or Steel Plates: These are bonded to the concrete surface using epoxy adhesives. They are effective in increasing the flexural strength of the beam.

Advantages: Minimal disruption to the structure, corrosion-resistant, and relatively easy to install. Disadvantages: Limited load-carrying capacity improvement, aesthetics, and long-term durability may be a concern.

Steel Angle or Channel Section: U-shaped Steel Channels: These are bolted or welded onto the sides of the beam. They enhance the beam's flexural strength and stiffness.

Advantages: Relatively simple installation, increased load-carrying capacity, and stiffness. Disadvantages: May affect aesthetics, require additional space, and could be prone to corrosion if not properly protected.

Steel Plates Embedded in Concrete: Steel plates can be embedded within the existing concrete beam during construction or added later through a retrofit.

Advantages: Excellent load-carrying capacity and stiffness enhancement.

Disadvantages: Requires significant construction work, potential issues with corrosion if not adequately protected, and can be costly

External Steel Beams or Channels: Welded or Bolted Steel Beams: Placing steel beams externally beneath the existing RCC beam can significantly increase load-carrying capacity.

Advantages: High load-carrying capacity improvement, clear span below the beam, and flexibility in design.

Disadvantages: Requires careful structural analysis, extensive construction work, and can impact the aesthetics of the structure.

Steel Reinforcement Bars (Rebars): Additional steel reinforcement bars can be added to the existing concrete beam to increase its load-carrying capacity and ductility.

Advantages: Enhances both strength and ductility, commonly used in seismic retrofitting. Disadvantages: Requires careful detailing and construction work, may not be suitable for all situations.

Hybrid Approaches: Combining multiple strengthening techniques, such as external steel plates with embedded steel bars, can provide a balanced approach to address various aspects of beam strengthening.

Advantages: Customizable to specific structural requirements.

Disadvantages: Complex design and construction, potentially higher costs.

Steel Plate Bonded with Mechanical Fasteners: Steel plates are attached to the concrete surface using both epoxy adhesive and mechanical fasteners, such as bolts or anchor rods. This combination provides both adhesion and mechanical connection.

Advantages: Enhanced load-carrying capacity, good bond strength, and increased stiffness. Disadvantages: Requires precision in drilling holes for fasteners, potential corrosion of fasteners if not protected, and aesthetic concerns.

Each of these methods has its own set of advantages and disadvantages, and the choice of which method to use depends on the specific structural requirements, budget constraints, and project constraints. A structural engineer or retrofitting specialist should be consulted to determine the most appropriate method based on the specific needs of the RCC beam and the surrounding structure. When designing a strengthening approach using structural steel for an RCC beam, it is crucial to consider the specific structural requirements, budget constraints, aesthetics, and long-term durability. Consulting with a structural engineer or a professional experienced in retrofitting and strengthening techniques is highly recommended to ensure the safety and effectiveness of the chosen approach. Additionally, local building codes and regulations should be followed to ensure compliance and safety.

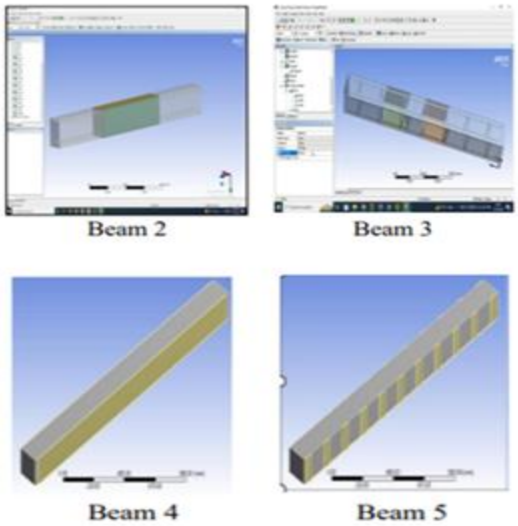

Figure 2.1 Shows different design configuration modelling by ANSYS Workbench 15.0

3. To analyse the performance of beam strengthened with structural steel.

Table 3.1 shows the plot of comparison between deformations calculated in ANSYS Workbench 15.0 for Beams.

Table 3.1: comparison between analytical and ANSYS stress calculation.

Two points Bending of simply supported Beam					
Deformation (M) Max					
Time (Sec)	Beam 1	Beam 2	Beam 3	Beam 4	Beam 5
1	0.00068	0.00044	0.00064	0.00035	0.00042
2	0.00136	0.00087	0.00129	0.0007	0.00084
3	0.00204	0.00131	0.00193	0.00104	0.00125
4	0.00273	0.00175	0.00257	0.00139	0.00167
5	0.00341	0.00218	0.00322	0.00174	0.00209

Fig. 3.1 shows the plot of maximum deformation (M) v/s Time (Sec) of all specimens with simply supported Beam

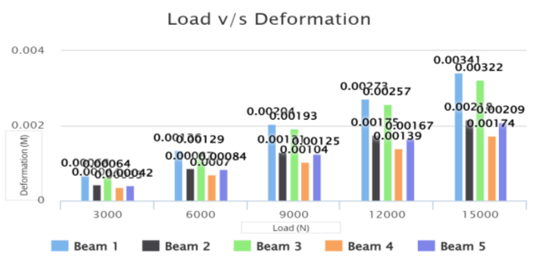

Figure 3.1 Maximum Load v/s deformation (M) of all specimens with simply supported Beam

4 To design different approaches for retrofitting of RCC beam using structural steel for partially damaged beams.

This methodology is useful for retrofitting method (for the 3rd objective) for repairing precracked beams pre-cracked. The cracked beams were clean with polished paper. The lose parts of the beams are removed from the beams and wash the crack with water. Take it 2 hrs to dry and after that fill the crack with mortar (cement: sand) and attach the jack to the bottom of the beam to remove the bend of the beam for 1 day. After that angle were attached to bottom of beam at two corners as retrofitting with the help of epoxy and hardener. In this first retrofitted beam with cement is tested on loading frame and deformation were calculated similarly retrofitted with steel angle is tested and deformation is noted.

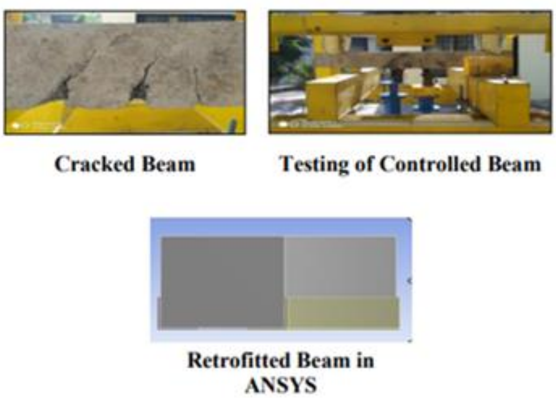

Figure 4.1 Shows different design configuration modelling by ANSYS Workbench 15.0

5. To analyze the performance of beam retrofitted with Structural Steel for partially damaged beams.

Table 5.1 shows the plot of comparison between deformation calculated by experimental method and in ANSYS Workbench 15.0 for controlled beam and retrofitted Beam.

Table 5.1: Comparison between controlled beam and ANSYS deformation calculation.

Two points Bending of simply supported Beam			
Deformation (M) Max			
Time(Sec)	Beam 1	Controlled Beam	Retrofitted Beam in ANSYS
1	0.00074	0.00090	0.00088
2	0.00147	0.00178	0.00174
3	0.00217	0.00263	0.00258

Fig. 5.1 shows the plot of comparison between deformation calculated by experimental method and in ANSYS Workbench 15.0 for controlled beam and retrofitted Beam.

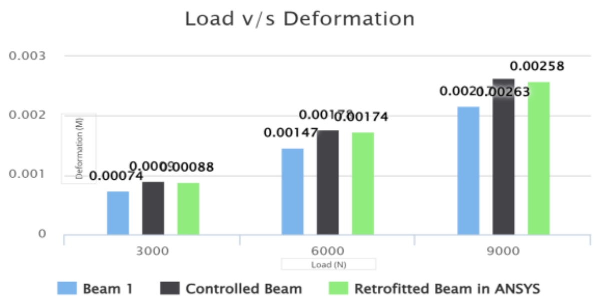

Figure 5.1 Maximum Load v/s deformation (M) of all specimens with simply supported Beam

CONCLUSION

1.0 Conclusion: In this research, we are developing an approach to strengthen and retrofit concrete beams using structural steel. Our study focuses on retrofitting beam specimens using steel plates or angles. To achieve this, we conducted finite element modelling in ANSYS, exploring various beam configurations. We then compared these results with both analytical predictions and experimental testing performed on a 200-ton loading frame. From our findings, we draw the following conclusions:

1. The finite element model performed using the ANSYS program had a fair agreement with the obtained theoretical results.
2. Steel plates and angles have proven to be effective in reinforcing concrete beams, demonstrating their ability to enhance the performance of structures.
3. Using batten plates and angle for strengthening of beam, column and frame has been proven to be effective since it increases the resistance to deformation.

4. In comparison to Beam 1, the attachment of plates to all three sides of beam i.e. Beam 4 results in a notable 49% reduction in deformation, as observed through analysis in ANSYS Workbench.

5. It can be concluded that Beam 5 exhibits a 39% reduction in deformation, while Beam 2 and Beam 3 demonstrate reductions of 36% and 6%, respectively, compared to the reference Beam 1 as observed through analysis in ANSYS Workbench.

6. The finite element model performed using the ANSYS program had a fair agreement with the obtained experiment results.

7. Based on the results, it is determined that beams retrofitted with angles attached to the edges display an approximate 20% reduction in deformation compared to the control beam, as analysed through both ANSYS simulations and experimental methods.

2.0 Future Scope

1. Study of different shapes of beam and columns on a similar line.

2. Study of multiple bays and multiple stories of RCC frame.

3. The same study can be carried out by using different thicknesses of steel at a differentlocation.

4. The same study can be carried out by using different strengthening materials other than structural steel.

5. Analysis of column for attaching batten plates in different angles that is in inclined position

REFERENCES

1. S., C., Jayasinghe., S.A., Ravindra, Abeysinghe., H., D., Yapa. (2022). Structural Retrofitting of Impaired Dapped-end Beams: A Review. Canadian Journal of Civil Engineering, doi: 10.1139/cjce2021-0627

2. Hamsavathi, Kannan., Soorya, Prakash, K.., Kavimani, V., Kavimani, V.. (2022). Improving structural performance of concrete beams by U-wrapped basalt fibre: a retrofitting approach. World Journal of Engineering, doi: 10.1108/wje-07-2022-0289

3. S.M., Mohseni, Shakib., Abu, Zakir, Morshed., Md., Ibrahim, Kholil., Md., Akhtar, Hossain. (2022). Simulation of reinforced concrete beam retrofitted with steel angles subjected to flexure. Multidiscipline Modeling in Materials and Structures, doi: 10.1108/mmms-12-2021-0208

4. Rodrigo, Falcão, Moreira., José, Miguel, Castro., Humberto, Varum. (2022). A New Displacement- based Design Procedure for the Retrofitting of RC Buildings with Steel Braces. ce/papers, doi: 10.1002/cepa.1813

5. Syed, Fasahat., Prof., D., N., Kakde. (2022). Retrofitting of Beams using Fibre Reinforced Polymer. International Journal of Advanced Research in Science, Communication and Technology, doi: 10.48175/ijarsct-7056

6. Sonali, Abeysinghe., H., D., Yapa. (2022). Numerical simulation of damaged reinforced concrete halfjoint beams: towards appraisal and retrofitting. Proceedings of the Institution of Civil Engineers, doi: 10.1680/jstbu.21.00004

7. Natalia, Sharma. (2021). Study on Retrofitting and Strengthening of Reinforced Concrete Beams Using Fibrous Concrete. International Journal for Research in Applied Science and Engineering Technology, doi: 10.22214/IJRASET.2021.37637

8. A Review on Structural Stabilization and Strengthening Through Retrofitting. doi: 10.1007/978-981-19-0189-8_46 2022

9. Mariona, Tomàs. (2022). Seismic Retrofitting Method Using CFRP Sheets for H-Section Steel Beam with Variable Cross Section. Journal of Structural Engineering-asce, doi: 10.1061/(asce)st.1943- 541x.0003292

10. Min, Sook, Kim., Young, Hak, Lee. (2021). Flexural Behavior of Reinforced Concrete Beams Retrofitted with Modularized Steel Plates. Applied Sciences, doi: 10.3390/APP11052348.

11. Silpa, S., Chinsu, Mereena, Joy. (2021). Seismic Retrofitting of Structures Using Steel Bracing: An Overview. doi: 10.21467/PROCEEDINGS.112.32.

12. Titik, Penta, Artiningsih., L, Lirawati., Navi, Helmi. (2021). Retrofitting of Reinforced Concrete Beams Using a Fiberglass Jacketing System. doi: 10.30659/JACEE.4.1.44-50

13. I., B., Muhit., Nur-E-Tanjina, Jitu., M., R., Alam. (2021). Structural shear retrofitting of reinforced concrete beam: multilayer ferrocement technique. doi: 10.1007/S42107-020-00306-3

14. Nabeel, A., Al-Bayati., Dhiyaa, H., Mohammed., Nawfal, A., Abdul, Jabbar. (2021). Retrofitting of SCC Deep Beams With Circular Openings Using CFRP. Engineering and Technology Journal, doi: 10.30684/ETJ.V39I7.74 .

Corresponding Author

Mr. Nikhil Hanmant Bagal*

Post-Graduate Student, Dept. of Civil Engineering, SVERI's College of Engineering, Pandharpur, Maharashtra