Educational Administration: Theory and Practice
2023,29(3), 836-842
ISSN:2148-2403
https://kuey.net/
Research Article

Analysis Of Retrofitting Methods For Enhancing Structural Resilience Of RC Moment-Resisting Frame Buildings

Dr. Ajay Swarup[1*], Bhosale Dinish Dilip[2]

[1*]Research Guide, Department of Civil Engg., Sri Satya Sai University of Technology and Medical Sciences, Sehore, Madhya Pradesh
[2]Research Scholar, Department of Civil Engg., Sri Satya Sai University of Technology and Medical Sciences, Sehore, Madhya Pradesh.

Citation: Dr. Ajay Swarup,et.al (2023), Analysis Of Retrofitting Methods For Enhancing Structural Resilience Of RC Moment-Resisting Frame Buildings,Educational Administration: Theory and Practice, 29(3), 836-842
Doi: 10.53555/kuey.v29i3.7325

ARTICLE INFO

ABSTRACT

In earthquake-prone regions, ensuring the operational continuity of critical infrastructure like hospitals is paramount to saving lives. Retrofitting existing structures stands as a proactive strategy to bolster resilience against seismic events. This study compares multiple retrofitting techniques for reinforcing a G+10 RC moment-resisting frame building. We evaluate various jacketing methods such as CFRP, steel, GFRP, and RC through structural analysis using ETABS software and subsequent simulations in ANSYS. The research aims to determine the most effective retrofitting approach, considering factors like structural performance, feasibility, environmental impact, maintenance, and cost-effectiveness. Results indicate that each jacketing material offers unique advantages in mitigating column deformation, providing valuable insights for engineers to enhance structural integrity and community resilience.

Keywords: Structural analysis, ETABS software, ANSYS simulations, Retrofitting effectiveness, Structural performance, Feasibility

Introduction

In the fast-paced world we live in, it's vital to ensure that our buildings and infrastructure can endure the challenges of time and adapt to new circumstances. Retrofitting, the practice of reinforcing and upgrading existing structures, plays a pivotal role in bolstering structural resilience. Through retrofitting, we can elevate the performance of buildings, bridges, and various infrastructure elements, rendering them more resilient to natural disasters, shifting environmental dynamics, and evolving requirements. Retrofitting offers a proactive approach to fortifying our built environment against the unpredictable forces of nature and the ever-changing demands of society. By reinforcing structures with modern materials, technologies, and design methodologies, we not only extend their lifespan but also enhance their capacity to withstand the rigors of the future. This proactive stance is particularly crucial in regions prone to seismic activity, extreme weather events, or other environmental hazards.

Moreover, retrofitting enables us to optimize existing infrastructure to meet contemporary standards of sustainability, energy efficiency, and safety. By incorporating green building practices, energy-efficient systems, and smart technologies into retrofit projects, we can reduce environmental impact, minimize resource consumption, and enhance occupant comfort and safety. Furthermore, retrofitting presents an opportunity to revitalize aging infrastructure, preserving architectural heritage while integrating modern amenities and functionalities. This balance between preservation and innovation ensures that our built environment remains both culturally significant and functionally relevant in the face of evolving societal needs and technological advancements. In essence, retrofitting embodies a proactive and sustainable approach to fortifying our buildings and infrastructure against the uncertainties of the future. By investing in retrofit projects, we not only safeguard our built heritage but also lay a resilient foundation for generations to come, ensuring that our structures can withstand the test of time and adapt to the challenges that lie ahead.

Methodology

After an earthquake, it's crucial to ensure that essential buildings, such as hospitals, remain operational to provide life-saving services. Retrofitting, the process of strengthening existing structures to withstand seismic activity, is a proactive approach to minimize earthquake damage and ensure the safety of occupants. When selecting a retrofitting method, several factors must be considered to ensure effectiveness and practicality. Firstly, assess the current condition and performance of the structure to determine the required level of improvement. Additionally, the chosen retrofitting method must meet the specific performance goals while considering factors such as execution feasibility, environmental impact, ease of maintenance, and cost-effectiveness.

This study compared various jacketing retrofitting methods to determine which was most suitable for strengthening a G+10-storey RC moment-resisting frame building. The building's dimensions, as shown in figures 1 and 2, including plan dimensions and floor height, were considered in the analysis. Here, we analyze the structural elements, including floor slabs, beams, and columns, using ETABS software. By conducting a comparative study, researchers can evaluate the effectiveness of each retrofitting method in achieving the desired performance improvements while considering practical constraints and economic factors. This approach enables engineers to make informed decisions about which retrofitting method is most suitable for ensuring the structural integrity of important buildings like hospitals, ultimately enhancing community resilience to seismic events.

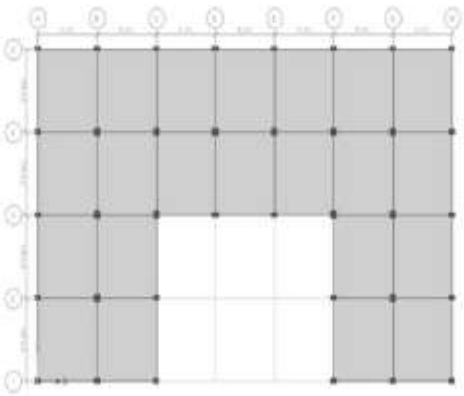

Figure 1. Building Model Plan

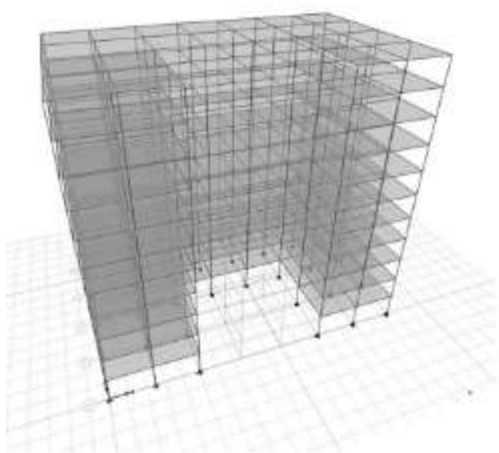

Figure 2. 3D Building Model

Following the completion of the model, a comprehensive analysis is conducted, focusing primarily on response spectrum analysis. We choose this method due to its effectiveness in evaluating structural response under seismic loads. We meticulously apply loading conditions, adhering to default load combinations, using the specifications outlined in IS 875.

Subsequent to the analysis phase, the design process ensues. We follow standard protocols to ensure structural integrity and safety. Upon completion, the structure undergoes meticulous scrutiny, identifying any areas of concern. In this case, we identify a failed column that requires further investigation. We employ CAD modeling to delve deeper into the intricacies of the failed column. We utilize ANSYS 18.1 Workbench, a finite element software renowned for its robustness, for this purpose. Figure 3 depicts the CAD model, which provides a visual representation of the column under examination.

The column undergoes a linear static analysis within the ANSYS environment. This analysis serves to elucidate the behavior of the structure under varying loads and conditions. We meticulously simulate both scenarios, with and without jackets, to discern their impact on the structural integrity of the column. This rigorous process of analysis and simulation provides insights into the structural performance, enabling informed decisions regarding necessary modifications or reinforcements to ensure the safety and longevity of the structure.

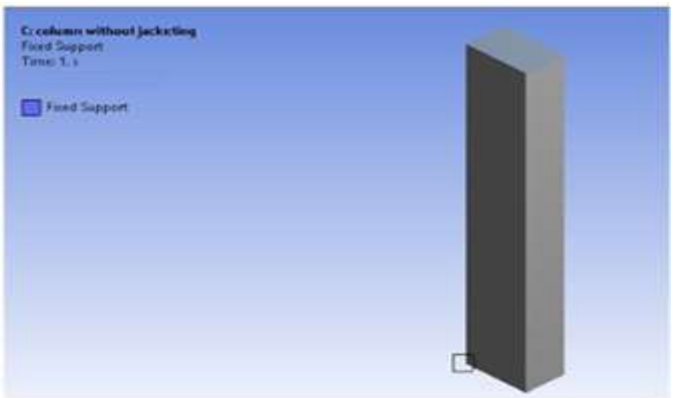

Figure 3. Structural Stability of Fixed Support Columns

Result and Discussion

In this scenario, we conduct the analysis and design of a building using the software ETABS. The architectural plan for the fourth storey and its elevation are provided in Figures 4 and 5, respectively. However, the analysis process identified certain structural elements as failing, particularly a column with dimensions of 350x550. We isolate the design load Pu, which acts on the column, to further investigate the causes and implications of this failure. We then import this load into ANSYS, another analysis software, for a more detailed analysis.
In ANSYS, engineers can perform a variety of simulations and analyses to understand why the column is failing under the designated load. This may involve stress analysis, buckling analyzes, or other forms of structural assessment to pinpoint weaknesses in the column's design or the overall structural system. By transferring the design load to ANSYS, engineers can explore potential solutions or modifications to rectify the issues identified in ETABS. This iterative process allows for a comprehensive understanding of the structural behavior and enables engineers to make informed decisions to enhance the building's stability and safety.

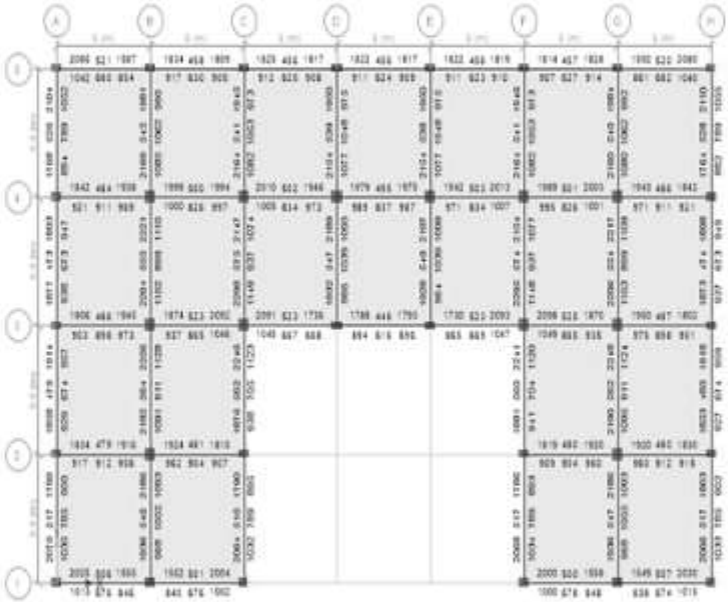

Figure 4. Structure of 4 Storey

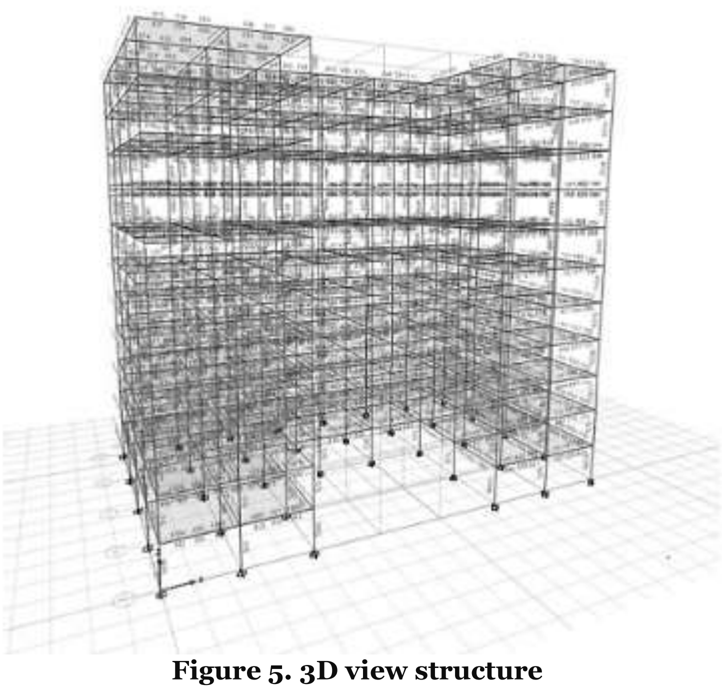

Figure 5. 3D view structure

We obtained certain results after completing the analysis and design process using the ETABS software. Specifically, we discovered the failure of column number 22 on the fourth floor of the building. The analysis revealed that the axial load (Pu) acting on column 22 is 3707.325 kN.

This indicates that the column is unable to withstand the applied load and has failed under the given design conditions. Additional analysis is required to better understand the reasons for this failure and explore potential solutions. As a result, we used ANSYS software to further investigate the Pu value for column 22. In ANSYS, engineers conduct a more detailed analysis to identify the specific factors contributing to column 22's failure. This may involve examining stress distribution, load-carrying capacity, and structural stability.

Result

- **Column without Jacketing**

In this scenario, there's an attempt to assess a failed column that measures 350x550 using ETABS design software. The subsequent step involves replicating this column using the ANSYS 18.1 Workbench, employing finite element analysis (FEA) for a linear static analysis. The objective is to comprehend the structural behavior of the column under various loading conditions.

Initially, we model a concrete control column specimen to establish a baseline for comparison. As a result, this model serves as the foundation for developing the jacketed column model. The dimensions chosen for the column in the simulation are 350x550x3000mm, as illustrated in Figure 6, depicting the geometry of the column devoid of any jacketing.

The column's fixed support configuration, which implies no freedom of movement at the support location, is noteworthy. This fixed support condition is crucial for accurately representing real-world scenarios where columns are often securely anchored to foundations or other structural elements.

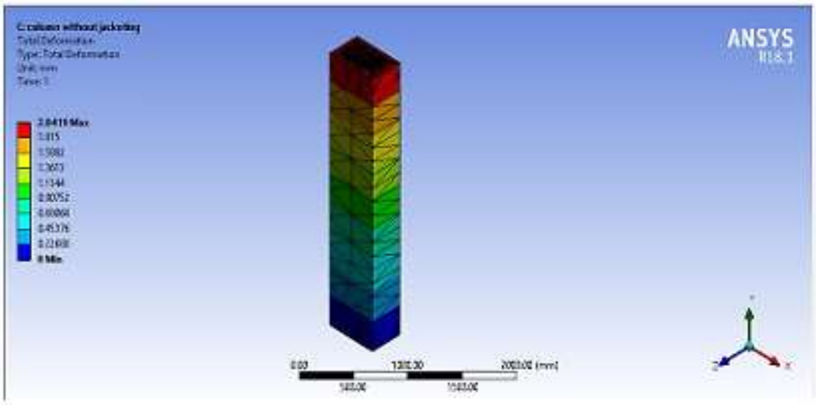

Figure 6. Column without Jacketing

- **Column with CFRP Jacketing**

To mitigate the deformation of the column, engineers have opted for a method involving the application of a Carbon Fiber Reinforced Polymer (CFRP) plate as jacketing. Engineers affix this 40-mm-wide and 8-mm-thick CFRP plate to the column's surface. This approach aims to enhance the structural integrity of the column by providing additional support and strength, thereby minimizing deformation.

Figure 7 depicts the column's configuration with the CFRP jacketing in place. This graphical depiction likely demonstrates the application of the jacketing to the column, providing a clear understanding of the intervention's implementation.

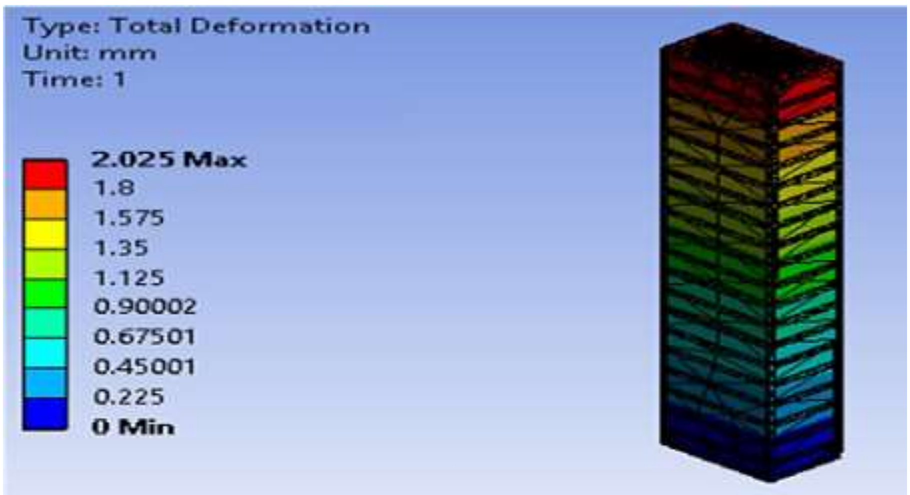

Figure 7. Column with CFRP jacketing

- **Column with Steel Jacketing**

The application of a steel plate as jacketing serves as a strategy to mitigate the deformation of the column. We affix this 40-mm-wide and 8-mm-thick plate around the column. By doing so, the column gains reinforcement, enhancing its capacity to withstand the applied load. The concept of jacketing involves enveloping the column with a material that bolsters its structural integrity, effectively minimizing deformation and enhancing its load-bearing capIn this case, the designated load of 3707.325 kN fortifies the column against deformation, with the steel plate acting as a robust shield.

Figure 8 illustrates the column's configuration with the steel jacketing in place. This geometric representation sheds light on how the jacketing integrates with the column, emphasizing its positioning and relationship with the structural elements. The steel jacketing, through thoughtful design and implementation, plays a critical role in ensuring the column's stability and resilience under significant loads. This approach highlights the significance of strategic reinforcement techniques in structural engineering, which implement proactive measures to improve performance and longevity.

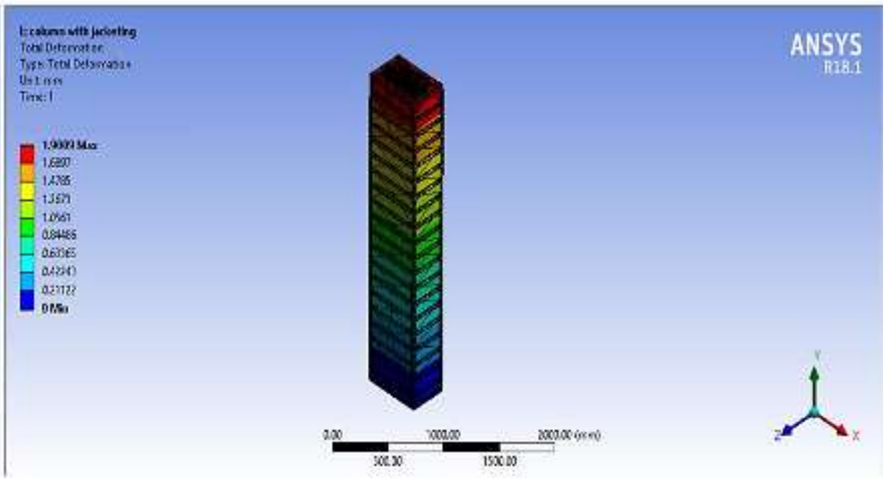

Figure 8. Column's configuration with the steel jacketing

- **Column with GFRP Jacketing**

To minimize the deformation of a column, engineers have employed a technique using Glass Fiber Reinforced Polymer (GFRP) plate as jacketing. This involves wrapping the column with a 40-mm-wide and 8-mm-thick layer of GFRP material, as depicted in Figure 9 of the provided documentation.
By enveloping the column with this specialized material, engineers aim to enhance its structural integrity and resistance to deformation. GFRP, known for its high strength and lightweight properties, serves as an effective reinforcement, helping the column withstand external forces and maintain its shape under load.
Figure 9's geometry demonstrates the application of GFRP jacketing to the column, which covers its surface to offer comprehensive support and protection. This method offers a practical solution for reducing deformation in columns, contributing to the overall stability and safety of the structure.

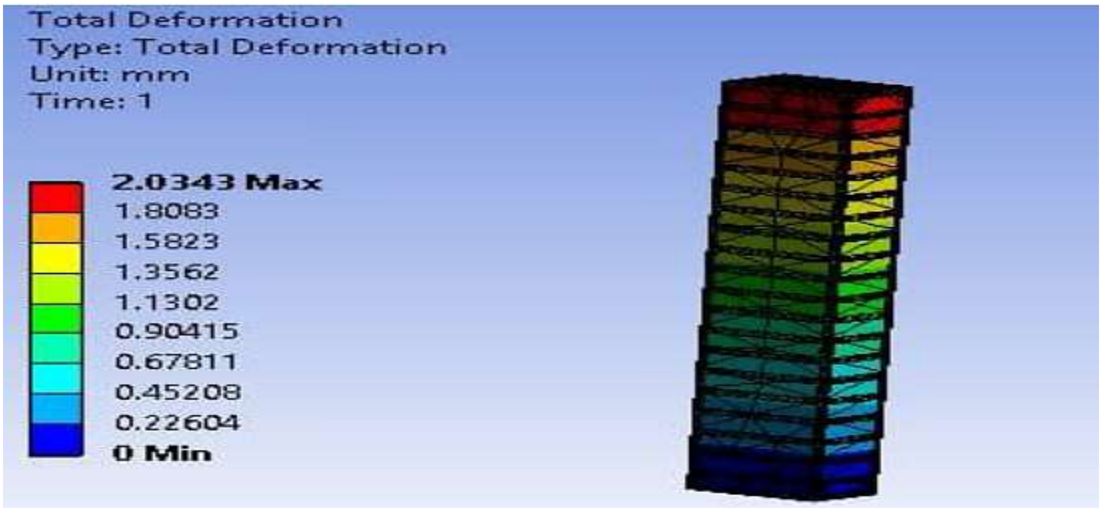

Figure 9. Column with GFRP Jacketing

• Column with RC Jacketing

We employ reinforced concrete (RC) jacketing to minimize column deformation. This involves wrapping the column with additional layers of reinforced concrete. The aim is to enhance the column's strength and stiffness, reducing the risk of deformation, especially under heavy loads or in seismic events. We follow IS 15988:2013 guidelines in the design process. These standards provide specifications and procedures for designing reinforced concrete structures, ensuring they meet safety and performance requirements. By adhering to these standards, engineers can ensure the structural integrity of the column with RC jacketing.
Figure 10 illustrates the column's geometry with RC jacketing. This visual representation helps engineers understand the layout and dimensions of the jacketing, allowing for precise implementation during construction. It demonstrates the integration of additional reinforced concrete layers with the existing column, strengthening it against deformation.

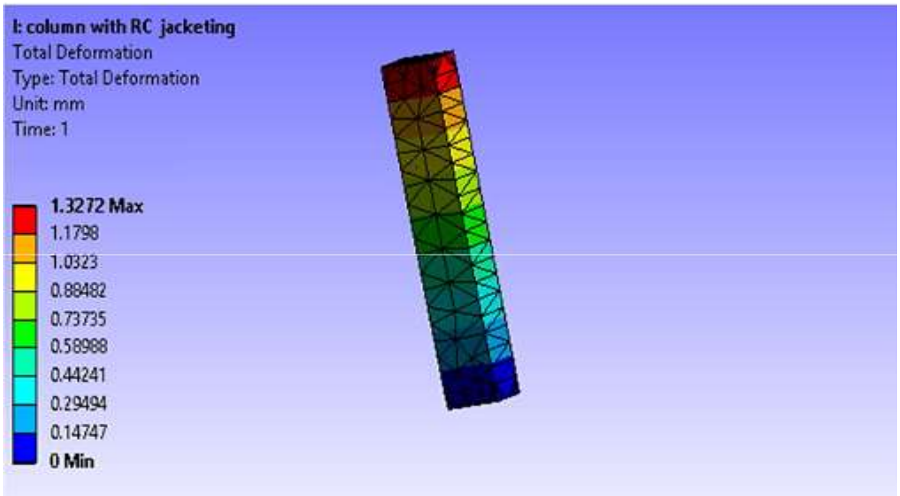

Figure 10. Optimizing Column Strength: Exploring Maximum Deformation with RC Jacketing

In the analysis conducted using ANSYS, different types of columns were studied, including simple columns without jacketing, columns with steel jacketing, columns with RC (reinforced concrete) jacketing, and columns with CFRP (carbon fiber reinforced polymer) and GFRP (glass fiber reinforced polymer) jacketing.
Figure 11 compares and presents the maximum deformation of these columns. This comparison allows us to understand how the different types of jacketing affect the column deformation. By analyzing this data, we can determine which type of jacketing is most effective in reducing deformation and improving the structural integrity of the columns.

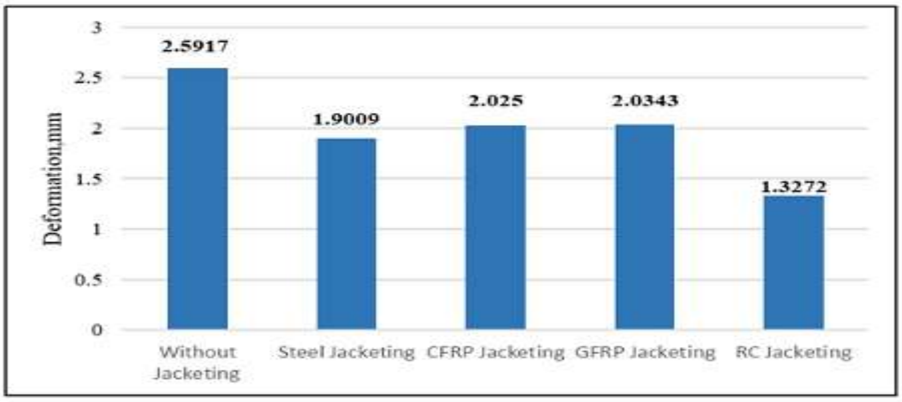

Figure 11. Effectiveness of Various Jacketing Materials on Column Deformation

Conclusion

Retrofitting existing structures is a crucial endeavor to ensure the safety and functionality of essential buildings following seismic events. Through a comprehensive analysis of various jacketing methods, this study sheds light on effective strategies for strengthening RC moment-resisting frame buildings. The comparison of different retrofitting materials reveals nuanced differences in their ability to mitigate column deformation, thereby offering engineers valuable guidance in selecting the most suitable approach for specific structural needs. By prioritizing factors like performance, feasibility, environmental impact, maintenance, and cost-effectiveness, engineers can make informed decisions to enhance the resilience of critical infrastructure, ultimately safeguarding lives and promoting community well-being in earthquake-prone regions.

References

1. Senthilkumar, E, Murugesan, A, and Thirugnanam, G.S (2010), Experimental study on behaviour of Retrofitted with FRP wrapped RC Beam Column Exterior Joints Subjected to cyclic loading, International Journal of Civil and Structural Engineering, 01, 0976 – 4399.
2. Pandey, G.R, Mutsuyoshi, H and Aravinthan, T(2007), Retrofitting Reinforced Concrete Bridge Frames Using Externally Bonded FRP Sheets, Asia-Pacific Conference on FRP in Structures (APFIS 2007), S.T. Smith (ed) © 2007 International Institute for FRP in Construction.
3. Kevadkar, M.D, and Kodag, P.B (2013), Lateral Load Analysis of R.C.C. Building, International Journal of Modern Engineering Research (IJMER), 03, 1428-1434.
4. Antonio Nanni and Bradford, N.M (1995), FRP Jacketed concrete under uniaxial compression, Construction and Building Materials, 09,115-124.
5. AbediniMehrmashhadi,J, Mussa,M.H, Ansari,M and Tohidmomeni (2017),Evaluation of concrete Structures Reinforced with FRP bars: A Review, Journal of Asian Scientific Research,07, 165-175.
6. Abdullah and Takiguchi (2003), An Investigation into behaviour and strength of RC columns strengthened with ferrocement jackets, Cement and Concrete Composites, 25,233-242.
7. Tiwary, A.K, and Mani Mohan (2015), Strengthening Of Exterior Beam Column Joint With Modified Reinforcement Technique, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 32-37.
8. Campione, G, Miraglia, N and Papia, M(2004), Strength and strain enhancements of concrete columns confined with FRP sheets, Structural Engineering and Mechanics,18, 118-126.
9. Sawant, R.M, Junaid Khan, Jabeen Khan, and Waykar, S (2015), Behavior Of High Strength Fiber Reinforced Concrete Under Shear, International Journal of Civil Engineering and Technology (IJCIET), 06, 46-54.
10. Cosenza, E, Manfredi, G and Realfonzo, R, (1997), Behaviour and Modelling of FRP Rebars to Concrete, Journal of composites for construction,1,312-318.
11. Jodawat, A, Parekh, A, Marathe, B, Ketan Pawar , Sunny Patwa , YashSahu and Indrajeet Jain (2016), Retrofitting Of Reinforced Concrete Column by Steel Jacketing, Int. Journal of Engineering Research and Application,06,01-05.
12. Colotti, V and Spadea, G (2001), Shear strength of RC beams strengthened with bonded steel or FRP plates, Journal of structural Engineering, 4,127-135.
13. Ashok kumar, G and Harish Nayak, B (2016) Seismic retrofit of RC building using jacketing – a review and case study, International Journal for Research in Applied Science and Engineering Technology, 5, 18064-18071.
14. Belal, M, Mohamed, H.M and Morad, S (2015) Behavior of reinforced concrete columns strengthened by steel jacket, HBRC Journal,11,201-212.
15. Elsamny, M.K, Hussein, A.A, Nafie, A.M and Abd-Elhamed, M.K (2013),Experimental Study of Eccentrically Loaded Columns Strengthened Using a Steel Jacketing Technique, International Scholarly and Scientific Research & Innovation,7,12-19
16. Tarabia, A.M, and Albakry, H.F (2014) Strengthening of RC columns by steel angles and strips,Alexandria Engineering Journal,53, 615-626.
17. Nagaprasad, P, RanjanSahoo, D and Durgeshrai, C (2009),Seismic strengthening of RC columns using external steel cage, International journal for earthquake engineering,38,1563-1586.
18. Montuori, R and Piluso, V (2009) Reinforced concrete columns strengthened with angles and battens subjected to eccentric load, InternatinalJornl Of Engg Trends And Technology, 31,539-550.
19. Raval, S and Dave, U.V (2013), Effectiveness of Various Methods of Jacketing for RC Beams, Procedia Engineering, 51, 230-239.
20. Chavan, R and M,Rukesh, P (2017), Retrofitting Techniques For Existing Multistoried Building, International Journal of Advanced Scientific Technologies in Engineering aSnd Management Sciences ,03,245-356.
21. Lakade, D and Pise, C.P (2015) Performance of RC Building Under Dynamic Forces and Suitability of Strengthening By FRP Jacketing, International Journal of Civil Engineering and Technology, 06,147-159.
22. Dhanush, S.S, Ummer Farooq Pasha, and Kumar, N.S (2017), Retrofitting of Existing RC Columns by Reinforced Concrete Jacketing Using ANSYS and ETABS, International Journal of Science and Research, 07, 114-121.
23. Robert Sonnenscheina, Katarina Gajdosova, and Ivan Holly (2016) FRP Composites and Their Using in the Construction of Bridges, Procedia Engineering 161, 477 – 482.
24. Nikita Gupta, Poonam Dhiman, and Anil Dhiman (2015) Design and Detailing of RC Jacketing for Concrete Columns, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 54-58.
25. Jayshree Chandrakar, and Ajay Kumar Singh (2017) Retrofitting of RCC Structral Members Using Concrete Jacketing, International Journal of Recent Development in Civil & Environmental Engineering , 2, 30-37.