International Journal of Orthopedic Research and Surgery

https://trpub.org/index.php/IJORSJ

Vol 1, Issue 1, 2026

"Assessment of Capacity in Retrofitted Residential Buildings for Transition to Commercial Use- research."

Ms. Kshitija Wamanrao Deshmukh[1,] Dr. M. M. Pawar[2], Dr. M. G. Deshmukh[3,] Mr.P. B. Bhaganagare[4],

Ms. S. N. Bahirwade[5]

[1,2,3,4] SVERI‟s College of Engineering, Pandharpur

[5]SVERI‟s College of Engineering (Polytechnic), Pandharpur

Abstract

This paper explores the integration of latest advanced materials and technologies with traditional retrofitting methods to optimize performance and cost-effectiveness. Case studies of retrofitted structures utilizing advanced techniques are analysed to assess their performance in real-world scenarios. Additionally, computational modelling and simulation techniques are utilized to predict the behaviour of retrofitted structures under seismic loading, providing valuable insights into their performance and durability. The paper also addresses challenges and considerations associated with the implementation of advanced retrofitting techniques, including material compatibility, construction logistics, and cost considerations. The importance of interdisciplinary collaboration between engineers, architects, and stakeholders is emphasized to ensure the successful implementation of retrofitting projects. This paper highlights the significance of employing advanced techniques such as Geopolymer and Glass fibre-reinforced polymer (GFRP) in retrofitting and strengthening existing structures to enhance their resilience against seismic loading. By leveraging these innovative technologies and methodologies, existing structures can be fortified to mitigate the impact of seismic events, safeguarding lives and preserving critical infrastructure.

Keywords - ***Retrofitting, Seismic Loading, Resilience, Advanced Techniques, Glass Fiber-Reinforced Polymers (GFRP), Geopolymer, Base Isolation Systems.***

Introduction

The Ultrasonic Pulse Velocity (UPV) test is a non-destructive testing method used to assess the quality and integrity of concrete structures. It operates on the principle of measuring the time taken by an ultrasonic pulse to traverse through a concrete structure. The velocity of the pulse is directly related to the density, uniformity, and elasticity of the material. In the context of structural assessment of a building, a higher pulse velocity typically indicates good quality and homogeneous concrete, while a lower velocity may suggest the presence of cracks, voids, or other defects. Therefore, the UPV test provides valuable insights into the structural health of a building, aiding in the identification of potential problem areas that may require further investigation or remediation.
Visual inspection of a building is a crucial first step in identifying any distresses or potential issues that may affect its structural integrity or functionality. This process involves a thorough examination of both the interior and exterior of the building, including the foundation, walls, roof, windows, doors, and other structural elements. Inspectors look for signs of damage or wear, such as cracks, leaks, dampness, bulging, deflection, or corrosion. They also assess the condition of the building‟s systems, including electrical, plumbing, and HVAC. The goal is to identify any immediate concerns and potential future problems. This information can then be used to develop a plan for necessary repairs or preventive measures, ensuring the longevity and safety of the building. It‟s important to note that while visual inspection can reveal a lot, some issues may require further investigation using more specialized techniques or equipment.
Structural Health Monitoring system (SHM) is a method of evaluating and monitoring the health of critical structures. It has been employed for many important projects because of its ability to respond to detrimental structural changes, enhancing structural reliability and improving life cycle management

Structural Health Monitoring provides a tool to ensure structural integrity and safety, detecting the growth of damages and evaluating the performance of infrastructures. Structural Health Monitoring is the process of using damage detection and characterization techniques for critical structures like bridges, wind turbines and tunnels. It is a non-destructive in-situ structural evaluation method that employs several types of sensors embedded or attached to the structure. Its process includes installing sensors, data acquisition, data transfer and diagnostics through which the structure's safety, strength, integrity and performance are monitored. If overloading or any other defects are observed, proper correction measures are suggested.

Literature Review

Investigated the efficacy of bio-based polyurethane coatings in enhancing the dynamic mechanical response of concrete under quasi-static and dynamic loads. Their experimental findings revealed that applying PU coatings on concrete specimens significantly increased dynamic resistance, especially with increased coating thickness. The study emphasized the potential of PU coatings, derived from palm kernel oil, as a sustainable and effective technique for protecting concrete structures against dynamic loads[1]. Improvements to the thermal performance of existing buildings is a vital activity to mitigate climate change, and often has additional benefits in the form of improved comfort, health and well- being for occupants. Despite the extensive body of literature in this area, it remains a difficult task to assess the performance of retrofit packages in occupied residential buildings. Experimental methods often fail to isolate the effect of retrofits from the numerous confounding factors, while modelling studies are prone to uncertainties and simplifications[2]. This paper provides an up-to-date review of the features and capabilities of 18 energy retrofit toolkits, including ECMs and the calculation engines. The fidelity of the calculation techniques, a driving component of retrofit toolkits, were evaluated. An evaluation of the issues that hinder effective retrofit analysis in terms of accessibility, usability, data requirement, and the application of efficiency measures, provides valuable insights into advancing the field forward[3]. Urban planners face significant challenges when identifying building energy efficiency opportunities and developing strategies to achieve efficient and sustainable urban environments. A possible scalable solution to tackle this problem is through the analysis of building stock databases. Such databases can support and assist with building energy benchmarking and potential retrofit performance analysis. However, developing a building stock database is a time-intensive modeling procedure that requires extensive data (both geometric and non-geometric). Furthermore, the available data for developing a building database is sparse, inconsistent, diverse and heterogeneous in nature[4]. This paper describes the development of a residential building stock model for the Kingdom of Saudi Arabia using an engineering bottom-up approach. The model is suitable for evaluating the impact of any energy efficiency or demand-side management program targeted for the residential building sector. The model accounts for the make-up and the characteristics of the existing Saudi housing stock using 54 prototypes representing KSA residential buildings including their type, vintage, and location. The model relies on a detailed building simulation tool to predict hourly energy consumption[5]. Understanding the process of domestic retrofit is important for learning and innovation. This is particularly the case for low carbon retrofits such as those undertaken under the UK's Retrofit for the Future (RftF) programme, with its aim to achieve an overall 80% carbon reduction by 2050. Current post-occupancy evaluation (POE) research has both theoretical and methodological limitations with implications for technical and behavioural research in the built environment. Drawing on relevant ideas and concepts from social practice theory and science and technology studies, principally prefiguration (constraints/enablement), black-boxing, heating and cooling practices, this paper demonstrates how the relationship between buildings and people could be reconceptualized as mutually constitutive and co-evolving through a process of „interactive adaptation‟[6]. Buildings consume more than one-third of the world‟s primary energy. Reducing energy use in buildings with energy efficient technologies is feasible and also driven by energy policies such as energy benchmarking, disclosure, rating, and labeling in both the developed and developing countries. Current energy retrofits focus on the existing building stocks, especially older buildings, but the growing number of new high performance buildings built around the world raises a question that how these buildings perform and whether there are retrofit opportunities to further reduce their energy use[7].

In this paper, an overview of the Kuwaiti energy sector characteristics is presented to include its generating capacity as well as its end-use consumption over the last two decades. Moreover, a detailed analysis of the total and end-use energy consumption attributed to various building types is provided. The paper presents the specific regulations of the building energy conservation code of practice using its original version of 1983 and its revised version of 2010. The code enforcement mechanism is also outlined[8].

Methodology

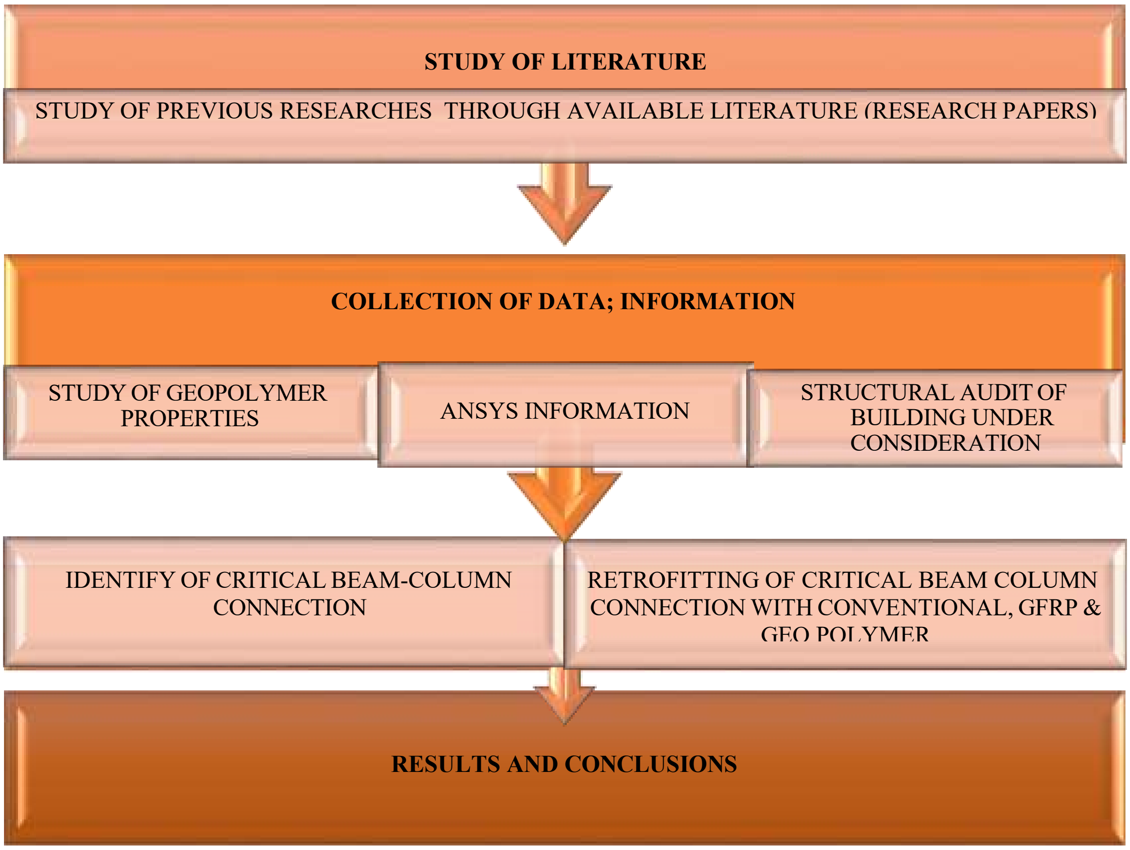
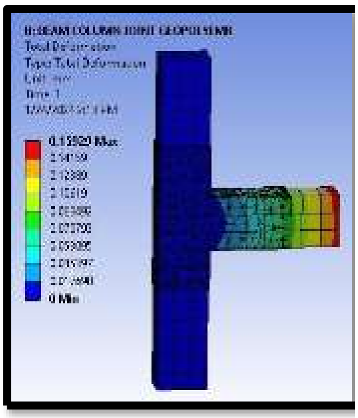


Fig 1 Flowchart

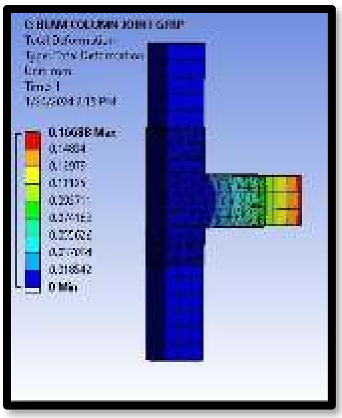
Representation of the Results Achieved in Ansys Software

The major goal of this research is to undertake a full structural analysis using ANSYS software to compare and assess models made of three different materials (as shown below) in order to determine the most effective material in terms of structural performance, seismic resilience and efficiency. This section meticulously dissects key parameters such as deformation, equivalent stress and equivalent strain, offering a comprehensive and quantifiable assessment of the seismic resilience and structural enhancement achieved through these retrofitting techniques. The incorporation of ANSYS not only enhances the precision of the study but also establishes a scientific basis for the conclusions drawn, bolstering the credibility and significance of the research findings.

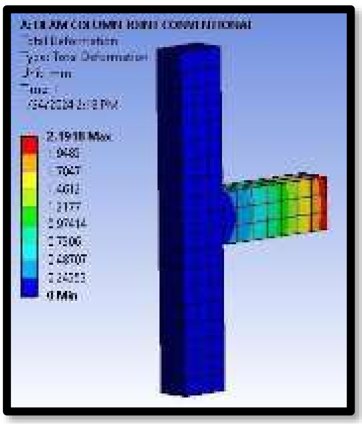
Model with Geo polymer **Model with GFRP** **Conventional Model**



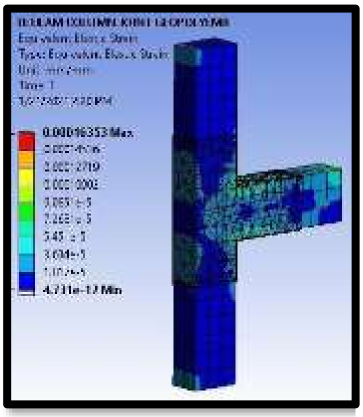
Total Deformation



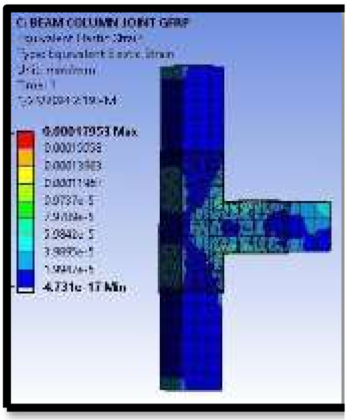
Total Deformation



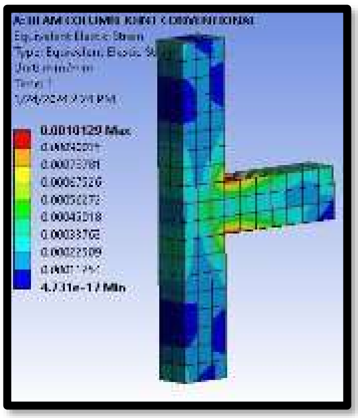
Total Deformation



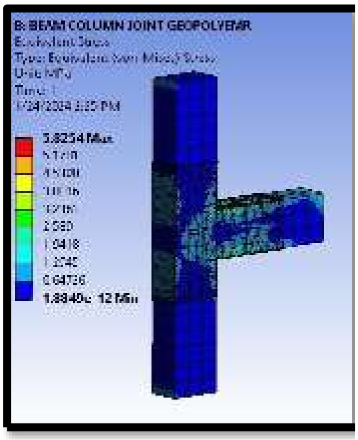
Equivalent Elastic Strain



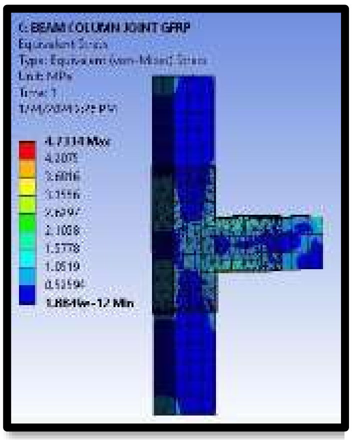
Equivalent Elastic Strain



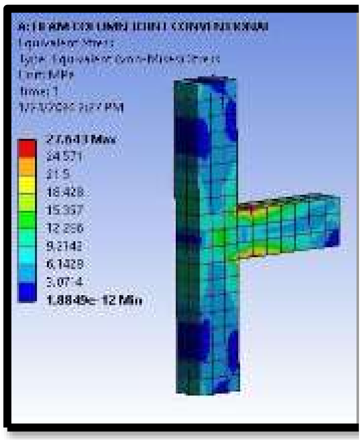
Equivalent Elastic Strain



Equivalent Stress



Equivalent Stress



Equivalent Stress

Key Material properties

- Geopolymers: Structures, Processing, Properties and Industrial Applications" by J. L. Provis and J. S. J. van Deventer.
- "Mechanics of Fiber and Textile Reinforced Cement Composites" by Barzin Mobasher.

Table: 3.2 Key Material Properties

Property	GFRP	Geopolymer
Modulus of elasticity in KN/m^2	$2.1*10^5$	$3.0*10^5$
Poisson‟s ratio	0.26	0.3
Shear modulus in KN/m^2	1520	1500
Density in KN/m^3	17.3	26.5

Software Proposed: Staad Pro

STAAD.Pro is a structural analysis and design software tool that was created in 1997 by Research Engineers International. Bentley Systems acquired Research Engineers International in late 2005. STAAD Pro is a structural analysis and design software application that is extensively used across the globe. It complies with over 90 international design regulations for steel, concrete, wood, and aluminium. It may use a variety of analytical techniques, ranging from classical static analysis to more contemporary techniques such as p-delta analysis, geometric non-linear analysis, pushover analysis (Static-Non Linear Analysis), or buckling analysis. Additionally, it may make use of a variety of dynamic analytic techniques, ranging from time history analysis to response spectrum analysis. The response spectrum analysis capability works with both user-defined and a variety of international code- defined spectra. Additionally, STAAD Pro is compatible with products such as RAM Connection, Auto PIPE, and SACS, as well as a variety of other engineering design and analysis software, which facilitates cooperation across the many disciplines involved in a project. STAAD may be used to analyse and design a wide variety of structural structures, ranging from plants and buildings to towers, tunnels, metro stations, and water/wastewater treatment facilities.

Modelling of building on STAAD.Pro

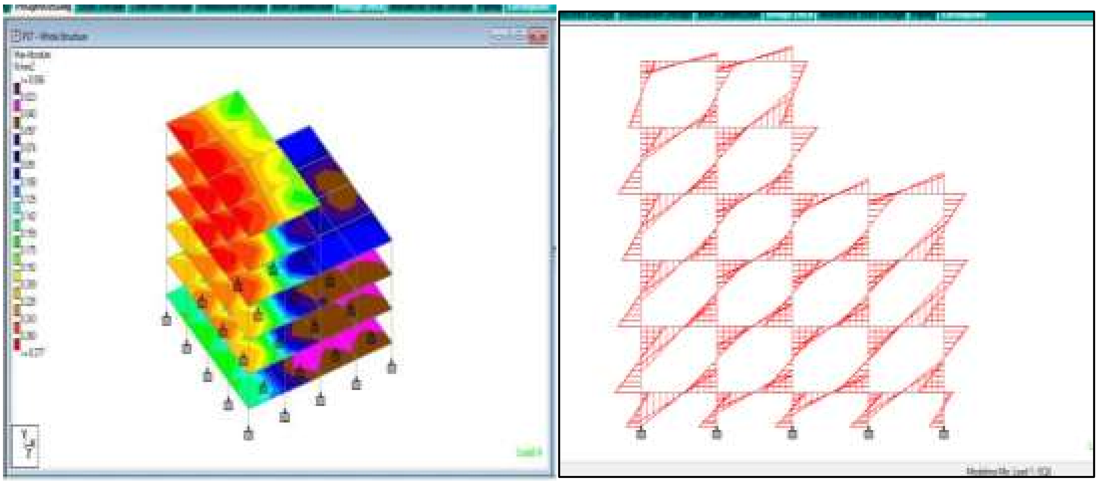


Fig 2 Modelling of building on STAAD.Pro

Structural Analysis of the Building under Consideration

The seismic loading conditions are a critical aspect of the structural analysis for the G+3 RCC building. Seismic loads, which represent the forces exerted on the building during an earthquake, are significant factors in determining the structural integrity and stability of the building. These loads are typically defined based on the seismic zone in which the building is located, in this case, Zone IV. including the distribution of forces throughout the structure, the potential for structural deformation, and the adequacy of the building's seismic design measures. The goal of the structural analysis is to ensure that the building can withstand seismic events and maintain its safety and functionality.

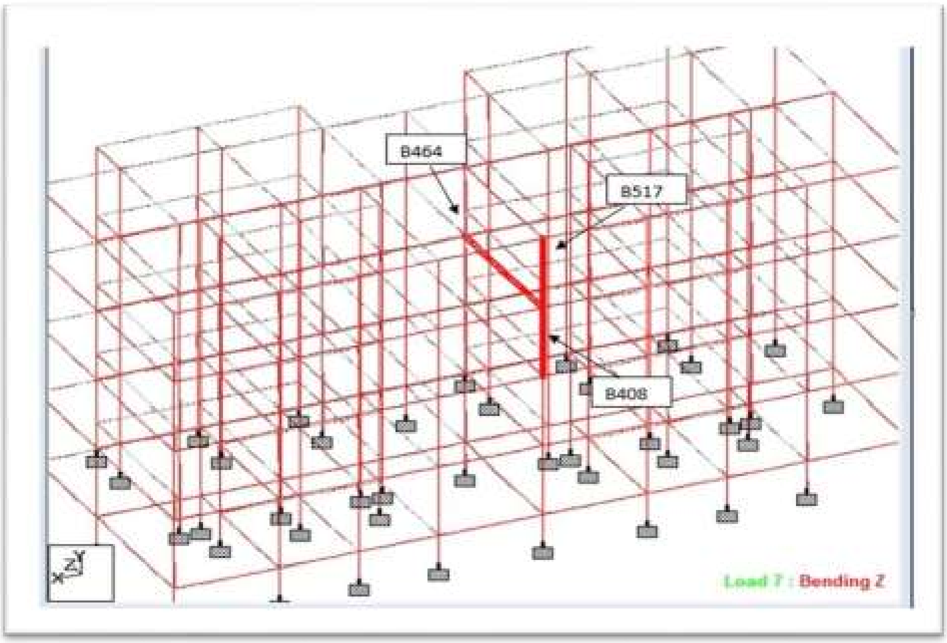


Fig: 3 Plan view

Seismic analysis of the building

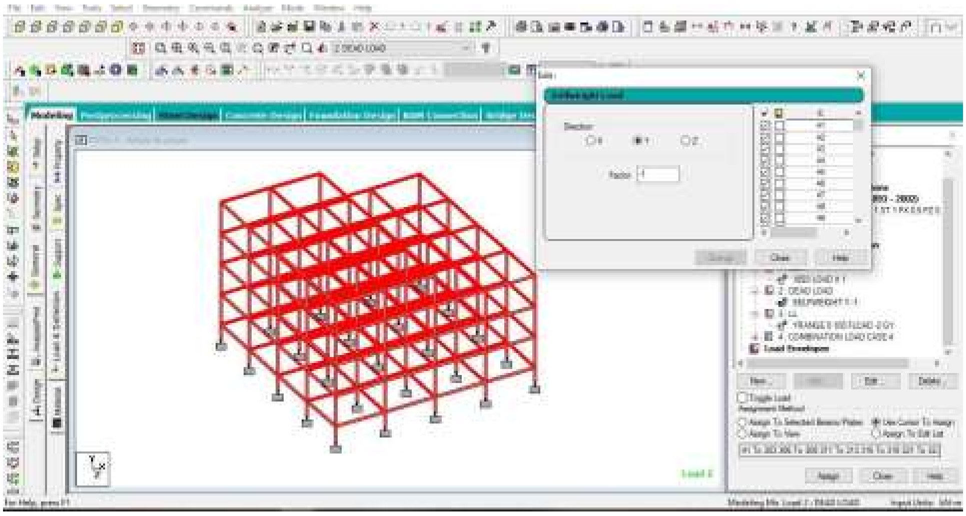


Fig: 4 Dead load

Beam-Column Connections

The beam-column connection is one of the few vital regions determining the efficiency of a framed or partially-framed structure. The present need is to develop a rational analytical model capable of predicting the ultimate capacity of a variety of embedded steel member precast connections. The development of this analytical model is based on the results of a series of experiments in which the different variables like effect of column axial load, effect of additional welded reinforcement, effect of shape of embedded member were studied. The analytical model has been used to construct a series of non-dimensional design curves for connections with or without additional welded reinforcement. The connection between the beam and column must be strong enough as it serves as part of the vertical load resisting system in order to comply with one of the failure modes in which the beams must fail before columns. The joint will be the most critical area to resist the reaction forces. Its characteristics affect the global behavior of the whole structure. Therefore, the strength of the joint has to be higher than the strength of the member it joins. As in RCC Beam-Column joint due to the closely spaced reinforcement it obstructs the easy flow of concrete in it and may lead to improper compaction of concrete at joint of honey combing. The designed joint may fail in shear and the beam bars slipped only after the first cycle of inelastic loading.

The building under consideration was analyzed for the standard combination of loads i.e. 1.2(DL+LL+EQX) and the beam with maximum bending moment (B464) was identified for analysis in ANSYS Workbench 16.

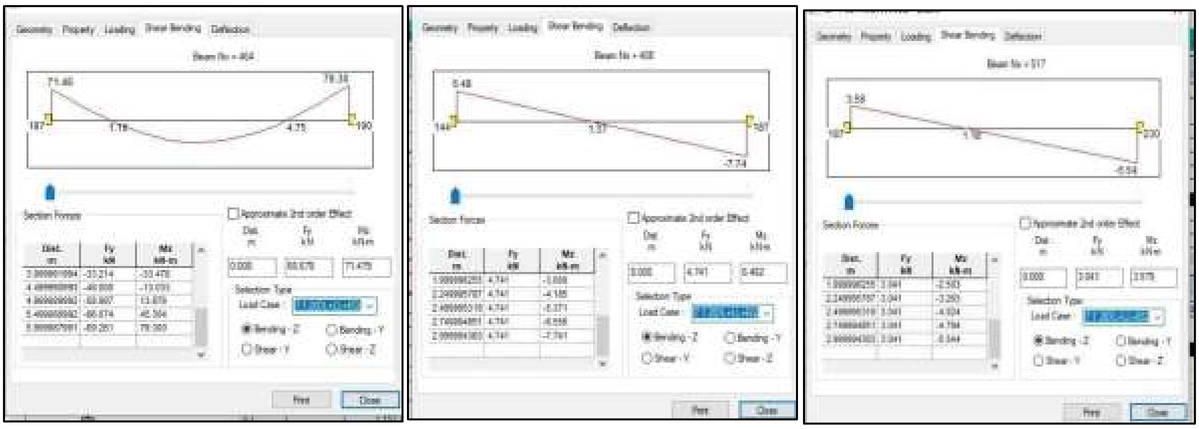


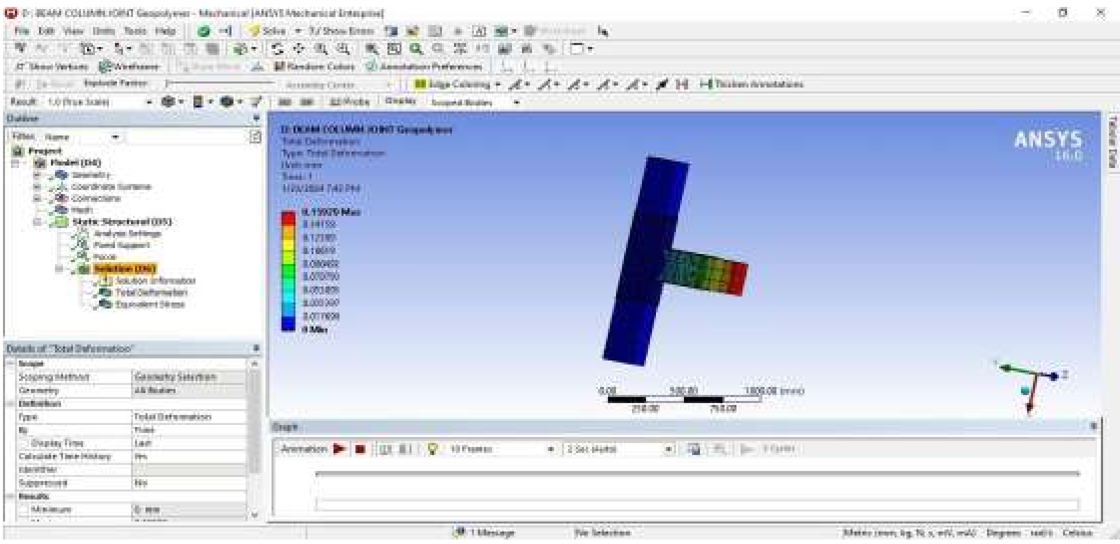
Fig 5 identifying critical joints (analyzed using STAAD.Pro software)

Retrofitting of the Structure

Seismic events pose a significant threat to structures, necessitating robust retrofitting strategies to enhance seismic resilience and overall structural performance. The following comparative analysis critically evaluates the three mentioned retrofitting techniques by examining key technical parameters and performance indicators. These observations will subsequently be attempted to correlate in the upcoming sections of the paper using analytical results. A few examples of retrofitting using various techniques under consideration are as under:

Conventional With **GFRP bars** **With Geopolymer**

Retrofitting of the Critical Joint using Geopolymer based technique



Conclusion

In the quest to identify the critical beam-column joint within the enduring G+3 RC edifice, our meticulous utilization of advanced STAAD.Pro software resulted in a precise pinpointing of this pivotal juncture. This endeavor, conducted within the framework of a rigorous structural audit, ensured a thorough assessment of the building's integrity, focusing keenly on extreme conditions of shear force and bending moment. Our comparative analysis further enriched our understanding, as we delved into an exhaustive exploration of retrofitting methodologies. Leveraging the formidable capabilities of Finite Element Method (FEM) analysis, we discerned that the Glass Fiber Reinforced Polymer (GFRP) retrofitting technique yielded minimal equivalent stress, followed closely by Geopolymer-based retrofitting. In stark contrast, conventional techniques exhibited notable escalations in stress levels. Moreover, our scrutiny of equivalent strain underscored the superiority of Geopolymer-based retrofitting, with GFRP solutions trailing closely behind. Conversely, conventional techniques displayed pronounced elevations in equivalent strain, indicating a less favorable structural response. Our meticulous calculations further unveiled significant disparities in total deformation across retrofitting methodologies, with Geopolymer-based solutions demonstrating the most favorable outcomes. This disparity extended to load-carrying capacity, where both GFRP and Geopolymer-based solutions exhibited substantial augmentations, surpassing conventional techniques. Finally, our comprehensive assessment culminated in the validation of augmented structural strength and longevity conferred by modern retrofitting techniques. The discernible increase in seismic resilience extends newfound confidence in the structural integrity of the retrofitted building, prolonging its lifespan by a conservative estimate of 8-10 years and ensuring sustained safety and functionality for its occupants.

References

[1] H. M. C. C. Somarathna, S. N. Raman, D. Mohotti, A. A. Mutalib, and K. H. Badri, "Behaviour of concrete specimens retrofitted with bio-based polyurethane coatings under dynamic loads," *Constr. Build. Mater.*, vol. 270, p. 121860, Feb. 2021, doi: 10.1016/j.conbuildmat.2020.121860.

[2] A. Carratt, G. Kokogiannakis, and D. Daly, "A critical review of methods for the performance evaluation of passive thermal retrofits in residential buildings," *J. Clean. Prod.*, vol. 263, p. 121408, Aug. 2020, doi: 10.1016/j.jclepro.2020.121408.

[3] S. H. Lee, T. Hong, M. A. Piette, and S. C. Taylor-Lange, "Energy retrofit analysis toolkits for commercial buildings: A review," *Energy*, vol. 89, pp. 1087–1100, Sep. 2015, doi: 10.1016/j.energy.2015.06.112.

[4] A. Javanmardi, K. Ghaedi, F. Huang, M. U. Hanif, and A. Tabrizikahou, "Application of Structural Control Systems for the Cables of Cable-Stayed Bridges: State-of-the-Art and State-of-the- Practice," *Arch. Comput. Methods Eng.*, vol. 29, no. 3, pp. 1611–1641, May 2022, doi: 10.1007/s11831-021-09632-4.

[5] M. Krarti, M. Aldubyan, and E. Williams, "Residential building stock model for evaluating energy retrofit programs in Saudi Arabia," *Energy*, vol. 195, p. 116980, Mar. 2020, doi: 10.1016/j.energy.2020.116980.

[6] L. F. Chiu, R. Lowe, R. Raslan, H. Altamirano-Medina, and J. Wingfield, "A socio-technical approach to post-occupancy evaluation: interactive adaptability in domestic retrofit," *Build. Res. Inf.*, vol. 42, no. 5, pp. 574–590, Sep. 2014, doi: 10.1080/09613218.2014.912539.

[7] T. Hong, L. Yang, D. Hill, and W. Feng, "Data and analytics to inform energy retrofit of high performance buildings," *Appl. Energy*, vol. 126, pp. 90–106, Aug. 2014, doi: 10.1016/j.apenergy.2014.03.052.

[8] M. Krarti, "Evaluation of large scale building energy efficiency retrofit program in Kuwait," *Renew. Sustain. Energy Rev.*, vol. 50, pp. 1069–1080, Oct. 2015, doi: 10.1016/j.rser.2015