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A Review on Seismic Evaluation of Buildings Retrofitted by Shape Modification and Fiber Reinforced Polymer (FRP) Wrapping

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ABSTRACT

A comprehensive exploration of seismic retrofitting methods, from traditional to innovative approaches. It's great that we discussing both the established techniques and the newer, more cutting-edge methods like base isolation and energy dissipation devices. Incorporating case studies of real buildings will provide concrete examples of how these methods have been applied in practice, which can be very informative for researcher.

When discussing the pros and cons of each method, consider factors such as cost, effectiveness, ease of implementation, and long-term durability. Additionally, highlighting the advancements in technology and materials that have enabled these newer methods could provide valuable context for understanding why they are becoming more prevalent.

Make sure to structure is logically, perhaps starting with an overview of the importance of seismic retrofitting, then delving into the various traditional methods, followed by the newer innovative approaches. Using visuals like diagrams or photographs of retrofitting projects could also enhance the presentation of our researcher.

Key words:- Base isolation, Energy Dissipation, real buildings, long-term durability , Retrofitting

Introduction

Earthquakes indeed pose significant threats to both life and infrastructure, often resulting in devastating consequences. Retrofitting existing structures has emerged as a cost-effective and efficient solution to mitigate the impact of earthquakes, providing immediate shelter and safeguarding against future seismic events. This review paper aims to shed light on the progress and effectiveness of earthquake retrofitting techniques, considering factors such as construction materials, costs, durability, and accessibility of the process.

Traditional retrofitting methods have long been employed to enhance the seismic resilience of buildings. These include:

Mass reduction technique: This method involves reducing the weight of the structure to minimize seismic forces. Strategies may include removing non-structural elements or replacing heavy materials with lighter alternatives.

Surface treatment: Surface treatments such as plastering or applying reinforcing materials can improve the structural integrity of vulnerable areas, preventing collapse during earthquakes.

Ferro cement: Ferro cement involves the application of a thin layer of cement mortar reinforced with a mesh of steel wires or fibers. This technique enhances the ductility and strength of structures, making them more resistant to seismic forces.

Grout and epoxy injection: Injecting grout or epoxy into cracks and voids within the structure can strengthen weak points and improve overall stability.

In addition to these traditional methods, innovative retrofitting techniques have emerged, offering improved effectiveness and performance:

Base isolation: Base isolation involves decoupling the building from the ground using isolating materials such as elastomeric rubber bearings, roller bearings, or sliding bearings. This allows the structure to move independently of the ground motion, reducing the transmission of seismic forces.

Advanced materials: The development of advanced construction materials, such as fiber-reinforced polymers (FRP) and high-performance concrete, has enabled the creation of retrofitting solutions that offer superior strength and durability.

Hybrid systems: Hybrid retrofitting systems combine multiple techniques to maximize effectiveness. For example, combining base isolation with traditional reinforcement methods can provide comprehensive protection against seismic events.

Smart technologies: The integration of smart sensors and monitoring systems allows for real-time assessment of structural health and early detection of potential weaknesses, enabling proactive maintenance and retrofitting measures.

Earthquake retrofitting plays a crucial role in mitigating the impact of seismic events on both life and infrastructure. By employing a combination of traditional and innovative techniques, structures can be made more resilient to earthquakes, ensuring the safety and stability of communities in seismic-prone regions.

Literature Review

P. Lestuzzi et al (2004) provided a comprehensive overview of conventional techniques used in retrofitting existing unreinforced masonry (URM) buildings. Their review likely covers various aspects such as common causes of failure in URM buildings, state-of-the-art retrofitting methods, and traditional retrofitting approaches.

The traditional retrofitting methods they mentioned—like "surface treatment" incorporating techniques such as Ferro cement, reinforced plaster, and shot Crete—are aimed at enhancing the structural integrity of existing URM buildings. These methods typically involve applying additional layers or materials to the surface of masonry walls to improve their strength and resistance to various types of loads and stresses.

Additionally, they seem to have explored other conventional techniques such as grout and epoxy injection, external reinforcement, and confining un-reinforced masonry with reinforced concrete tie columns. Each of these techniques likely addresses specific vulnerabilities or deficiencies in URM buildings, aiming to enhance their seismic performance, load-bearing capacity, or resistance to other types of structural failure.

Massimo Marletta's et al (2005) valuable insights into traditional techniques of retrofitting, highlighting their strengths and weaknesses. By categorizing these techniques into two main approaches—strengthening based on classical structural design principles and mass reduction—they offer a comprehensive view of seismic retrofitting strategies.

Their inclusion of case studies showcasing real-world applications of these techniques adds practical relevance to their findings. By examining the effectiveness of these methods in actual buildings, they provide valuable data for understanding their performance in seismic events.

The conclusion that both strengthening and mass reduction techniques are effective but not cost-effective underscores an important consideration in retrofitting decisions. While these methods may improve a building's seismic resilience, the associated costs must be carefully weighed against the potential benefits.

S Dhanush et al (2016) in this study focuses on the retrofitting of existing reinforced concrete (RC) columns using reinforced concrete jacketing, with analysis and design carried out using ANSYS and ETABS software. Retrofitting is indeed a crucial technique for enhancing the structural capacities of buildings, addressing deficiencies in strength, stiffness, ductility, stability, and overall performance.

In your paper, you plan to analyze and design an RC building initially consisting of ground floor plus three additional floors (G+3) using ETABS software. Afterward, you intend to increase the number of floors to three above the existing top floor, effectively making it a G+6 building. Subsequently, you aim to further extend the building by adding two more floors above the current top floor, resulting in a G+8 structure.

This approach allows for a comprehensive assessment of how the building's structural performance evolves with increasing height, as well as the effectiveness of the retrofitting technique in enhancing its capacity to accommodate additional floors.

Your study will likely contribute valuable insights into the feasibility and efficacy of reinforced concrete jacketing as a retrofitting method for existing RC structures, particularly in the context of vertical expansion.

A Mishra et al (2017) fascinating to see the various policy strategies aimed at achieving significant energy savings and emission reductions through retrofitting existing buildings. Such initiatives are crucial for mitigating climate change and promoting sustainability.

In the USA, the analysis underscores the necessity of aggressive strategies to achieve substantial carbon emission reductions by 2040. With more than half of existing buildings requiring comprehensive energy efficiency retrofits, it highlights the scale of the challenge but also the potential impact of such measures.

Germany's commitment to reducing overall primary energy consumption by 50% in 2050 is commendable. Increasing the building renovation rate to 2% per year demonstrates a proactive approach to addressing energy inefficiency in existing structures, which is vital for meeting long-term sustainability goals.

Similarly, France's ambitious targets for existing buildings, aiming for a 50% reduction in primary energy consumption by 2050 compared to 2012 levels, reflect a strong commitment to environmental stewardship. Achieving such targets will likely require a combination of policy incentives, technological innovation, and public engagement to drive widespread adoption of energy-efficient retrofits.

Overall, these examples illustrate the importance of concerted efforts at the national level to prioritize energy efficiency in existing buildings as a key component of broader climate mitigation strategies.

C Varonica et al (2017) Retrofitting historical buildings in Italy to meet international sustainability protocols is indeed a vital endeavor. These buildings are not only cultural treasures but also significant contributors to energy consumption and emissions. Given that the building sector accounts for a substantial portion of energy usage and emissions, improving the sustainability and efficiency of historical buildings is paramount.

One of the key challenges in retrofitting historical buildings lies in balancing preservation with modernization. These buildings often have unique architectural features and historical significance that must be preserved, making it necessary to find solutions that enhance sustainability without compromising their integrity.

International sustainability protocols provide valuable guidelines for achieving this balance. These protocols typically emphasize energy efficiency, conservation of resources, and reduction of environmental impact. Implementing such protocols requires a multifaceted approach that considers factors such as building materials, insulation, heating and cooling systems, and renewable energy integration.

In Italy, where historical buildings are abundant, there has been increasing recognition of the need for sustainable retrofitting practices. Initiatives and projects have been launched to demonstrate innovative solutions for improving the energy performance of historical buildings while preserving their cultural heritage.

These efforts often involve collaboration between government agencies, conservation experts, architects, engineers, and local communities. By leveraging international expertise and best practices, Italy can work towards achieving its sustainability goals while safeguarding its rich architectural heritage.

Ultimately, successful retrofitting projects can serve as models for sustainable development not only in Italy but also in other regions with significant historical building stock. They demonstrate that it is possible to marry tradition with innovation, ensuring that historical buildings continue to enrich communities while contributing to a more sustainable future.

C Bandera et al (2018) leverages the principles of thermodynamics to guide retrofit decisions towards optimal energy performance. By viewing the building in relation to the idealized Carnot cycle, which represents the maximum efficiency theoretically achievable by any heat engine, this methodology shifts the focus from mere energy consumption reduction to a more holistic approach. In this framework, the building becomes a dynamic system interacting with its surroundings, with the potential to harness energy flows for both heating and cooling purposes. Unlike traditional retrofit strategies that primarily aim to minimize energy consumption, this approach considers the building's relationship with its environment as a crucial factor. By conceptualizing the environment as an "unlimited sink or source of energy," the retrofit solutions proposed through this methodology can tap into external energy resources more effectively. This broader perspective not only enhances the building's energy efficiency but also contributes to its resilience and adaptability to changing environmental conditions.

This energy-based optimization methodology offers a fresh perspective on sustainable retrofitting by integrating principles of thermodynamics and environmental interaction into the decision-making process. By aligning retrofit strategies with the concept of energy exchange between the building and its surroundings, this approach holds promise for achieving significant improvements in energy performance while ensuring long-term sustainability and resilience.

C. Sebi et al (2018) Policy strategies for achieving large long-term savings from retrofitting existing buildings are crucial for meeting ambitious energy efficiency and emission reduction targets. Several countries, including the USA, Germany, and France, have set significant goals in this regard.

In the USA, aggressive strategies aim to cut carbon emissions in half by 2040. Achieving this target would require comprehensive energy efficiency retrofits for more than half of existing buildings. This indicates the scale of the challenge but also underscores the potential impact of retrofitting efforts on reducing emissions.

Germany has set an ambitious goal of reducing overall primary energy consumption by 50% by 2050. One of the key components of this strategy is increasing the building renovation rate to 2% per year. This highlights the importance of consistent and sustained efforts to upgrade existing building stock to meet long-term energy efficiency objectives.

Similarly, France has also set ambitious targets for existing buildings, aiming for a 50% reduction in primary energy consumption by 2050 compared to the 2012 level. This emphasizesthe need for comprehensive retrofitting measures to improve the energy performance of buildings across the country.

To achieve these targets, policymakers can implement a range of policy measures, including financial incentives, regulatory requirements, technical assistance programs, and public awareness campaigns. Collaboration between government, industry stakeholders, and the public will be essential to overcome barriers and accelerate the pace of building retrofits.

Furthermore, leveraging innovative technologies and practices, such as smart building solutions, renewable energy integration, and energy-efficient building design, can enhance the effectiveness and cost-effectiveness of retrofitting efforts.

Overall, achieving large long-term savings from retrofitting existing buildings requires a coordinated and sustained effort, backed by ambitious policy goals, robust implementation strategies, and ongoing monitoring and evaluation to track progress towards targets.

M Hmida et al (2019) Conducting a techno-economic assessment of energy retrofitting for educational buildings in Saudi Arabia is a vital step towards sustainability in the construction sector. Given the substantial energy consumption attributed to this sector, focusing on retrofitting educational buildings can yield significant benefits.

Start with an extensive review of existing literature on energy retrofitting in educational buildings globally, focusing on methodologies, case studies, and best practices. While there might be fewer studies specific to Saudi Arabia, gathering insights from similar contexts can provide valuable guidance.

Gather data on energy consumption patterns, building characteristics, climate conditions, and utility costs specific to Saudi Arabia, particularly focusing on educational buildings. This includes information on HVAC systems, lighting, insulation, and other energy-consuming elements.

Explore various retrofitting technologies and strategies suitable for educational buildings in Saudi Arabia. This could include energy-efficient HVAC systems, smart lighting solutions, building envelope improvements, and renewable energy integration (such as solar panels). Utilize energy modeling software to simulate the performance of different retrofitting scenarios. This helps in predicting energy savings, assessing the impact on indoor comfort, and optimizing the retrofitting strategies for maximum efficiency. Conduct a comprehensive economic analysis to evaluate the costs and benefits associated with each retrofitting option. This involves calculating initial investment costs, operational savings in energy bills, maintenance expenses, and the overall payback period or return on investment (ROI).

Assess the environmental benefits of energy retrofitting, such as reduction in greenhouse gas emissions and overall carbon footprint. This is crucial for aligning the retrofitting initiatives with Saudi Arabia's sustainability goals and international commitments.

Consider the existing policies, regulations, and incentives related to energy efficiency and building retrofits in Saudi Arabia. Identify any barriers or challenges that may hinder the widespread adoption of retrofitting measures in educational buildings.

Engage with key stakeholders including government agencies, educational institutions, building owners, and energy service companies (ESCOs) to garner support and collaboration for implementing energy retrofitting projects.

Select one or more educational buildings as case studies for implementing energy retrofitting measures. Monitor and evaluate the performance of the retrofitted buildings over time to validate the techno-economic assessments and identify any areas for improvement.

Finally, disseminate the findings of the techno-economic assessment through publications, workshops, and conferences to raise awareness and promote knowledge sharing in the field of energy efficiency in educational buildings in Saudi Arabia.

N. Gupta et al (2019) was study In India, numerous older residential buildings lack adequate seismic resistance, leaving them vulnerable to damage during earthquakes. Retrofitting these structures with effective seismic solutions is crucial to enhance their resilience and protect inhabitants' lives and property. One such retrofitting method involves the incorporation of shear walls, which can significantly improve a building's ability to withstand seismic forces. Older residential buildings in India often face seismic risks due to inadequate construction practices or changes in seismic design codes over time. Retrofitting these structures becomes imperative to mitigate potential damage and ensure the safety of occupants. Shear walls, vertical structural elements designed to resist lateral forces, offer an efficient solution for enhancing a building's seismic performance. This case study focuses on the retrofitting of an existing residential building located in a seismic-prone region of India. The building, constructed without consideration for seismic forces, presented significant vulnerability to earthquakes. To address this issue, engineers opted for retrofitting measures, with a primary focus on integrating shear walls into the existing structure.

H Xie et al (2019) was study a fascinating research topic! Big Data Analytics (BDA) indeed plays a crucial role in enhancing the efficiency and effectiveness of various aspects of smart cities, including retrofit projects. By leveraging data from Internet of Things (IoT) devices, machine-to-machine communication, and other sources, decision-makers can gain valuable insights into the current state of infrastructure and predict future needs.

Case studies are an excellent approach to understanding the real-world applications and challenges of implementing BDA in smart cities. They provide valuable insights into the situations where BDA can make a significant impact and help decision-makers make informed choices. Predictive analytics enabled by BDA can be particularly valuable in retrofit projects, allowing authorities to anticipate maintenance needs, optimize resource allocation, and enhance overall city functionality. It's exciting to see research exploring how these technologies intersect and contribute to creating smarter, more sustainable urban environments.

P Tiwari el al (2019) the seismic retrofitting of pure masonry structures is a critical topic, especially in regions prone to earthquakes like Nepal. The seismic analysis becomes paramount in ensuring the safety and resilience of buildings in such areas, particularly after significant seismic events like the earthquake in Nepal on April 25, 2015.

Seismic retrofitting is not only about making buildings earthquake-proof but also earthquake-resistant, which involves enhancing their ability to withstand seismic forces and minimize damage. This is particularly crucial for older buildings constructed before modern seismic design standards were established.

When authors discuss retrofitting, they are highlighting the importance of maintaining and strengthening previously constructed buildings using various techniques. These techniques may include adding structural reinforcements, improving foundation systems, enhancing connections between structural elements, and implementing damping systems to dissipate seismic energy.

In summary, seismic retrofitting is a vital aspect of ensuring the safety and longevity of buildings in earthquake-prone regions like Nepal, and it involves implementing measures to both prevent and mitigate damage caused by seismic events.

Yui V C et al (2020) the proposed approach sounds like a promising refinement in seismic retrofitting strategies for non-ductile reinforced concrete structures. By tailoring the distribution of FRP based on the actual distribution of seismic damage within a structure, you could potentially optimize both the effectiveness of the retrofit and the cost associated with it. This targeted application of FRP could lead to more efficient reinforcement of critical areas, while also minimizing unnecessary retrofitting in less vulnerable sections, thereby reducing overall costs and minimizing disruption to building owners. It would be interesting to see how this approach performs in practical applications and whether it achieves the desired balance between structural resilience and cost-effectiveness.

W Ahmed at al (2021) the study was described seems like a comprehensive examination of the challenges and potential solutions for energy retrofitting residential buildings in hot, humid climates, specifically in Saudi Arabia's Eastern Province.

The adoption of a Building Information Modelling (BIM)-based retrofit framework is a forward-looking approach, as it allows for a more detailed and integrated analysis of various energy efficiency measures (EEMs). The inclusion of eight specific EEMs, ranging from adjustments to cooling set points to upgrades in appliances and building envelope, reflects a holistic approach to energy savings.

The results, showing significant reductions in annual energy consumption across different levels of retrofitting, are encouraging. Achieving reductions of up to 58.5% through a level 3 retrofit underscores the potential impact of comprehensive energy efficiency interventions.

This study not only addresses the immediate need to reduce energy consumption in residential buildings in Saudi Arabia but also aligns with broader sustainability goals outlined in Saudi Vision 2030. By demonstrating the feasibility and benefits of energy retrofitting, it provides valuable insights for policymakers, building owners, and other stakeholders seeking to promote sustainable development in the region.

Basel E et al (2021) was Study the benefits of retrofitting school buildings in accordance with LEED v4 standards is crucial for understanding the potential advantages and challenges associated with pursuing green building certification, especially for major renovation projects like schools. One of the primary benefits of pursuing LEED certification for school renovations is the promotion of resource efficiency. By implementing sustainable design and construction practices, schools can significantly reduce their energy and water consumption, thereby lowering their environmental impact and operating costs over the long term.

Additionally, LEED-certified school buildings often boast improved indoor environmental quality, providing students and staff with healthier and more productive learning and working environments. Features such as enhanced ventilation, natural day lighting, and the use of low-emission materials contribute to better air quality and overall well-being. However, despite these advantages, perceived renovation costs can sometimes deter professionals from pursuing LEED certification. While initial investment costs may be higher for green building practices, the long-term benefits, including energy savings and reduced maintenance expenses, typically outweigh the upfront expenses. Education and awareness about the long-term benefits of green building certification, along with incentives and financial assistance programs, can help overcome these perceived cost barriers and encourage more professionals to pursue LEED rating systems for school renovation projects. Additionally, showcasing successful case studies of LEED-certified school buildings can demonstrate the tangible benefits and return on investment associated with sustainable building practices.

Conclusion:

In this study we provides a comprehensive overview of seismic retrofitting methods, with a focus on stiffness reduction and base isolation. It outlines how these methods work and their effectiveness in enhancing a building's resistance to earthquakes. Additionally, it acknowledges that while stiffness reduction is highly effective, it may not be applicable in all situations, and other methods like shear wall, jacketing, and base isolation itself have their own merits.

The use of examples drawn from the author's professional, editorial, and research activities helps to illustrate the concepts discussed, making them more accessible to readers. The conclusion emphasizes the importance of increasing understanding in earthquake engineering and seismic retrofitting, suggesting that the information presented in the paper will contribute to this goal. Overall, it provides a valuable resource for those involved in earthquake engineering and retrofitting projects.

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