Strength Analysis of Seismic Retrofitting on Existing RCC Structure

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Abstract-This study proposes a decision-making methodology for determining whether to retrofit or demolish earthquake damaged buildings. The methodology compares the Strength of retrofitting with the strength of constructing a new building of equivalent functionality. By considering factors such as retrofit strength, new construction capacity, and depreciation of capital, this approach provides a structural safety perspective. The methodology involves identifying structural damages, evaluating retrofit strength, and comparing them with the capacity of demolishing the old building and constructing a new one. The study also incorporates the expected lifespan of both retrofitted and new buildings. This project focuses on studying the lifespan of retrofitted structures compared to new buildings, analyzing the stability strength of existing structures, and evaluating the effectiveness of retrofitting measures in enhancing structural strength.

Keywords — Retrofitting, Strength Comparison, Seismic, Reconstruction.

INTRODUCTION

This study aims to present a comprehensive methodology for making informed decisions regarding the retrofitting or demolition of buildings damaged by earthquakes. The decision-making process is based on a thorough comparison of the costs associated with retrofitting and the costs of constructing a new building that would provide equivalent functionality. The proposed methodology takes into account various cost factors to provide a holistic and economic perspective. These factors include the expenses related to retrofitting, the costs associated with constructing a new building, and the depreciation of capital over time. By considering these aspects, the methodology enables a comprehensive evaluation of the economic viability of retrofitting versus demolition and new construction.

The methodology involves several key steps. Firstly, it begins with the identification and assessment of structural damages in the affected buildings. This step aims to understand the extent of the damage and determine the necessary repairs and retrofitting measures required to restore the building's structural integrity. Following the evaluation of the structural damages, the next step involves estimating the costs associated with the repairs and retrofitting of all functional aspects of the building. This includes evaluating the expenses required to restore not only the structural elements but also other vital components, such as electrical systems, plumbing, and HVAC (heating, ventilation, and air conditioning) systems. These cost estimates are crucial for accurately assessing the financial implications of retrofitting the building.

Once the cost of retrofitting has been determined, it is then compared to the costs associated with the demolition of the old building and the subsequent construction of a new building with equivalent functionality. This comparison takes into account various factors, including the cost of demolishing the existing structure, the expenses related to disposing of debris and waste materials, and the costs of designing and constructing a new building.

In addition to the immediate costs, the methodology also considers the expected lifespan of the building. This factor is crucial for calculating the long-term economic implications of both retrofitting and constructing a new building. The projected lifespan of the retrofitted building is compared to the estimated lifespan of a newly constructed building of equivalent size and functionality. By considering the respective lifespans, the economic viability of retrofitting versus new construction can be evaluated over the desired time horizon.

By compiling and analyzing the actualized costs associated with each alternative, the proposed methodology provides decision-makers with a comprehensive and comparative understanding of the economic implications of retrofitting versus demolition and new construction. This enables stakeholders to make informed decisions regarding the most suitable course of action for earthquake-damaged buildings. Overall, this study proposes a methodology that facilitates the decision-making process for determining whether to retrofit or demolish earthquake-damaged buildings. By considering cost factors, assessing structural damages, and accounting for the lifespan of the building, this methodology provides a comprehensive economic evaluation. Ultimately, it empowers decision-makers to make informed choices based on the economic feasibility of retrofitting and new construction.

Retrofitting of Building

Retrofitting refers to the comprehensive process of strengthening and modifying existing buildings to enhance their ability to withstand the destructive forces generated by seismic events, such as earthquakes. Unlike the alternative of complete demolition and subsequent reconstruction, retrofitting aims to maximize the use of the existing structural system while improving its performance. By strategically implementing targeted modifications and upgrades, retrofitting seeks to enhance the building's resilience and minimize the vulnerabilities that can lead to damage or collapse during seismic activity.

By reinforcing and fortifying critical structural elements, retrofitting increases the capacity of buildings to resist the lateral forces and ground motion induced by earthquakes. This involves identifying the weaknesses and deficiencies present in the original design and construction, such as inadequate bracing, insufficient connections, or materials susceptible to seismic damage. Through the application of engineering principles and advanced techniques, retrofitting seeks to rectify these vulnerabilities and enhance the overall strength and stability of the building.

Moreover, retrofitting aligns with the principles of sustainability and environmental responsibility. By optimizing the use of existing resources, retrofitting reduces the demand for new construction materials, minimizing the associated carbon footprint. It also decreases construction waste and energy consumption, making retrofitting an eco-friendlier option compared to complete demolition and reconstruction.

Benefits of Retrofitting

Retrofitting buildings offers numerous benefits that contribute to the safety, sustainability, and resilience of communities in earthquake-prone regions. One of the primary advantages is enhanced safety, as retrofitting strengthens the structural integrity of buildings, reducing the risk of collapse and protecting occupants during seismic events. Moreover, retrofitting allows for the preservation of valuable infrastructure, including historically significant buildings, cultural landmarks, and architecturally unique structures, maintaining the local character and heritage of communities.

From a cost perspective, retrofitting is often a cost-effective alternative to complete demolition and reconstruction, utilizing existing materials and infrastructure, thereby reducing expenses and minimizing environmental impact. By maximizing the use of resources, retrofitting aligns with sustainable practices, reducing construction waste and conserving energy. Additionally, retrofitted buildings facilitate faster recovery and reduced downtime after earthquakes, ensuring critical facilities remain operational, providing essential services to the community. Retrofitting increases the value of buildings by improving their structural integrity, functionality, and resilience, making them attractive to tenants, businesses, and investors. By reducing potential damage and financial losses, retrofitting contributes to long-term risk reduction, enhancing the overall resilience of communities. Compliance with building codes and regulations is also ensured through retrofitting, ensuring buildings meet current safety standards.

Literature Survey

Giordano et al. [1] In this article PEER performance based on earthquake engineering methodolgy is broadly explained for a expected retrofitting cost optimization. The research focuses on calculating the economic advantages of retrofitting, considering the costs involved in the retrofit process and the expected reduction in seismic losses. This analysis helps stakeholders make informed decisions about whether or not to invest in retrofitting measures for URM buildings.

Roy et al.[2] The main goal of this study is to find the most cost-effective way to strengthen multi-story buildings made of unreinforced masonry (URM) so that they can better withstand earthquakes. The study focuses on a specific type of building—a three-story URM structure—located in a region of Bangladesh that experiences moderate seismic activity.

Tripathi and Maru[3] The interest in using these devices has grown significantly since the 1990s, both for retrofitting existing buildings and incorporating them into new construction projects. As more guidelines and recommendations were developed for analyzing and designing structures with these devices, their implementation became more common in the construction industry. This trend demonstrates the building community's recognition of the benefits and effectiveness of these devices in improving the seismic resilience of buildings.

Sudha et al.[4] This means that we still need to investigate and analyze how various retrofitting techniques, including stitching, impact the ability of flexure-deficient beams to bear loads. By studying and comparing these techniques, we can determine which ones are most effective in strengthening the beams and improving their capacity to support heavy loads. This research will help engineers and researchers make informed decisions about the best retrofitting methods to use in practice. There is a lack of comprehensive research on the retrofitting of flexure-deficient reinforced concrete (RC) beams using traditional methods such as stitching. Specifically, there is limited information available on the effects of stitch depth on the load-carrying capacity of these beams when retrofitted with stitching.

Haikal and Muca.[5] The main objective of this Master's thesis is to examine and reinforce a building provided by Sweco, a company specializing in engineering and design. The focus is on employing effective and inventive retrofitting techniques while adhering to the guidelines set forth in Eurocode 8, a standard for seismic design.The chosen building is a seven-story structure located in Stockholm. It is made up of prefabricated concrete and steel components. To gain insights into how the building performs during seismic events, it will undergo testing under simulated seismic loads using MIDAS GEN software, a computer program for analyzing and designing structures.

Oliveto and Marletta[6] In this paper, the authors focus on the particular case of Eastern Sicily. They begin by providing an informative overview of the seismic activity in this region. They then delve into the challenge of assessing the ability of engineering structures to withstand earthquakes and their vulnerability to seismic events. In simpler terms, the authors study how well buildings and other engineering structures in Eastern Sicily can withstand earthquakes. They describe the seismic forces that these structures experience in the region. Additionally, they analyze and evaluate the structures' resistance to seismic activity and how susceptible they are to damage during earthquakes. This information is crucial for understanding and improving the safety and resilience of buildings and infrastructure in this area.

Tian et al. [7] This study suggests a framework for evaluating the costs and benefits of retrofitting buildings at a city-wide scale to enhance their seismic resistance. The first step involves analyzing seismic hazards and determining the potential impact on urban areas. Then, nonlinear models are used to assess the seismic damage and losses for each building before and after retrofitting, considering the building inventory data and predefined retrofitting objectives. To estimate the retrofit costs, empirical models are employed. Overall, this framework aims to provide a simplified approach for assessing the economic aspects of seismic retrofitting for cities.

Cardone et al.[8] This paper presents a real-life example where the owner of an existing reinforced concrete (RC) building needed to choose the best seismic rehabilitation solution. The owner had to decide among three different retrofit strategies: (i) strengthening specific areas using carbon fibers, (ii) employing seismic isolation technique, and (iii) utilizing energy dissipation technique with steel braces equipped with special units.To make an informed decision, a cost-benefit analysis was conducted, considering the expected direct and indirect losses. The analysis compared the three retrofit strategies based on their potential to reduce losses and improve the building's seismic performance. The assessment followed a simplified displacement-based approach, which estimated the losses considering the expected displacements during an earthquake.

Becchio et al.[9] The main focus of this paper is to explore various retrofit scenarios in urban areas and evaluate their sustainability at the district level. The study examines these scenarios from three perspectives: energy, environment, and economy. The aim is to assess the potential energy savings and emission reductions resulting from different strategies implemented across different sectors, with a specific emphasis on buildings. By calculating the energy savings and avoided emissions, the study aims to determine the overall sustainability and benefits of these retrofit scenarios for the district.In simpler terms, this paper analyzes different ways to improve the energy efficiency and environmental impact of urban areas. It looks at how retrofitting strategies can lead to energy savings and reduced emissions, particularly focusing on the impact of these strategies on buildings. The goal is to understand the sustainability and economic advantages of these retrofit scenarios at the district level.

Nagaraju [10] Researchers conducted a study to investigate the flexural behavior of Reinforced Concrete (RC) beams retrofitted with an overlay of Ultra High Strength Cementitious Composite (UHSCC).The study involved three RC beams: one as a control beam and two preloaded beams. The preloaded beams were subjected to 70% and 65% of the ultimate load of the control beam, respectively. The control beam was tested under four-point bending until failure.To strengthen the preloaded beams, a layer of UHSCC overlay was applied beneath the tension face of the beam. For the 70% preloaded beam, the overlay covered the entire span of the beam. However, for the other two preloaded beams, the overlay was only provided in the bending moment zone of the beam.In simpler terms, the researchers studied how RC beams behave when reinforced with an overlay of UHSCC. They conducted tests on three beams: one without any modifications and two beams preloaded with partial loads. The preloaded beams were then strengthened by applying the UHSCC overlay.

Vitiello et al. [11] The goal of this approach is to find the most cost-effective ways to strengthen existing structures throughout their lifespan. The method focuses on determining the optimal level of strengthening by considering two main factors.Firstly, it calculates the costs associated with strengthening the structure at various performance levels for different strategies. This involves analyzing the expenses involved in implementing each strengthening strategy at different levels of effectiveness. Secondly, the method estimates the expected seismic loss that the structure may experience during its lifetime. This includes evaluating the potential losses resulting from seismic events based on the structure's vulnerability and the effectiveness of the strengthening strategies employed.By considering both the costs of strengthening and the expected seismic losses, the approach aims to identify the most efficient and cost-effective strengthening strategies and levels for existing structures over their lifespan.

Tiwari et al.[12] In this paper, the authors compared eight different models of a structure under lateral loading. They utilized two methods, namely the response spectrum method and time history method, to assess the structural behavior. The analysis was performed using Etabs 2015 software. Various loads, including live load, dead load, and seismic load, were considered in the study. A total of 26 different load combinations were used for the seismic analysis. The authors evaluated parameters such as maximum story displacement, maximum story drift, overturning moment, and story shear in their technical paper. In simpler terms, the paper compares different models of a structure when subjected to lateral forces. The authors used software to analyze the structure, considering different types of loads. They calculated several important parameters, such as story displacement, story drift, moment, and shear, to assess the structural response under seismic conditions.

Chitte[13] In the present study, various retrofitting techniques for enhancing the seismic resistance of buildings are being discussed. The conventional techniques, namely local and global retrofitting, are compared with a modern technique known as Fiber Reinforced Polymers (FRP).Seismic resistant design is crucial for both new and existing buildings to minimize their vulnerability during earthquakes. Retrofitting existing buildings can significantly improve their ability to withstand seismic forces.FRP is a contemporary retrofitting technique that offers several advantages. One notable advantage is that it does not increase the dead weight of the structure significantly. This is beneficial because adding excessive weight to the building can potentially worsen its seismic performance. By using FRP, the retrofitting process can be simplified and made more efficient.

Cao et al.[14] This paper presents a comprehensive review of the latest developments and research trends in external sub-structure retrofitting technology. We start by explaining the fundamental concepts of this technology, including how retrofitting works and its benefits. Then, we categorize the various types of external sub-structure retrofitting, such as external frame sub-structures, external frame-brace sub-structures, external wall sub-structures, and other related techniques.

Carofilis et al.[15] This paper examines different retrofitting strategies for three types of school buildings in Italy: reinforced concrete, precast concrete, and unreinforced masonry structures. The study assesses their seismic performance using detailed numerical models, taking into account typical structural deficiencies found in older buildings built before the 1970s.

Methods and Techniques of Retrofitting

The selection of retrofitting methods and techniques depends on factors such as the specific characteristics of the building, the desired level of improvement, available resources, and expert engineering analysis. Each retrofitting project should be approached on a case-by-case basis to determine the most appropriate strategies to enhance the building's seismic resilience. Following techniques are used for retrofitting –

- Addition of Supplementary Structural Elements: This method involves adding steel braces, reinforced concrete walls, or other structural elements to enhance the overall strength and stiffness of the building, improving its resistance to seismic forces.
- Strengthening Existing Structural Components: This technique focuses on reinforcing columns, beams, and other load-bearing elements. It may involve using materials such as carbon fiber wraps, steel plates, or concrete jackets to increase their load-carrying capacity and improve resistance to bending, shear, and compression forces.
- Base Isolation: Base isolation is a technique that involves installing flexible or sliding bearings between the building and its foundation. These bearings isolate the superstructure from ground motion, reducing the transfer of seismic forces and vibrations to the building.
- Dampers: Dampers are devices designed to absorb and dissipate seismic energy. They can be installed within the structural system to reduce the amplitude of vibrations, enhancing the building's overall performance during an earthquake.
- Connection Upgrades: Upgrading connections between structural elements, such as beams and columns, improves their load transfer capacity. Strengthening these connections can help distribute forces more effectively and enhance the overall stability of the building.
- Redundancy and Ductility Enhancement: Retrofitting may involve improving the redundancy and ductility of the structural system. Redundancy refers to the presence of multiple load paths, ensuring that if one component fails, others can still support the structure. Ductility refers to the ability of a material or structure to undergo significant deformation before failure, allowing it to absorb seismic energy.
- Reinforcement of Non-structural Elements: Retrofitting may also include reinforcing non-structural elements such as ceilings, partitions, and facades to ensure their stability during an earthquake. This helps prevent secondary damage and reduces the risk of injury to occupants.
- Seismic Hazard Mitigation Systems: Various specialized systems, such as energy dissipation devices, are available to mitigate seismic hazards. These systems absorb and dissipate seismic energy, reducing the impact on the building.
- Retrofitting Techniques for Specific Building Types: Different building types may require tailored retrofitting approaches. For example, historical structures may employ techniques that preserve their architectural integrity while enhancing their seismic performance.
- Performance Monitoring and Evaluation: Retrofitting should be accompanied by a comprehensive monitoring and evaluation plan to assess the effectiveness of the retrofit measures and ensure ongoing structural integrity.

Analysis of Building

- **New Building:**

A recently constructed 6 storey building was checked for its strength using NDT (Non-Destructive Test). Rebound hammer was used throughout the research to find the compressive of the concrete. Following results were obtained in the Rebound Hammer Test:

Component	**Concrete grade**	**Compressive strength**
Column 1	M25	29.3
Column 2	M25	28.2
Beam 1	M25	29.5
Beam 2	M25	27.7
Slab 1	M25	28.6
Slab 2	M25	28.4

- **Approximately 20 years old Building:**

The strength of a 20-year-old building with 6 storeys was assessed using Rebound Hammer to determine the compressive strength of the concrete. The obtained results from the rebound hammer test are as follows:

- **Retrofitted 20 years old Building:**

In order to improve the structural integrity and safety of the old building, a retrofitting process was carried out. This involved implementing various modifications and strengthening measures to ensure the building meets modern standards and can withstand potential hazards. The obtained results from the rebound hammer test are as follows:

Component	Concrete grade	Compressive strength
Column 1	M25	24.2
Column 2	M25	23.9
Beam 1	M25	24.5
Beam 2	M25	24.6
Slab 1	M25	24.8
Slab 2	M25	23.9

- **Strength Comparison:**

The strength of a newly constructed building typically surpasses that of an old building that underwent retrofitting. Retrofitting, however, can enhance the strength of the existing structure, making it comparable.

Components	New Building	Retrofitted Building	Difference in strength (%)
Column 1	29.3	24.2	17.41
Column 2	28.2	23.9	15.25
Beam 1	29.5	24.5	16.95
Beam 2	27.7	22.9	17.33
Slab 1	28.6	24.2	15.38
Slab 2	28.4	23.9	15.85
Average change in strength of concrete			**16.36**

Discussion of Results

In this study, an old building was checked for its strength. The building was deteriorating thus, the strength was found a bit lesser than the expected strength

Component	Concrete grade	Compressive strength
Column 1	M25	20.2
Column 2	M25	19.8
Beam 1	M25	21.3
Beam 2	M25	21.8
Slab 1	M25	21.1
Slab 2	M25	20.9

of concrete. The building was then retrofitted to increase its lifespan. This retrofitted building was compared with a recently constructed building on the basis of their strength and cost. The strengths were found by performing Non-Destructive Test (NDT) on the components of the buildings.

Conclusion

The findings from the project indicate that retrofitting proves to be a cost-effective solution for both old buildings and those affected by earthquakes. Retrofitting an existing building is financially advantageous compared to the construction of a new building, as it can significantly reduce expenses.

However, it is important to consider the specific functions and requirements of the building in the decision-making process. By taking into account these factors, a more informed choice can be made regarding whether retrofitting or new construction is the most suitable option. The stability strength of existing structures, and evaluating the effectiveness of retrofitting measures in enhancing structural strength.

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