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Design A Retrofitting Device As A Earthquake Resistant : Critical Review

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Abstract:

In regions prone to seismic activity like the Pacific Ring of Fire, ensuring the structural integrity of buildings is paramount to mitigating the devastating impact of earthquakes [1]. Retrofitting stands as a crucial process aimed at fortifying existing structures to withstand seismic forces [2]. Among various retrofitting devices, dampers play a pivotal role in absorbing the kinetic energy generated during seismic events [3]. Dampers counteract the tensile and compressive forces that jeopardize structural integrity, with their arrangement contingent upon materials and principles employed [4].Strategic placement of dampers is imperative to maximize their effectiveness in absorbing movement and forces [5]. They are typically positioned diagonally across floors or connected to opposing corner sides, depending on the damper type, enhancing the building's resilience [6]. Seismic retrofitting, including the integration of girders, emerges as quintessential to modify existing structures and render them more resilient against seismic activity [7].Recent scientific focus has shifted towards retrofitting methods to bridge the gap in seismic safety for existing buildings [8]. Various techniques such as RC/mortar jacketing, steel jacketing, and FRP jacketing have been explored to enhance flexural and shear capacities [9]. FRP jacketing, particularly, stands out for its ease of installation and competitive effectiveness [10]. Additionally, innovative approaches like TRM jacketing have shown promise in increasing strength and deformation capacity [11].Empirical research, such as that conducted by Saeedi and Abbasi (2017), highlights the efficacy of retrofitting techniques like girder-column connections in enhancing the seismic resilience of aging reinforced concrete buildings [12]. Experimental studies, like those by Almeida et al. (2016), underscore the effectiveness of retrofitting solutions such as BRBs in limiting structural damage and improving resilience [13]. Furthermore, advancements in analytical methods and numerical simulations contribute to refining retrofitting strategies and understanding structural behavior under seismic loading conditions [14].Integrating girders as a retrofitting solution offers a promising avenue for enhancing the seismic resilience of aging reinforced concrete buildings [15]. Through comprehensive investigations and innovative approaches, researchers have demonstrated significant improvements in structural integrity and seismic performance. This holistic approach not only addresses immediate safety concerns but also contributes to long-term sustainability and resilience against earthquakes. As seismic threats persist, proactive retrofitting measures remain crucial in safeguarding lives and infrastructure.

Keywords: Seismic retrofitting, earthquake engineering, structural resilience, PET FRP, metal dampers, historic buildings, GESB system, cross-section dampers, external sub-structure retrofitting, friction dampers, shaking table tests

I. INTRODUCTION

Old construction buildings, particularly those made of reinforced concrete (RC) structures, face significant seismic risks due to their inherent vulnerabilities. Traditional and innovative retrofitting techniques play a crucial role in enhancing the seismic resilience of these structures. While modern seismic design standards primarily focus on new constructions, there exists a gap in addressing the seismic safety of existing buildings. Recent scientific attention has shifted towards retrofitting methods to bridge this gap, with a focus on local measures targeting specific structural elements.

Among the various retrofitting techniques, the integration of girder-column connections has emerged as a promising solution. Saeedi and Abbasi (2017) demonstrated the efficacy of girder-column connections in enhancing the seismic resilience of aging RC buildings through experimental testing and analytical analysis. Their research highlighted the structural improvements achieved by this retrofitting technique, providing practical recommendations for seismic retrofitting approaches.Another notable retrofitting method involves the use of fiber-reinforced polymer (FRP) composites, as investigated by Mahdavipour, Eslami, and Jehel. Their reliability-based approach evaluated the seismic performance of RC buildings retrofitted with FRP composites, emphasizing the importance of accounting for uncertainties in material properties and loads.

Furthermore, Almeida et al. (2016) studied the seismic retrofit of RC school buildings using Buckling Restrained Braces (BRBs), showcasing significant improvements in strength and deformation capacity. Additionally, Deng, Shao, and Hassanein conducted experimental tests on steel corrugated web girders with compression tubular flanges, suggesting better shear behavior and post-buckling strength compared to conventional girders.

In the context of vulnerability assessment methodologies, rapid visual screening procedures such as those outlined by FEMA 154 provide systematic approaches to identify vulnerable buildings. These methodologies enable accurate assessments of seismic risk, contributing to effective mitigation strategies and resilience planning.

The paper by D'Ambrisi, Cristofaro, and De Stefano presents predictive models for evaluating concrete compressive strength in existing buildings, offering improved prediction accuracy compared to existing literature formulas. This research contributes to more effective seismic risk evaluation and mitigation strategies in existing buildings. Integrating girders as a retrofitting solution offers promising avenues for enhancing the seismic resilience of old construction buildings. Through comprehensive investigations and innovative approaches, researchers have demonstrated significant improvements in structural integrity, thereby addressing immediate safety concerns and contributing to long-term sustainability and resilience against earthquakes.

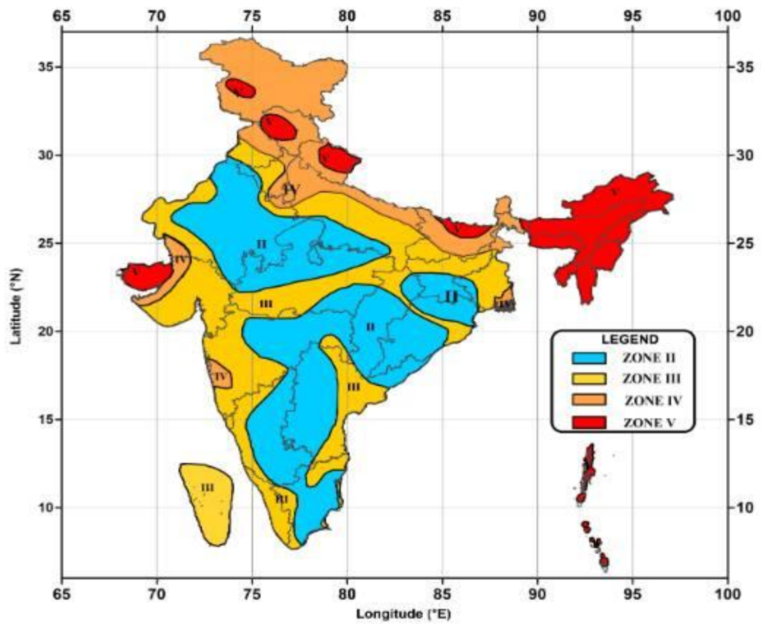


Fig no 1 –Sesmic Zone India Map [26]

II. LITERATURE PAPERS

2.1 Global Review

2.1.1 Saeedi and Abbasi (2017) conducted a comprehensive investigation into the seismic retrofitting of aging reinforced concrete buildings by employing girder-column connections. Their research, published in the Journal of Earthquake Engineering and Engineering Vibration, integrated experimental testing with analytical analysis to assess the efficacy of this retrofitting technique. By utilizing both physical models and computational simulations, they elucidated the structural improvements attained through the implementation of girder-column connections, thereby furnishing practical recommendations for seismic retrofitting approaches. The study contributes valuable insights into enhancing the seismic resilience of older reinforced concrete structures, thereby addressing significant concerns regarding their safety and performance under seismic loading conditions[12].

2.1.2 Existing buildings face significant seismic risks, particularly reinforced concrete (RC) structures, which form a substantial portion of the building stock. Traditional and novel retrofitting techniques are crucial for enhancing the seismic resilience of these buildings. The introduction of modern seismic design standards primarily addresses new constructions, leaving a gap for the seismic safety of existing buildings. Recent scientific focus has shifted towards retrofitting methods to bridge this gap. Local measures, targeting specific structural elements, include techniques like RC/mortar jacketing, steel jacketing, and fiber-reinforced polymer (FRP) jacketing. These methods enhance flexural and shear capacities, as well as ductility. Among these, FRP jacketing stands out for its ease of installation and competitive effectiveness. Different types of fibers, such as carbon (CFRP) and glass (GFRP), offer varying advantages in retrofitting applications. Another innovative approach involves Textile Reinforced Mortar (TRM) jacketing, which addresses some drawbacks of FRP, such as poor behavior under high temperatures and resin application challenges. TRM, utilizing fibrous materials embedded in cementitious mortars, has shown promise in confining RC elements and increasing their strength and deformation capacity. While each retrofitting method has its strengths and limitations, a combination of techniques may be necessary for comprehensive seismic upgrading. Further research and practical applications are essential to refine these techniques and ensure the seismic resilience of existing RC buildings [16].

2.1.3 In this study, Mahdavipour, Eslami, and Jehel investigate the seismic performance of reinforced concrete (RC) buildings retrofitted with fiber-reinforced polymer (FRP) composites through a reliability-based approach. Their focus lies in evaluating the collapse capacity and ductility of inadequately confined RC structures subjected to various FRP retrofitting configurations, including wrapping and flange-bonded techniques. Employing a combination of nonlinear pushover analysis and computational reliability analysis using Latin Hypercube Sampling (LHS), the study aims to ascertain the collapse capacity and ductility of retrofitted structures. The results highlight the efficacy of this reliability-based approach in facilitating robust comparisons between different retrofitting strategies, while also scrutinizing the failure modes of both original and retrofitted frames. By emphasizing the necessity of accounting for uncertainties in material properties, loads, and geometry, the paper underscores the significance of such considerations for accurately assessing the seismic performance of retrofitted RC structures, thereby offering valuable insights for enhancing the resilience of existing infrastructure against seismic events [24].

2.1.4 The vulnerability assessment methodologies discussed in this section provide valuable insights into evaluating the seismic risk of buildings. Rapid Visual Screening (RVS) procedures, such as those outlined by FEMA 154 and applied in various countries including Canada, Japan, Turkey, and New Zealand, offer systematic approaches to identify buildings vulnerable to seismic hazards. These methods, such as the Seismic Priority Index (SPI) in Canada and the Seismic Performance Index (IS) in Japan, categorize buildings based on structural and non-structural indices, facilitating targeted evaluation stages. Additionally, methodologies like the GNDT approach in Italy and the European Macro-Seismic (EMS) approach provide comprehensive frameworks for assessing building vulnerabilities, incorporating parameters related to structural attributes and seismic responses. By combining these approaches, a more holistic understanding of building vulnerabilities can be achieved, as demonstrated by correlations between the GNDT and macro-seismic methodologies. These methodologies enable accurate assessments of seismic risk, contributing to effective mitigation strategies and resilience planning [29].

2.1.5 The paper titled "Predictive Models for Evaluating Concrete Compressive Strength in Existing Buildings" by A. D'Ambrisi, M.T. Cristofaro, and M. De Stefano presents a comprehensive investigation into the assessment of concrete compressive strength in existing reinforced concrete (rc) structures. Focused on buildings in the Italian region of Tuscany constructed between the 1950s and 1990s, the study evaluates the reliability of both destructive and non-destructive testing methods. Notably, new models are proposed for the sclerometric and ultrasonic methods, which exhibit improved prediction accuracy compared to existing literature formulas across different construction decades. Moreover, the study assesses the combined Sonreb method, highlighting its effectiveness in integrating sclerometric and ultrasonic approaches. By emphasizing the significance of accurately estimating concrete strength for seismic assessment, the paper underscores the role of these predictive models in enhancing the reliability of non-destructive testing methods. Overall, the findings contribute to more effective seismic risk evaluation and mitigation strategies in existing buildings[32].

2.1.6 Almeida et al. (2016) conducted a study on the seismic retrofit of existing reinforced concrete (RC) school buildings using Buckling Restrained Braces (BRBs), aiming to optimize their performance across different levels of the structure. Through nonlinear static and dynamic numerical analyses, they assessed the effectiveness of the retrofit solution proposed, based on the design method formulated by Kasai et al. (1998). Their findings underscored the significant increase in strength, deformation capacity, and energy dissipation achieved by the BRB retrofit, thereby limiting structural damage to acceptable levels. The study highlighted the growing interest in passive control systems like BRBs for improving the seismic resilience of existing structures, particularly in regions prone to high seismic activity such as Japan, the USA, and Italy. Despite the absence of specific design provisions for BRBs in European standards, the study suggested their potential as a promising retrofitting solution for old RC structures if properly considered. The case study of a three-storey school building in Portimão, Portugal, designed before seismic design codes were enforced, provided practical insights into the effectiveness of BRBs in enhancing structural performance through pushover and nonlinear dynamic analyses using artificial accelerograms. Overall, the research emphasized the need for standardized design procedures to facilitate the widespread application of BRBs in retrofitting projects, contributing to the seismic resilience of existing RC buildings [36].

2.1.7 Deng, Shao, and Hassanein conducted experimental shear tests on steel corrugated web girders (SCWGs) with compression tubular flanges, focusing on their use in conventional buildings. They compared these girders with conventional SCWGs with plate flanges, analyzing failure modes and bearing capacities. Finite element (FE) models were used to study factors like tubular flange depth, web thickness, and slenderness ratio. The results showed that the new girders with tubular flanges have better shear behavior and post-buckling strength. The study also suggested the need for a new design model to address the tubular flange effect in existing shear design methods for SCWGs with plate flanges[41].

2.1.8 Tetougueni, Maiorana, Zampieri, and Pellegrino review recent advancements in analyzing plate girders under in-plane loading. They highlight improvements in understanding steel plate instability, the role of stiffeners, and the effects of holes. The paper also discusses the historical context of research and its evolution. Overall, it provides a comprehensive overview for designing buildings and structures. Certainly! Here's the repeated text: The behavior of plate girders under in-plane loading has been intensively studied during the last two decades, either to bring new insights, to propose new design methods, or to update the existing ones. Many intensive experimental tests, analytical, and numerical analyses have been performed thanks to the European research projects financed by the Research Fund for Coal and Steel (RFCS), with the objective to encourage the optimized use of steel elements, most of all as plate structural elements, in the design of steel and composite structures, like bridges. This paper summarizes various researches and recent developments made on plate steel girders with an emphasis on analytical, experimental, and numerical works. The investigation has been divided into three parts. Firstly, a historical overview of the research and works done by the first researchers is provided, and then recent developments are summarized in a literature review. The work is concluded by an illustrative example of the applicability of formulas found in the literature, and the main results in terms of suggestions for design and construction are presented [50].

2.1.9 Tetougueni et al.'s paper addresses the scarcity of experiments on small-scale steel corrugated web girders (SCWGs) used in conventional buildings. The study conducts three full-scale shear capacity experiments on SCWGs with varying web heights and thicknesses to fill this research gap. Using ABAQUS software, the authors compare experimental and numerical results, focusing on factors such as web height, thickness, fold widths, and corrugation angles. They also compare available design strengths with experimental and numerical findings, providing recommended design models for SCWGs in conventional steel buildings. The study concludes that increasing the thickness of the corrugated web is more effective than increasing web height, fold lengths, or corrugation angles for enhancing shear design efficiency while balancing between weight and shear strength. This research offers valuable insights for improving the design and construction of SCWGs in buildings [56].

2.1.10 This paper provides a comprehensive review of innovative seismic retrofitting techniques utilizing shape memory alloys (SMAs) for reinforced concrete structures. SMAs possess unique properties that enable them to undergo large deformations and recover their original shape when subjected to external stimuli, making them promising materials for seismic retrofitting applications. The review discusses various SMA-based retrofitting methods, including SMA cables, SMA bars, and SMA patches, highlighting their effectiveness in enhancing the seismic performance of reinforced concrete structures. Additionally, the paper examines experimental studies and numerical simulations investigating the behavior of SMA retrofit systems under seismic loading conditions. The findings contribute valuable insights into the potential of SMAs as a sustainable and resilient solution for retrofitting existing infrastructure against seismic hazards[61].

Conclusion:-
The integration of girders as a retrofitting solution for aging reinforced concrete buildings offers a promising avenue for enhancing their seismic resilience. Through comprehensive investigations and innovative approaches, researchers have demonstrated the efficacy of girder-column connections, fiber-reinforced polymer (FRP) composites, and other techniques in bolstering the structural integrity of existing constructions. By strategically placing girders at midspan and employing reliable retrofitting methodologies, such as BRBs and shape memory alloys (SMAs), these studies have shown significant improvements in the buildings' ability to withstand seismic forces. This holistic approach not only addresses the immediate safety concerns but also contributes to the long-term sustainability and resilience of old construction buildings against earthquakes.

III. RETROFITTING TECHNIQUES :-

3.1 Coloumn jacketing
Figure no 2 represents Column jacketing is employed as a retrofitting technique to enhance the earthquake resistance of existing structures by strengthening and stabilizing their columns.

Materials Used :-
1. Concrete: Applied as an additional layer around the existing column.
2. Steel: Plates or meshes are used to provide confinement and reinforcement.
3. Fiber Reinforced Polymers (FRP): Lightweight, high-strength wraps are used for encasing the column.

Process :-
1. Surface Preparation: The existing column surface is cleaned and roughened to ensure proper bonding.
2. Reinforcement Installation: Steel bars, meshes, or FRP materials are placed around the column.
3. Formwork Setup: Formwork is installed to hold the new material in place during application.
4. Material Application: Concrete is poured, steel plates are secured, or FRP is wrapped around the column.
5. Curing and Finishing: The material is allowed to cure and the surface is finished as needed.

Figure no 2 - Coloumn jacketing [38]

Benefits :-

1. Increased Load-Bearing Capacity: The column's ability to support vertical loads is enhanced.
2. Improved Ductility: The column is allowed to deform more without failing, absorbing seismic energy.
3. Enhanced Shear Strength: Better resistance to seismic shear forces is provided.
4. Cost-Effective and Versatile: This method is suitable for various structures, including older buildings and critical infrastructure.

Applications

1. Older Buildings: Structures are updated to meet modern seismic codes.
2. Historical Structures: Architectural integrity is preserved while strength is enhanced.
3. Critical Infrastructure: The functionality of essential buildings post-earthquake is ensured.

Drawbacks :-

1. Increased Size: The column's dimensions are increased, which can reduce usable space and may not be feasible in confined areas.
2. Additional Weight: The overall weight of the structure is increased, which may affect the foundation and other structural elements.
3. Aesthetic Impact: The appearance of the original columns may be altered for historical or architecturally significant buildings.
4. Construction Disruption: The retrofitting process can be disruptive to building occupants and operations, requiring careful planning and execution.
5. Material Costs: High-quality materials like FRP can be expensive, and the overall cost of the retrofit can be substantial.
6. Complexity in Implementation: Skilled labor and precise engineering are required to ensure effectiveness and safety.

Conclusion

While column jacketing is recognized as a highly effective method for enhancing the earthquake resistance of structures, it is important for both its benefits and drawbacks to be considered. Structural strength, ductility, and shear resistance are improved, making buildings safer during seismic events. However, the potential for increased size, weight, aesthetic changes, construction disruption, high material costs, and complexity must be carefully weighed in the decision-making process. The practical complexity of implementing pocket jacketing can further complicate the installation, requiring meticulous planning and specialized expertise.

3.2 Seismic Retrofitting Using Reinforced Concrete Shear Walls\

Figure no 3 represents Seismic retrofitting with reinforced concrete shear walls is aimed at enhancing the earthquake resistance of existing structures by providing lateral stiffness and strength to resist seismic forces. Materials Used Reinforced Concrete: Concrete combined with steel reinforcement to improve tensile strength. Steel Reinforcement: Rebars or mesh integrated within the concrete to enhance its structural capacity.
Process :-
1. Design and Analysis: Structural analysis to determine the optimal location, size, and reinforcement details for the shear wall.
2. Surface Preparation: Existing surfaces where the shear wall will connect are cleaned and roughened to ensure proper bonding.
3.Formwork Setup: Formwork is installed to create the mold for the shear wall.
4.Reinforcement Installation: Steel reinforcement is placed according to the design specifications.
5. Concrete Pouring: Concrete is poured into the formwork and allowed to cure.
6. Curing and Finishing: The concrete is properly cured, and the formwork is removed. The surface is then finished as needed.
Benefits :-
1.Increased Lateral Strength: Shear walls significantly improve the structure's ability to resist lateral forces from earthquakes.
2.Enhanced Stiffness: The addition of shear walls reduces the lateral deflections and sway during seismic events.
3.Improved Stability: Shear walls provide stability to the structure, reducing the risk of collapse.
4.Versatility: Suitable for a wide range of building types and sizes.
5.Integrated Design: Can be designed to integrate with existing architectural features and structural elements.

Reinforced Concrete Shear Walls [45]
Figure no 3

Applications :-
1.High-Rise Buildings: To enhance the lateral load resistance of tall structures.
2. Residential Buildings: Improve safety and stability in homes, especially in earthquake-prone areas.
3.Commercial Structures: Ensuring business continuity and safety by retrofitting commercial buildings.
4.Critical Infrastructure: Hospitals, schools, and emergency facilities to ensure functionality post-earthquake.

Drawbacks:-
1.Space Reduction: Shear walls occupy significant space, potentially reducing usable floor area.
2.Weight Increase: The addition of concrete shear walls increases the overall weight of the structure, which may impact the foundation and other structural elements.
3.Construction Disruption:- The installation process can be disruptive to occupants and building operations,
4. Aesthetic Changes: May alter the appearance of the building, especially if not well integrated into the existing design.

5. Cost: The material and labor costs can be high, particularly for large or complex projects.
6.Implementation Complexity: Requires detailed engineering design and skilled labor to ensure proper installation and effectiveness.
7.Not Flexible to Existing Structures: Retrofitting with shear walls may not be feasible for all existing structures, especially those with limited space or architectural constraints.
Additional Considerations
Foundation Strengthening: In some cases, the existing foundation may need to be strengthened to support the additional loads from the new shear walls, adding to the overall cost and complexity.
Time-Consuming: The process of installing shear walls can be time-consuming, potentially leading to extended periods of construction activity.
Permitting and Approval: Obtaining the necessary permits and approvals from local authorities can be a lengthy and complex process, especially for significant structural modifications.
Impact on Building Systems: The installation of shear walls may interfere with existing building systems such as plumbing, electrical, and HVAC, requiring modifications and additional coordination.

Conclusion
Reinforced concrete shear walls are an effective solution for seismic retrofitting, offering significant benefits in terms of increased lateral strength, stiffness, and stability. However, they are not always flexible to existing structures, especially those with space limitations or architectural constraints. Despite the drawbacks and challenges associated with their implementation, proper planning, design, and execution are critical to ensuring the successful integration of shear walls in existing structures, thereby enhancing earthquake resistance and safety.

3.3 Steel diagonal bracing
Figure no 3 represents Steel diagonal bracing is a seismic retrofitting technique employed to enhance the earthquake resistance of existing structures by providing additional lateral support and stiffness.
Materials Used:-
Steel Braces: Diagonal members made of steel, strategically placed within the structure to resist lateral forces generated by earthquakes.

Process :-
1.Structural Assessment: Evaluation of the existing structure to identify vulnerabilities and determine the need for retrofitting.
2.Design and Analysis: Engineering analysis to design the placement, size, and configuration of steel diagonal braces, ensuring optimal seismic performance.
3.Installation Preparation: Preparation of the building and site for the retrofitting process, including access arrangements and safety precautions.
4.Brace Fabrication: Fabrication of steel braces according to the design specifications, ensuring quality and structural integrity.
5.Brace Installation: Placement and attachment of steel braces at strategic locations within the building, typically in a diagonal configuration to counteract lateral forces.
6.Connection to Structure: Secure attachment of steel braces to existing structural elements, ensuring effective load transfer and stability.
7.Finishing: Completion of any necessary finishing work, including cosmetic enhancements and restoration of the building's appearance.

Benefits
1.Increased Seismic Resistance: Steel diagonal bracing enhances the structure's ability to withstand lateral forces generated by earthquakes, reducing the risk of damage or collapse.
2.Improved Structural Stability: Bracing systems provide additional lateral support, minimizing deflections and sway during seismic events.
3.Cost-Effectiveness: Retrofitting with steel braces can be a cost-effective solution compared to other seismic retrofitting methods.
4.Minimal Disruption: Installation of braces typically involves minimal disruption to building occupants and operations, allowing for continued functionality during the retrofitting process.

Figur no 4 - Steel diagonal bracing[54]

Applications

1.Commercial Buildings: Retrofitting existing commercial structures to meet modern seismic codes and standards, ensuring occupant safety and structural integrity.

2. Industrial Facilities: Enhancing the seismic resilience of industrial buildings and facilities, safeguarding critical infrastructure and operations.

3.Historic Structures: Preserving the architectural heritage of historic buildings while improving their earthquake resistance, ensuring their longevity and cultural significance.

Drawbacks:-

1. Aesthetic Impact: Steel braces may alter the appearance of the building, particularly for architectural or historic structures, potentially compromising their visual integrity.

2. Space Constraints: Installation of diagonal braces may require sufficient space within the building, potentially impacting interior layouts and functionality.

3. Complex Installation: Proper installation of steel braces demands skilled labor and engineering expertise, involving intricate structural modifications and detailing.

Compatibility Challenges: Existing buildings may lack suitable structural elements to which steel braces can be securely attached, limiting retrofitting options in certain cases.

4. Maintenance Requirements: Steel braces may require periodic inspection and maintenance to ensure their continued effectiveness and structural integrity over time, adding to long-term ownership costs.

Additional Considerations :-

Building Interconnection: Connecting multiple buildings using steel diagonal bracing may pose challenges and may not always be feasible, limiting its application in certain contexts.

Code Compliance: Retrofitting with steel braces must comply with relevant building codes and regulations to ensure structural safety and regulatory compliance.

Conclusion

Steel diagonal bracing is a valuable seismic retrofitting technique, offering enhanced earthquake resistance and structural stability to existing buildings. While it provides significant benefits in terms of seismic performance and cost-effectiveness, careful consideration of drawbacks such as aesthetic impact, space constraints, installation complexity, and maintenance requirements is essential. By addressing these considerations and leveraging engineering expertise, steel diagonal bracing can effectively enhance the seismic resilience of buildings, ensuring the safety and longevity of structures in earthquake-prone regions.

IV. COMPARISM OF VARIOUS RETROFITTING TECHNIQUES

Table no 1

Sr.no	Technique Used	Effectiveness	Drawbacks	Results
1	Concrete Jackets	Highly effective in increasing deformation capacity and earthquake resistance	Retention of adverse effects of short lapping in some cases, especially affecting hysteretic energy dissipation. Labor and time-intensive installation.	Significant increase in deformation capacity, particularly in columns with smooth bars. Effective mitigation of adverse effects of short lapping in ribbed bars. Promising results for seismic retrofitting. However, potential damage to the structure during the installation process should be considered.
2	Special Concentric ally Braced Frames	Moderate	- Complex installation process increases construction time and cost. - May not be suitable for all building configurations or soil conditions. - Vulnerable to damage if not properly maintained.	- Reduction of maximum storey drifts by approximately 50% compared to MRFs. - Moderate decrease in inter-storey drifts (average 25-30%). - Requires meticulous design and installation to ensure effectiveness against earthquake seismic action.
	Moment Resisting Frames	High	- May not provide sufficient damping during seismic events, leading to higher residual displacements. - Limited effectiveness in regions with extremely high seismic activity. - Reduced design flexibility compared to other systems.	- Most cost-effective option with an average 70% reduction in inter-storey drifts compared to MRFs. - Maximum storey drifts reduced by around 70% compared to MRFs and 50% compared to SCBFs. - Installation process is relatively simpler compared to other techniques, contributing to its efficacy against earthquake seismic action. - Requires less structural steel, reducing construction costs.
	Buckling Restrained Braced Frames	Moderate to High	- Installation complexity increases the likelihood of errors. - High upfront costs may deter adoption in budget-constrained projects. - Requires specialized expertise for design and installation.	- Slightly superior effectiveness compared to SCBFs. - Similar reduction in inter-storey drifts as SCBFs. - Complex installation process necessitates careful planning.
3	Shear Wall	High	Alteration in appearance, may require significant attention to foundation design for installation, existing space occupied during installation	Significant improvement in seismic performance, increased lateral load carrying capacity, solved soft storey issue, additional cost incurred for retrofitting

V. RESEARCH OBJECTIVES:-

1. Investigate the effectiveness of earthquake retrofitting devices, with a focus on integrating girders into old construction buildings lacking earthquake-resistant features.
2. Assess how the addition of girders at midspan and on alternative floors enhances the stiffness of the building.
3. Evaluate the contribution of added girders to the earthquake resistance of the building.

4.Conduct empirical, computational, and observational analyses to provide insights into the efficacy of incorporating girders as a retrofitting strategy.

5. Determine the extent to swhich integrating girders bolsters structural resilience against seismic forces.

VI.MATERIAL REQUIREMENTS:-

6.1 shake table

Fig no 5 - Shake Table

Figure no 5 represents An earthquake shake table is a crucial tool for model testing in seismic research. It mimics earthquake motions to assess how structures respond, aiding engineers in designing earthquake-resistant buildings. By subjecting scale models to simulated seismic forces, researchers can study structural behavior and test retrofitting techniques. This experimentation helps enhance the safety and resilience of infrastructure in earthquake-prone regions. Shake tables play a pivotal role in advancing earthquake engineering, contributing to more robust building designs and disaster mitigation strategies.

6.2 Girder

Fig no 6 - Steel Girder With Plates

Figure no 6 represents Girders are structural elements used to support the weight of the building and distribute loads to the columns or walls. In retrofitting, girders may be added or strengthened to enhance the structural integrity of the building. They are typically made of steel or reinforced concrete, providing strength and stability to the structure.

6.3 Nuts and Bolts:

Fig no 7 - Nuts & Bolts [31]

Figure no 7 represent Nuts and bolts are fasteners used to connect different structural components together. In retrofitting, high-strength nuts and ensuring the stability and load transfer between retrofit elements and the original building components.

6.4 Channel Section Plate:

Figure no 8 represent Channel section plates, often made of steel, are used to provide additional reinforcement to structural members such as beams, columns, or walls. They are installed to distribute loads more evenly and prevent localized damage or failure during seismic events or other loading conditions. Channel section plates help in improving the overall ductility and strength of the structure without significantly increasing its weight.

Fig no 8 - Channel Section Plates [34]

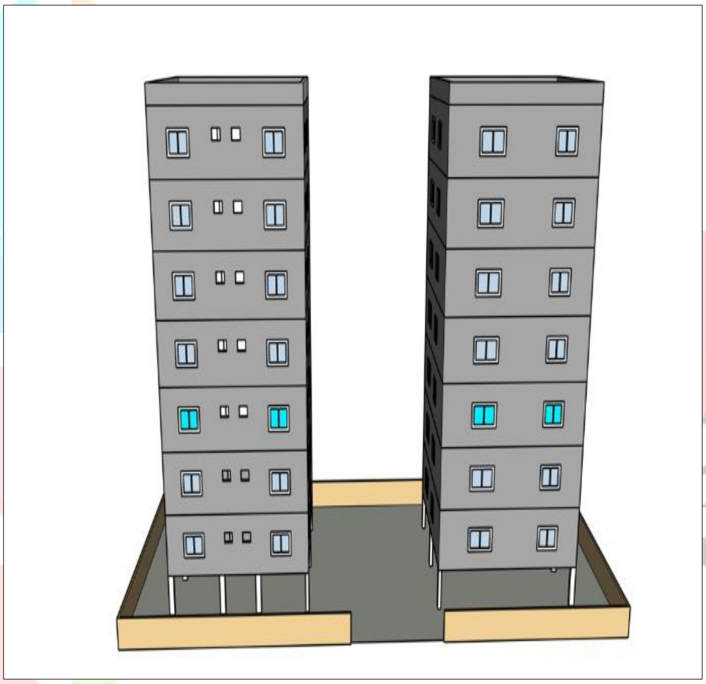
VII. METHODOLOGY:-

1. Identification of Old Construction Buildings: Begin by selecting suitable old construction buildings that are vulnerable to seismic hazards. These buildings should represent typical structures with known weaknesses in their structural integrity.
2.Seismic Assessment: Conduct a comprehensive seismic assessment of the selected buildings to evaluate their current condition and identify potential vulnerabilities. This assessment may include structural analysis, site evaluation, and historical data review to determine the level of earthquake risk.
3.Selection of Retrofitting Devices: Choose appropriate retrofitting devices based on the specific needs and characteristics of the buildings. In addition to traditional options such as base isolators, dampers, and shear walls, consider utilizing girders as a retrofitting device. Girders offer structural reinforcement and can be strategically installed to enhance the building's seismic resilience. Assess the feasibility and effectiveness of incorporating girders into the retrofitting strategy to improve the structural performance during earthquakes.
4.Installation of Retrofitting Devices: Install the selected retrofitting devices according to manufacturer specifications and engineering guidelines. Ensure that the devices are strategically positioned to reinforce critical structural elements and dissipate seismic energy effectively.
5.Modeling of Untreated Buildings: Develop models of two old construction buildings without any retrofitting devices. These models should accurately represent the existing structural configuration and vulnerabilities of the buildings.
6.Modeling of Retrofitting with Girders: Develop models of two additional buildings to illustrate the retrofitting technique involving girders. Position a girder at the mid-span of each building, connecting them

alternatively with the use of nuts, bolts, and channel section plates. Ensure proper alignment and anchorage of the girders to the columns, enhancing structural stability and load distribution throughout the building.
7.Incorporation of Channel Section Plates: Integrate channel section plates into the retrofitting method by connecting them to the columns. These plates serve to reinforce the connections between the girders and columns, enhancing structural integrity and load distribution.
8.Ice Stick Model Representation: Construct ice stick models to represent the structural components of the buildings, including columns, girders, and channel section plates. Use adhesive or fasteners to assemble the ice stick components into a cohesive model, accurately depicting the retrofitting configurations.
9.Experimental Testing: Conduct experimental testing using the ice stick models to simulate seismic loading conditions. Apply controlled forces or vibrations to assess the structural response and performance of the untreated buildings versus those retrofitted with devices and girders.
10.Analysis of Results: Analyze the experimental results to evaluate the effectiveness of the retrofitting methods in enhancing earthquake resistance. Compare the structural behavior, displacement, and stress distribution between untreated buildings and those retrofitted with devices and girders.

VIII. VISUALIZATION

8.1 G+7 Without retroffting Building



G+7 Without Retrofitting Solution
Fig no - 9 (Created by Author)

Figure no 9 represent the construction of two seven-story buildings without adherence to earthquake safety standards poses severe risks to occupants and surrounding areas, particularly in seismic-prone regions. Without adequate seismic resilience, these structures are vulnerable to catastrophic damage and collapse during an earthquake, potentially resulting in loss of life and extensive property damage. Retrofitting measures are imperative to mitigate these risks and ensure the safety of occupants and nearby communities. Structural assessments, coupled with retrofitting interventions such as the integration of girders, base isolators, or shear walls, can significantly enhance the buildings' ability to withstand seismic forces. By implementing these measures, the structural integrity of the buildings can be fortified, minimizing the potential fors devastation and ensuring the resilience of the built environment in seismic events.

8.2 G+7 With Retrofitting Building

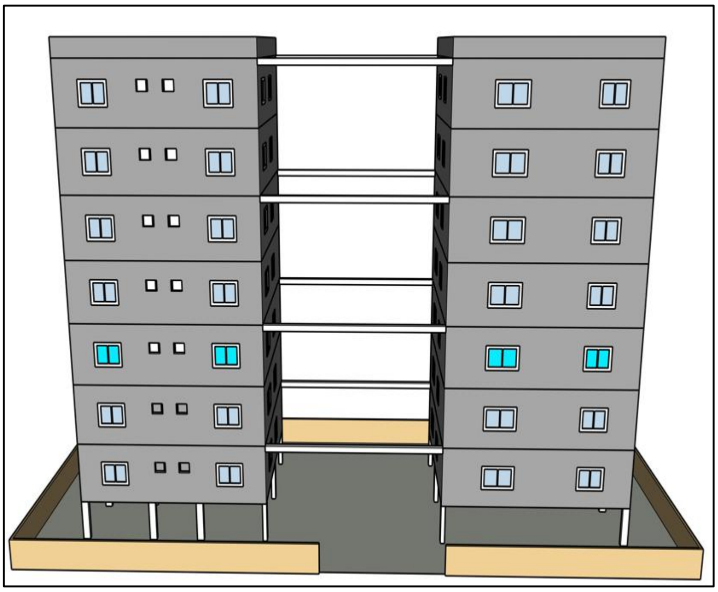


Fig no G+7 With Retrofitting Solution
Fig no 10 (Created by Author)

Figure no 10 represent In retrofitting a G+7 building, installing girders strategically at mid-span between floors offers crucial reinforcement. These girders act as supplementary support structures, significantly enhancing the building's resilience against seismic forces. By distributing loads more effectively and minimizing structural vulnerabilities, this approach strengthens the overall integrity of the building. In the event of an earthquake, the presence of these girders helps dissipate seismic energy and mitigate potential damage, thus ensuring the safety of occupants and preserving the structural stability of the building. Additionally, the strategic placement of girders minimizes disruptions to the building's functionality and aesthetics while maximizing the effectiveness of the retrofitting solution. Overall, integrating girders in this manner provides a robust and practical means of enhancing the seismic resilience of the G+7 structure.

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