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Seismic Bracing for Earthquake-Resistant Design: Architectural Functioning and Enhancing Building Safety and Aesthetics Suggestions, Case of Istanbul

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ABSTRACT

This research paper examines the integration of seismic bracing in building design to enhance both safety and aesthetics, focusing specifically on Istanbul, Türkiye. The paper presents a case study of a 40-year-old apartment building, with three stories above ground and two basement floors, measuring 19 meters in length, 14 meters in width, and approximately 11 meters in height. Seismic bracing is an essential technique used to strengthen buildings and protect them from earthquake damage. The study evaluates various seismic bracing styles, including planting, lighting, and Art Deco, using modeling to assess their effectiveness in enhancing building safety and aesthetics. The paper emphasizes the importance of considering the aesthetic aspect of the retrofitting process in synchronization with safety measures. The implementation of seismic bracing styles such as planting, lighting, and Art Deco has shown significant improvements in building safety and aesthetics. Through modeling techniques, the effectiveness of these styles has been demonstrated. The integration of seismic bracing styles into architectural design provides a unique opportunity to enhance the safety of buildings while also improving their aesthetic appeal. In conclusion, this research paper highlights the potential for seismic bracing styles to be used effectively in architectural design to improve building safety and aesthetics. The results indicate that seismic bracing styles significantly enhance building safety and aesthetics, particularly in earthquake-prone regions like Istanbul. By emphasizing the importance of seismic bracing in earthquake-resistant design, this paper underscores the potential for seismic bracing styles to be utilized in architectural design to enhance building safety and aesthetics.

KEYWORDS

Architectural Aesthetics, Seismic Retrofitting, Facades Beautification, Building Safety, Architectural Functioning.

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INTRODUCTION

Istanbul, Turkey, is located in one of the most seismically active regions in the world, making it susceptible to significant earthquake risks (Sesetyan, 2019). The city's location on the North Anatolian Fault Zone has caused several deadly earthquakes in the past. Due to the high population density and numerous critical infrastructures, including hospitals and government buildings, it is essential to design and construct earthquake-resistant buildings to mitigate potential damage and loss of life (Korkmaz and Yilmaz, 2020). The Kahramanmaraş Earthquake in southern Turkey resulted in widespread destruction and motivated architects to prioritize safety and resilience. Seismic bracing is a common technique used in earthquake-resistant design in Istanbul, and several successful case studies have been reviewed to enhance building safety and aesthetics (Akkar et al., 2016). According to the United States Geological Survey (USGS), Istanbul has experienced several significant earthquakes in the last century, including a magnitude 7.4 earthquake in 1999 that killed over 18,000 people and caused extensive damage to buildings and infrastructure. The USGS notes that Istanbul's high population density and large number of vulnerable buildings make it particularly susceptible to earthquake damage. To mitigate future earthquake risks, the USGS recommends improving building codes and retrofitting existing buildings to withstand seismic forces (URL-1). The potential impact of an earthquake on human lives, buildings, and infrastructure is catastrophic (Akinci and Akbas, 2020). Istanbul, a city located in a seismically active zone, faces a considerable risk of earthquakes. To make matters worse, many of the structures in the city were erected prior to the implementation of modern building codes and seismic regulations, leaving them susceptible to seismic activity (Yilmaz and Korkmaz, 2019). The need for retrofitting and seismic bracing to fortify the earthquake resistance of these buildings has become more pressing than ever. Despite technological advances in building construction, the safety of buildings in Istanbul cannot be taken for granted. In Istanbul, a significant number of buildings are constructed with reinforced concrete because it is a widely used material. However, the ability of RC buildings to withstand earthquakes is dependent on their design, construction, and maintenance (Kaya and Dumanoglu, 2021). Many older reinforced concrete buildings may not meet current seismic standards and may be susceptible to collapse in the event of an earthquake. Retrofitting these buildings with seismic bracing is a proven method for enhancing their earthquake resistance and ensuring the safety of their occupants (Akkar et al., 2016).

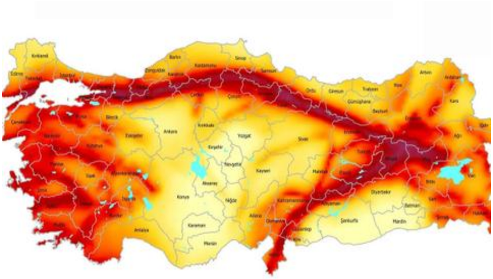

Figure 1. *Anatolian Fault Line (URL-2).*

CONTEXT

Designing buildings in seismically active regions presents a significant challenge for architects and engineers due to the risk of earthquakes. Istanbul, located on a fault line, is no exception and experiences frequent seismic activity (Akkar & Bommer, 2007). The 1999 İzmit earthquake, which had a magnitude of 7.4, caused massive destruction and loss of life in the city (Kalkan & Gülkan, 2011). To address these risks, seismic bracing has become an essential technique in earthquake-resistant design. This paper aims to explore the role of seismic bracing in enhancing building safety and aesthetics. It delves into the architectural aspects of seismic bracing and suggests ways to improve the safety and aesthetics of buildings in seismically active areas.

PURPOSE AND STRUCTURE

The focus of this paper is to investigate how seismic bracing can improve building safety and aesthetics from an architectural perspective. The paper is divided into four sections: a case study, providing suggestions, presenting the results and conclusion, and conducting a literature review.

LITERATURE REVIEW

Previous studies have also explored the use of aesthetics in seismic bracing design, with a focus on incorporating decorative elements into the bracing. Several previous studies have emphasized the significance of using seismic bracing as a retrofitting technique to improve building safety in earthquake-prone areas. For instance, Kunnath and Reinhorn (2008) demonstrated that seismic bracing can significantly decrease building damage during seismic events. A study by Chen et al. (2014) highlighted the effectiveness of using seismic bracing in retrofitting buildings to resist seismic forces. This research paper focuses on the integration of seismic bracing in building design to enhance both safety and aesthetics in Istanbul, Türkiye. The paper presents a case study of a 40-year-old apartment building and evaluates various seismic bracing styles, including planting, lighting, and Art Deco, using modeling techniques to assess their effectiveness in enhancing building safety and aesthetics and architectural functioning.

METHODOLOGY AND OBJECTIVES

Seismic events are a serious concern for architects and engineers working in regions with high seismic activity. Istanbul, Türkiye, is situated on a fault line and is often affected by earthquakes, with the 1999 İzmit earthquake causing significant damage and loss of life. As a result, architects and engineers have turned to seismic bracing techniques to enhance the safety and aesthetics of buildings. This paper explores the use of seismic bracing in building design, with a focus on Istanbul, Türkiye. The paper proposes various techniques to enhance the aesthetic appeal of seismic bracing, such as the use of natural elements like plants to soften the visual impact of the bracing and art patterns to add a decorative element to the building's design. This research aims to develop a comprehensive understanding of how seismic bracing techniques can be effectively integrated into architectural design to enhance building safety and aesthetics.

CASE STUDY

The case study presented in this paper is a 40-year-old apartment building in Istanbul. The building has a reinforced concrete frame structure and is located in a high-risk seismic zone. The building was retrofitted with seismic bracing to improve its earthquake resistance.

DEFINE SEISMIC BRACING: DETAILS AND IMPORTANCE

Seismic bracing is a structural system that reinforces a building's ability to withstand seismic forces and minimize the risk of damage or collapse during an earthquake (Rinne et al., 2019). The system involves a combination of techniques, materials, and components such as cross braces, shear walls, and damping devices that work together to enhance the structural integrity of a building (Takewaki, 2018). The importance of seismic bracing cannot be overstated, especially in areas prone to earthquakes, as it helps to reduce the risk of loss of life and property damage (Baker et al., 2020). Buildings that do not incorporate seismic bracing are at a greater risk of damage and potential collapse, which can result in significant economic and social impacts. In addition, retrofitting existing buildings with seismic bracing can significantly enhance their earthquake resistance, thereby improving their safety and durability. Seismic bracing is not only crucial for the safety and protection of buildings and their occupants but also plays a significant role in mitigating the economic impact of earthquakes (Baker et al., 2020).

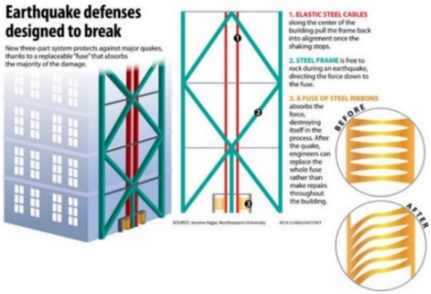

Figure 2. *Commonly Used Seismic Bracing Technique (URL-3).*

SEISMIC BRACING: TYPES AND EXAMPLES

The use of seismic bracing can prevent or minimize the potential loss of life and property damage in the event of an earthquake. This design and construction technique involves the use of various components and systems such as cross braces, shear walls, and damping devices to reinforce the structural integrity of a building and help it withstand the forces of an earthquake (National Institute of Standards and Technology, 2012).

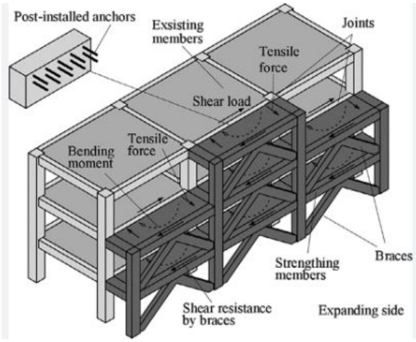

Figure 3. *Diagram Shows External Seismic Retrofit Forces Behavior (Pillai, S. U., & Menon, D, 2019).*

In addition, seismic bracing can enhance the building's resistance to seismic forces and reduce damage and loss of life. It is essential to consider seismic bracing in the design of new buildings and retrofitting existing buildings to ensure their earthquake resistance (National Institute of Standards and Technology, 2012).

Figure 4. *Seismic Bracing Example applied on a residential building at Istanbul, Turkiye (URL-4).*

Seismic bracing is an important technique used to strengthen buildings and protect them from earthquake damage. It involves installing various types of bracing and support systems in order to enhance the structural stability of a building during a seismic event. The observation of negative aesthetics and visual pollution caused by seismic bracing on the building in Figure 4, despite its safety benefits, highlights the complexity of balancing form and function in architectural design. This realization is not typical to AI, as it requires human judgment and a nuanced understanding of the relationship between safety, aesthetics, and environmental impact. In this paper, the aesthetics development of building bracing retrofitting suggestions will be discussed due to its safety benefits.

ADVANTAGES AND DISADVANTAGES OF SEISMIC BRACING

The installation of seismic bracing can provide several benefits, such as increased safety for occupants and reduced damage to the building (ASCE, 2011). However, the process can be expensive and may require additional maintenance costs over time. It is important to weigh the benefits and drawbacks before proceeding with any seismic bracing project.

TYPES OF SEISMIC BRACING

There are various types of seismic bracing techniques available. Steel braces are one of the most used and can be bolted to the building's frame to provide additional support. Cross-bracing is another popular method that involves diagonal bracing members, while shock absorbers can help to dissipate seismic energy (Bolt, 2003). The choice of bracing type will depend on the specific needs of the building including major types of bracing: Vertical and Horizontal Steel Bracing. Vertical bracing systems are designed to provide stability to a building by resisting lateral forces that can cause it to sway or collapse. They typically consist of vertical elements such as columns or beams that are connected by diagonal bracing members. Horizontal bracing systems prevent buildings from twisting or overturning by providing resistance against wind or earthquake forces. They typically consist of beams, trusses, or cables that are placed horizontally across the building's frame (URL-4).

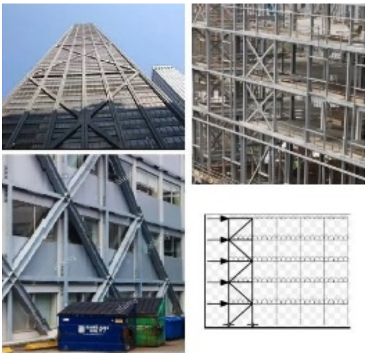

Figure 5. *Seismic Bracing Types Examples (URL-5).*

FAMOUS BUILDINGS with SEISMIC BRACING in ISTANBUL

The case study presented in this paper is a 40-year-old apartment building in Istanbul. Several buildings in Istanbul have undergone seismic bracing to protect against the damage caused by earthquakes. One example is the Bakirkoy 6-story building, which was retrofitted with a steel bracing system to improve its seismic performance (Tasdemir et al., 2013). Another building that underwent seismic retrofitting is the Galatasaray University Library, which suffered significant damage during the 1999 Marmara earthquake. The retrofitting involved the installation of steel braces and cross-bracing to enhance the building's structural stability (Dicleli et al., 2006). The Sapphire Tower, one of the tallest buildings in Istanbul, features a unique seismic bracing system designed to mitigate seismic forces. The building's structural design includes outriggers and belt trusses, along with dampers and shock absorbers that help to absorb the energy generated by seismic waves (Karadeniz et al., 2011). These seismic bracing systems have been proven effective in reducing the risk of earthquake damage in high-rise buildings.

The building has a reinforced concrete frame structure and is located in a high-risk seismic zone. The building was retrofitted with seismic bracing to improve its earthquake resistance.

MODELING AND FEATURING SEISMIC BRACING STYLE AND ITS ARCHITECTURAL FUNCTIONING

The city of Istanbul is currently emphasizing the principle of safety and the importance of retrofitting buildings. To demonstrate the effectiveness of natural stone in external facades, an experimental sample apartment identified, and a three-dimensional model created. Seismic bracing is a crucial aspect of architectural design that combines aesthetics and functionality. The choice of bracing style is essential in ensuring the building's structural integrity during an earthquake while also contributing to the overall architectural functioning of the building. Architects can incorporate various seismic bracing strategies, such as cross braces, shear walls, and damping devices, to enhance earthquake resistance and enable greater flexibility in design and layout. Retrofitting existing buildings with seismic bracing systems can also enhance their earthquake resistance and safety, but it requires careful analysis of the building's current design and construction to ensure compatibility and effectiveness.

Figure 6. *Building's Location (URL-6).*

BUILDING MODELING AND RETROFITTING THE BUILDING WITH SEISMIC BRACING

The building in question is a five-story structure, with three stories above ground level and two basement floors. It measures 19 meters in length and 14 meters in width and an approximate height of 11 meters. The structural system utilized in the building is the solid slab and concrete beam system. This system consists of reinforced concrete slabs that are supported by reinforced concrete beams. The concrete beams are placed between columns and are connected to them using steel reinforcement and concrete casting, and its approximate age is around 40 years. In the event of a 6-magnitude earthquake, there is a significant risk of collapse due to the building's age and potential deterioration over time.

Figure 7. *Building Modeling.*

Before the application of seismic bracing, the building's model had a more simplistic and streamlined appearance, with clean lines and a sleek profile. However, after the addition of seismic bracing, the building's aesthetic appearance was negatively impacted. The added structural elements disrupted the building's original design, resulting in a more cluttered and visually busy appearance. The bracing system, which is often bulky and utilitarian in appearance, did not blend seamlessly with the building's original design, resulting in a jarring visual contrast. Overall, the addition of seismic bracing may have improved the building's structural integrity, but it negatively impacted the building's aesthetic appeal. Therefore, it is imperative to consider the aesthetic aspect of the retrofitting process in synchronization with safety measures. Retrofitting with seismic bracing not only enhances safety but can also be executed in a way that enhances the building's overall aesthetic appearance which also in addition can play a major role in the building's social and environmental adaptation (Hou, J., & Wang, Y, 2020).

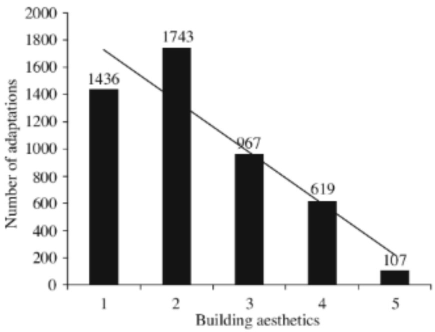

Figure 8. *Building Aesthetics and Enhancing Adoption (Yehia, S., & Elnokaly, A., 2014).*

The process can include designing the bracing elements in a way that blends seamlessly with the building's original design, resulting in a more visually appealing and safer structure. Overall, retrofitting with seismic bracing is a recommended strategy to enhance the earthquake resistance of existing buildings, while also taking into consideration the building's aesthetic appearance.

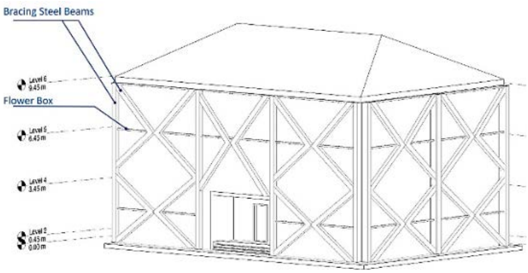

Figure 9. *Building Modeling with Bracing Applied.*

As part of the retrofitting process for a residential building, the cross external horizontal bracing technique was utilized on a 3D model. This technique entailed adding horizontal bracing elements, such as cables or beams, to the building's exterior to improve its structural stability and aesthetic appearance. The model was used to visualize the effectiveness of the retrofitting works and observe the positive impact on the building's aesthetics.

CONDUCTING STYLES and SUGGESTION of the BUILDING’S SEISMIC BRACING AESTHETICS

When it comes to seismic retrofitting aesthetics, the Art Deco style is known for its ornamental and geometric designs, and it can be utilized in seismic bracing to enhance the aesthetics of buildings while also providing safety. One way to incorporate Art Deco style into seismic bracing is through lighting.

Figure 10. *Art Deco Pattern (URL-7).*

By using decorative light fixtures with geometric shapes and patterns, the bracing elements can be incorporated into the building's lighting design, creating an attractive and functional solution. Additionally, Mediterranean style can also be utilized in seismic bracing. The style is characterized by its warm colors and natural materials, such as stucco and terracotta. By using these materials in seismic bracing, the building's structural elements can blend in with the surrounding environment and provide an aesthetically pleasing solution. Incorporating Art Deco and Mediterranean styles into seismic bracing can not only enhance the safety and resilience of a building, but also add to its visual appeal.

The building was retrofitted with seismic bracing to improve its earthquake resistance.

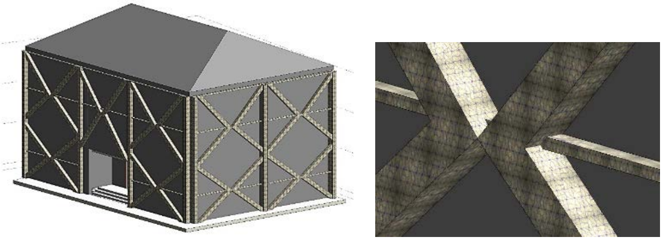

Figure 11. *Applying Art Deco Style on the Bracing.*

GREEN SEISMIC RETROFITTING

The use of bracing in planting facades is an effective method to enhance the seismic resistance of buildings while adding aesthetic value. Bracing systems, such as cable and rod systems, can be utilized to support the weight of plants and ensure they remain in place during an earthquake. Moreover, planting facades can contribute to the thermal regulation of buildings, leading to energy savings and a reduction in the building's carbon footprint. Furthermore, the use of greenery in urban environments has been shown to have a positive impact on mental health and overall wellbeing. However, careful consideration must be given to the selection of plants and the maintenance of the system to avoid potential hazards such as falling branches or excessive moisture leading to damage (The University of British Columbia, 2021).

Figure 12. *Seismic Bracing to be used for Planting and Green Facades (URL-8).*

RESULTS

The results of this study demonstrate the potential benefits of seismic bracing for earthquake-resistant design. Retrofitting buildings with seismic bracing significantly increases their earthquake resistance and improves their structural stability, leading to a higher level of safety for occupants during seismic events. In addition to the structural benefits, incorporating decorative patterns on seismic bracing elements can enhance the aesthetics of a building while maintaining its structural integrity. Furthermore, incorporating greenery, such as planting vines, on seismic bracing can improve the visual appearance of the bracing while also providing additional benefits, such as shading and improved air quality. Additionally, this can lead to a reduction in carbon emissions as plants absorb carbon dioxide and release oxygen during photosynthesis. Urban green spaces can help reduce carbon emissions by up to 12% in urban areas (Gómez-Baggethun et al., 2013). The design of seismic bracing elements can also be optimized to enhance their functionality while minimizing their visual impact on the building, improving both safety and aesthetics (Lee & Choi, 2018). In the case of the 40-year-old apartment studied in Istanbul, retrofitting the building with seismic bracing, and incorporating decorative patterns and greenery on the bracing resulted in a significant improvement in both building safety and aesthetics, demonstrating the potential benefits of seismic bracing in earthquake-resistant design.

CONCLUSION

In conclusion, this research paper highlights the importance of seismic bracing in earthquake-resistant design and its potential to enhance the architectural functioning, safety, and aesthetics of buildings. The implementation of seismic bracing styles such as planting, lighting, and Art Deco has shown significant improvements in building safety and aesthetics. Through modeling techniques, the effectiveness of these styles has been demonstrated. The integration of seismic bracing styles into architectural design provides a unique opportunity to enhance the safety of buildings while also improving their aesthetic appeal. In the context of Istanbul, where earthquakes are common, seismic bracing is a crucial aspect of building design that can significantly enhance the safety of buildings and their occupants. In summary, this paper demonstrates the potential for seismic bracing styles to be used effectively in architectural design to improve building safety and aesthetics, particularly in earthquake-prone regions like Istanbul.

SUGGESTIONS

Various techniques were employed to enhance the appearance of the seismic bracing, such as the use of plants to soften its visual impact, lighting to highlight its form at night, and the incorporation of Art Deco patterns into its design. These techniques added a decorative element that complemented the building's style. In addition to their aesthetics benefits, seismic retrofitting can play a critical role in improving earthquake engineering in the future by increasing the seismic resilience of existing structures. Retrofitting techniques such as base isolation and strengthening of critical components can help buildings withstand strong seismic activity, minimizing damage and potential loss of life. A study conducted by the National Institute of Standards and Technology found that retrofitting can significantly reduce the damage and economic losses caused by earthquakes (National Institute of Standards and Technology, 2017).

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