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RESEARCH ARTICLE

Effect of Different Types of Bracing Systems on Seismic Performances of High Rise Buildings: A Review

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Abstract

This work discusses the incorporation of bracing systems in RCC structures in India to mitigate earthquake impact. It explores how bracing techniques can create open spaces by eliminating interior columns. RCC bracing offers advantages in stiffness and stability compared to conventional methods. The study evaluates different RCC bracing systems in high--rise buildings using STAAD.ProV8i software and compares their seismic performance. X- braced frames are found to be more efficient and secure during earthquakes than moment-resistant and V-braced frames.

Keywords: Base shear; High-rise reinforced concrete; analysis of modal response spectrum Seismic behavior; Seismic analysis; Steel bracing systems; 3D structural modeling; RCC bracing; Storey displacements

Introduction

As a result of steadily increasing seismicity in different regions across the world, earthquakes have grown into a massive force that must be taken into account when designing. Many established concrete- framed buildings in seismic zones are inadequate for surviving moderate to severe earthquakes. The biggest reasons for these structures' poor seismic behaviour are completely inadequate lateral resistance and poor reinforcement detailing. In past few years, a great deal of research has been focused on the investigation of strategy and intensive growth strategy techniques to enhance the earthquake resistance of concrete-reinforced frame members and structural features.

While a variety of these methodologies can significantly promote the lateral stiffness and resistance of structural members, proper seismic behavior is only going to be derived if the maintenance and rehabilitation of the structure can meet the earthquake's strength and ductility demands. Bracing systems appear as being among the most successful strategies for accomplishing this goal. Pure frame tall structures have almost vanished because they are usually ineffective and economically unviable.

To endure the almost all of the lateral pressure stimulated by a seismic events, braces are used in conjunction with a steel and concrete frames that resist momentary forces.

Even though vertical loads in high buildings are mostly systematic, they do not constitute many difficulties in analyzation or layouting. However, lateral loads caused by wind or seismic activity are a reason to be cautious. Tall building design must take these factors into account. All such lateral forces may result critical stresses in the structural system, as well as unwanted vibrations and extreme lateral sway to the structural members. Rapid advancements in the development of high- rise framed structures have highlighted the importance of restricting side sway caused by lateral loads. When compared to conventional rigid frames, braced frame structures have less lateral sway. The appearance of bracing systems in the frame changes the overall structural behavior, particularly when it is exposed to lateral loads.

There are numerous methods for installing braces to boost building earthquake protection. Typical diagonal bracing, X- bracing, chevron bracing, and V-bracing schemes are used to link the bracing concentric to the beam-column joint. Popov and Roeder introduced eccentric bracing, which combines the best qualities of both moment resistant frames and concentric braced frames [1]. Shear connections that are an inherent element of a beam improve energy dissipation capability in eccentric braced frames during a seismic stimulation. Yet, because it is a fundamental structural component, rebuilding a broken shear link after a large earthquake can be time consuming and costly. Ochoa [2] recently suggested a knee braced frame as an alternate approach. The elastic fuse element is employed in this system to prevent structural collapse by releasing energy during torsional buckling of the knee element. Balendra et al. [3] then revisited the knee braced structure and recommended several changes. Delaying the breakage of braces improves the seismic efficiency of non-ductile chevron bracing systems. In chevron, this can be accomplished by altering the brace and floor beams to a feeble brace and strong beam arrangement.

Its improved chevron braced design has an outstanding hysteretic response, with ductile braces distributing damage evenly across the building's height [4]. Tremblay et al. investigated the earthquake resistance of concentrically braced structural steel frames, such as diagonal and X-braced frames, under cyclic loads [5].

Literature Review

Tafheem and Khusru (2013) [13] have conducted an investigation comparing between eccentric and concentric steel bracing systems. This research modeled and analyzed six-story structural steel structures as a result of wind loading, lateral seismic loading, live load and dead load. Thus every eccentric v-bracing and concentric x-bracing is carried out similarly in structural system. Wind loads are computed using ASCE 7-05, and seismic lateral stresses are determined using the national building code of Bangladesh, BNBC 2006. The behavior of the structures is assessed in terms of displacement, storey drift, axial forces and bending moment using ETABS software. According to the findings of this study, more deflection is limited by concentric x-bracing with higher structure rigidity.

Hameed, Akmal, and Siddiqi (2014) [14] published an article that compared different bracing systems in high rise buildings. This research looks at five different categories of steel bracing structures in the form of structural weight, lateral stiffness and lateral displacement. STAAD Pro software was used to model and analyze concentric x-braced frames, concentric diagonal braced frames, eccentric inverted-v braced

frames, and concentric inverted-v braced frames. For the purpose of this research conducted, non-linear static analysis has been carried out. The eccentric inverted-v granted the smallest value of deflection based on the findings from this research. However, in the particular instance of cross x bracing, the minimum weight was obtained.

Khaleel and Kumar (2016) [15] presented research that evaluated the influence of earthquake excitation on regular and irregular steel frame structures with various steel bracing systems, where every other moment resisting frame, v-bracing, k- bracing, x-bracing, inverted-v bracing, and knee bracing system was evaluated in accordance with the IS 1983-2002 code. ETABS software was utilized to construct and analyze structural buildings with G+9 storeys. The characteristics such as displacement and base shear are investigated using the equivalent lateral force approach. The outcomes demonstrate that for both regular and irregular structures, X-bracing is the best bracing method to decrease story displacement, as well as having a high base shear due to its higher rigidity.

Mapar and Ghugal (2017) [16] published a study on the seismic reliability of tall steel structures with MRF and braced frames. For the purpose of this article, each of the cross, k, v and inverted-v bracing systems is chosen and deployed within a 25-story structure. ETABS 2013 program is used to explore the dynamic analysis. According to the data based on base shear storey drift and modal period, cross bracing is the best bracing solution.

Ghandak, Kulkarni, Devtale, and Sayyed (2016) [17] conducted research on steel bracing as a way of resisting lateral forces. G+9 storey steel buildings are constructed utilizing UC and UB British divisions to withstand seismic, wind, and gravity stresses in accordance with Indian standard 800-2007. In this study, various types of steel bracing are explored, with each of k-bracing, v-bracing, x-bracing, and inverted-v bracing being demonstrated with the design using STAAD Pro (v8i) software. According to the findings of this study, the k-braced building has the most lateral deformation while the v-braced building has the least weight.

Identification of Gaps

Insufficient research has been conducted on the behavior of various types of Lateral Bracing Systems in Steel Framed Structures.

There has been inadequate research on Steel Frame with Bracing Systems that comply with the new Seismic Code regulations (IS - 1893, 2016).

Additional research is needed to examine the various combinations of Bracing Systems utilized in steel constructions.

It is imperative to conduct a thorough investigation into the performance of different brace combinations.

Need and Scope of the Study

When designing and building any type of structure, we must consider two major

elements which lead the structure to fall apart: seismic force and wind force. These are extremely dangerous and unpleasant to the property of the structure; all of these lateral forces have the potential to cause critical stresses in the structural system, as well as undesirable vibrations and excessive lateral sway to the structural elements. The structure should therefore be constructed in such a manner that it can resist these influences instantly without any failure. As the height of a building increases, so does its vulnerability to these pressures; the effect of these forces likewise increases. As a result, structural design should take into account the behavior and effects of earthquake and wind forces on multi-story buildings.

This study will be conducted to better understand the performance and various metrics of structures when subjected to earthquake and wind forces, and in order to keep the structure stable and safe from these crucial stresses, multiple types of bracing systems and their combinations must be used while designing, and the effects of different bracings will also be examined throughout this research.

Objectives

The main objectives of this study titled “Effect of Different Bracing Systems on Seismic Performance of High Rise Steel Structures” shall be as follows:-

- To construct a steel-framed structure (regular and irregular in plan) for a typical high-rise building in a seismic zone and explore the structural behavior changes produced by different brace configurations.
- To assess the impact of a bracing system on various aspects of steel structures during seismic occurrences, and to increase base shear at the structure's bottom during an earthquake while limiting storey displacement and drift.
- To determine the most suitable pattern and positioning of Bracings that can be applied to Regular buildings, and subsequently extended to Irregular buildings, based on an analysis of various parameters such as Axial Force, Torsion, Bending Moment, Base Shear, Shear Stress, and Lateral Sway. This evaluation will be conducted under earthquake conditions, in accordance with the new seismic code IS: 1893- 2016.To study the behavior of Re-entrant corners in buildings with plan irregularities using different Bracing arrangements.
- To study the behaviour of Re-entrant corners in buildings with plan irregularities using different Bracing arrangements.

Research Methodology

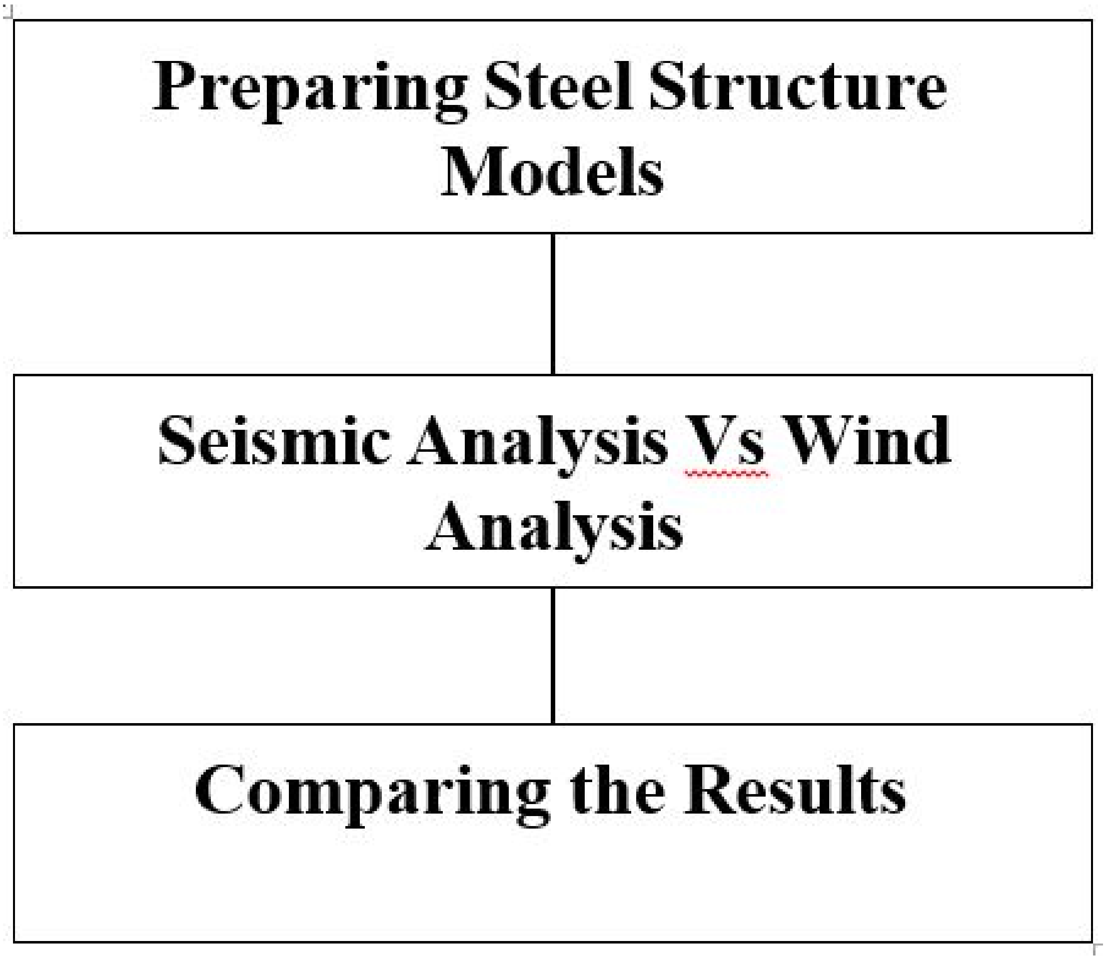

Figure 1: Block Diagram of Research Methodology.

Preparing Steel Structure Models

The first stage of the current work is to prepare various steel frame structures. For this reason, Bentley's Staad. Pro software will be used, and various analysis and design parameters will be used in accordance with their respective codes.

Wind Analysis and Seismic Analysis

Dynamic seismic performance evaluation (Response Spectrum Analysis) must be carried out in accordance with the revised seismic code IS: 1893-2016. During the seismic analysis, the following seismic parameters must be considered:

Seismic Zone: V

Response Reduction Factor: 5 Importance Factor: 1.2

Wind analysis of a steel frame structure in compliance with IS: 875 (Part 3) - 1987 and various wind factors and coefficients must be chosen from the code.

Understanding of both codes is required in order to meet the goals of this research.

Comparing the Results

After assessing and creating all of the models, a thorough examination of the resulting data is required. It should be noted that no errors should occur during the analysis process; otherwise, the findings will not be generated. The results must be properly represented so that the study work clearly displays the comparison of all connected buildings. Various parameters will be used for comparison.

Modeling and Analysis

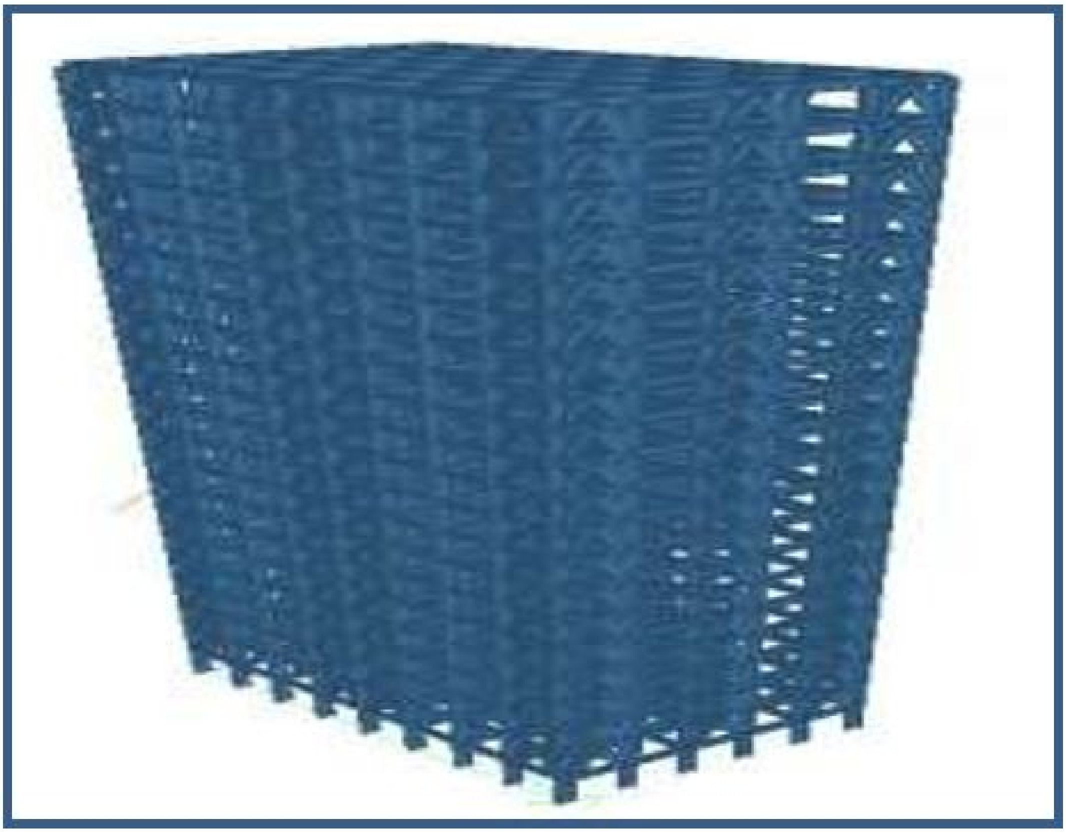

Figure 2: 2X- Brace

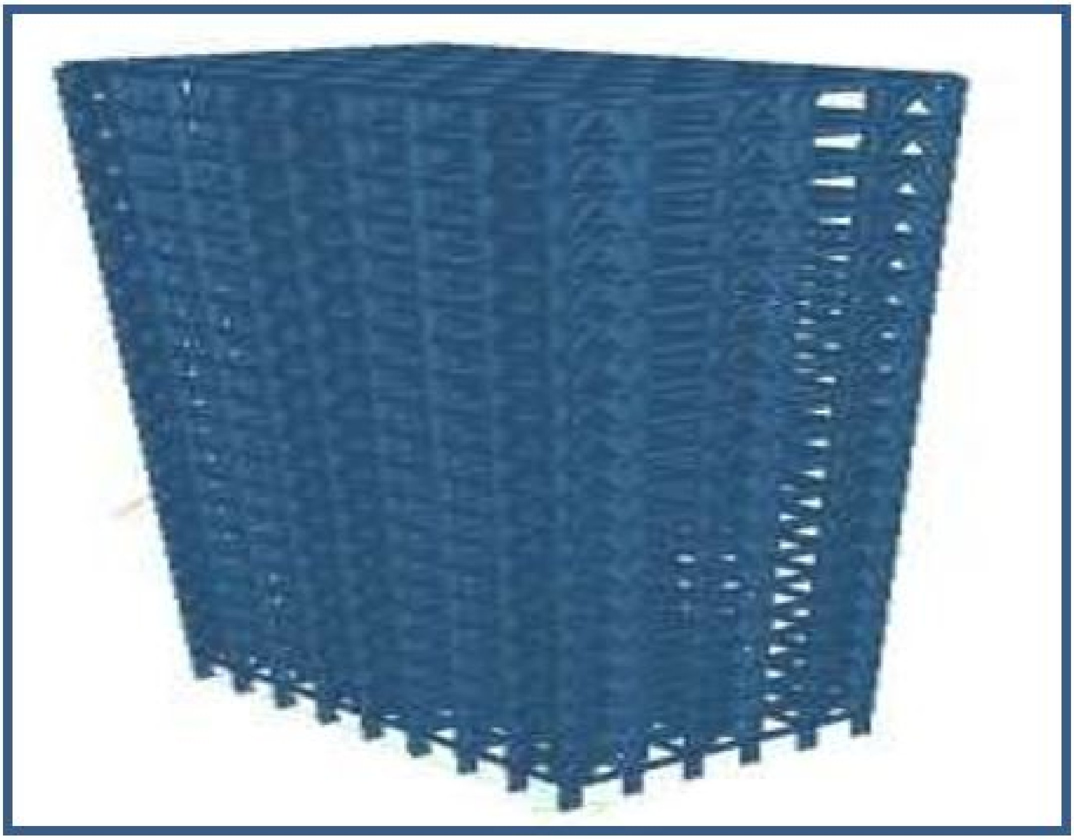

Figure 3: 3Inverted V-Brace

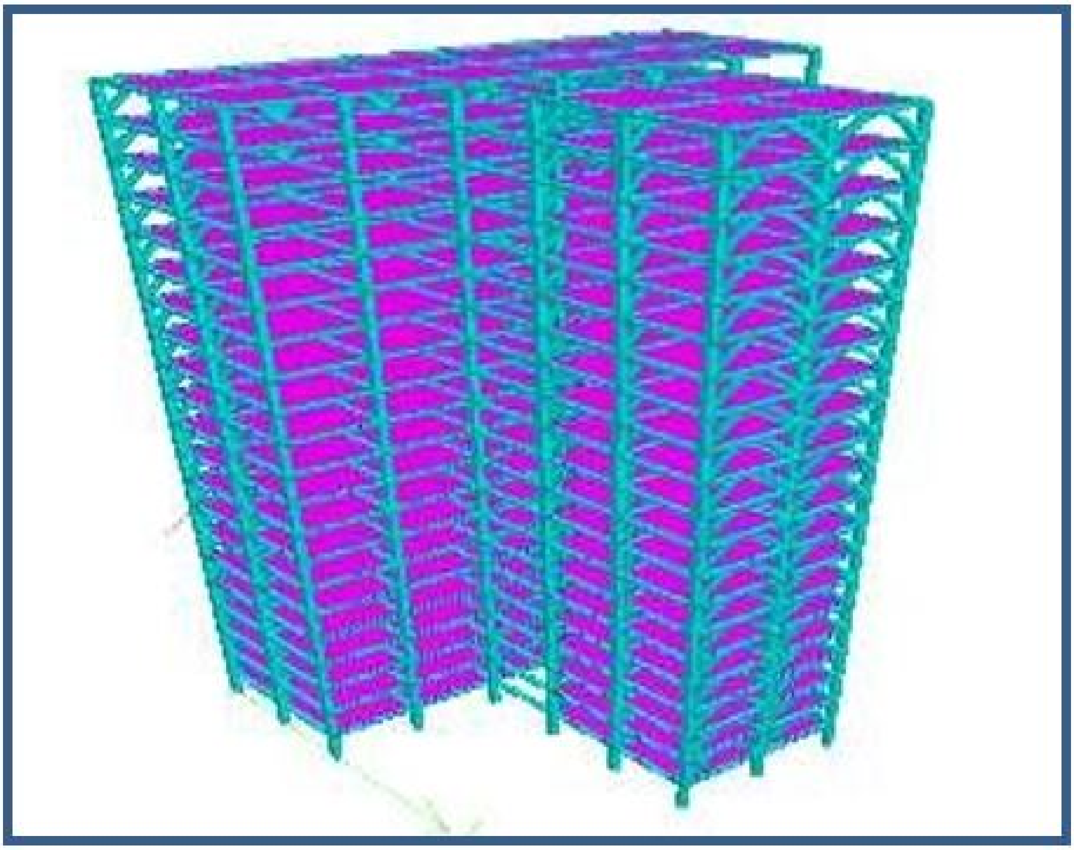

Figure 4: 4A - Arch Brace

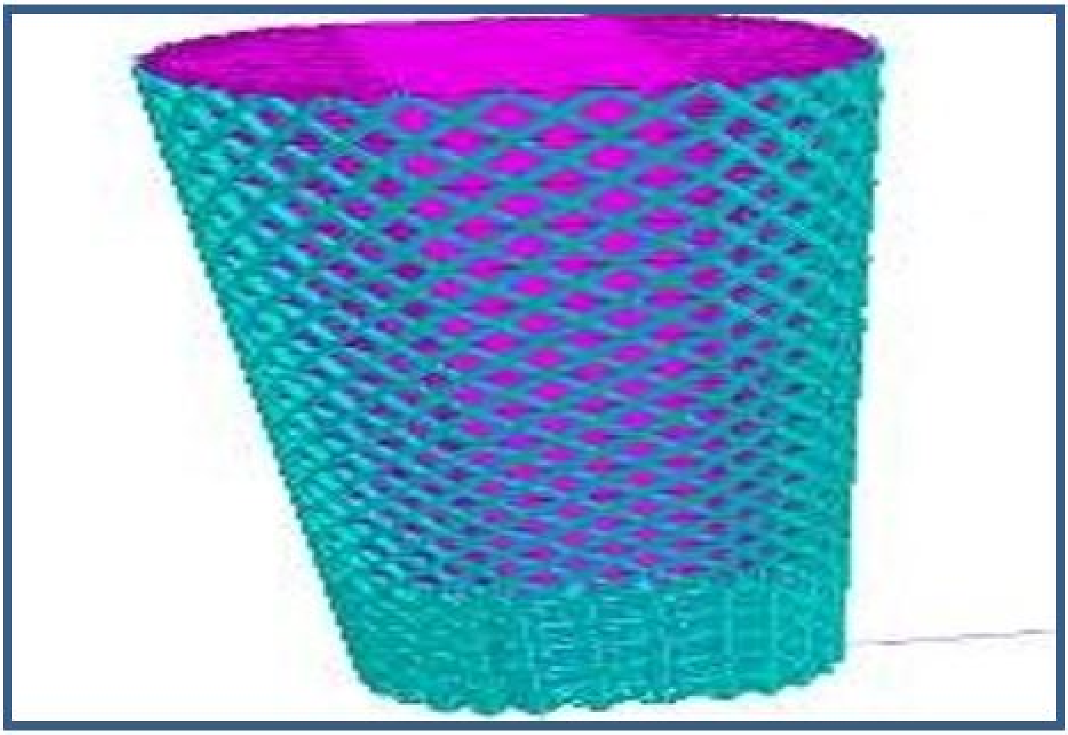

Figure 5: 5Diagonal brace

Results and Discussion

Table 1: Maximum Displacement

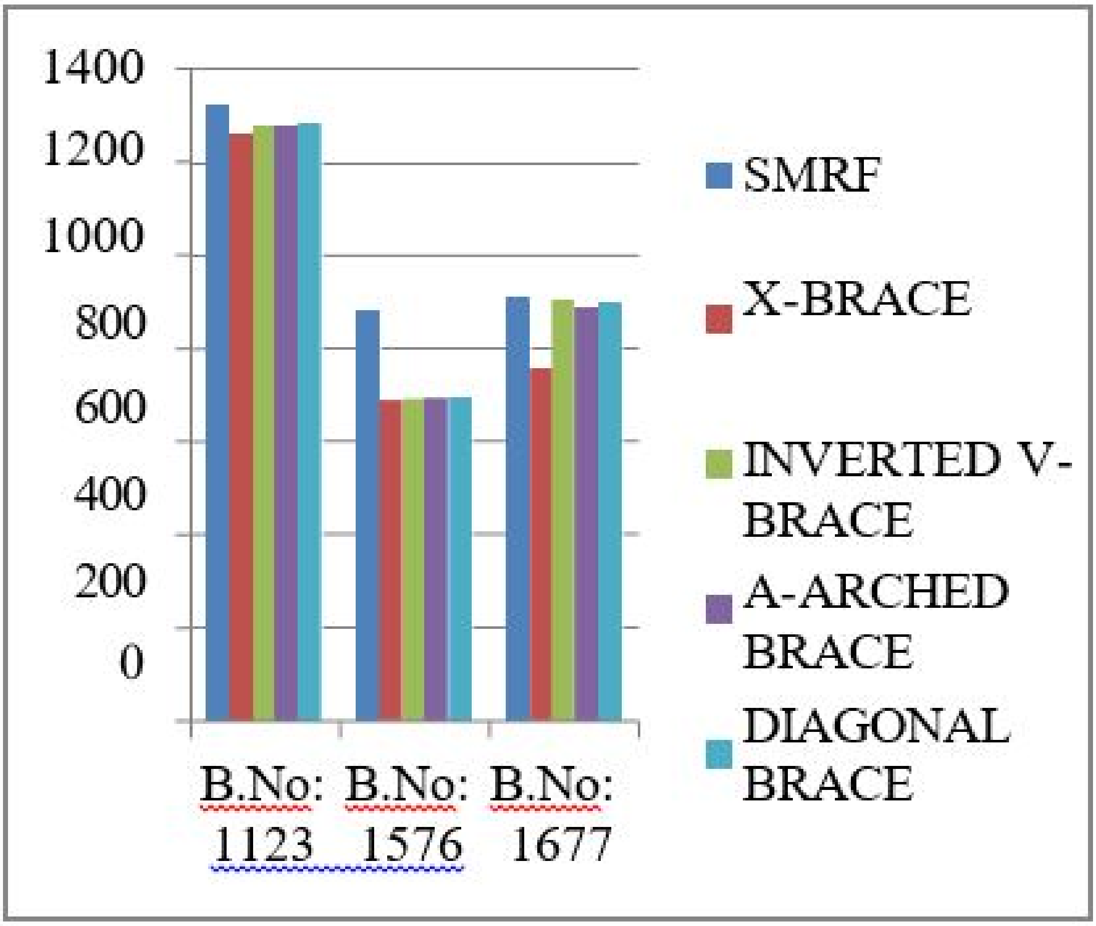

Figure 6: Displacement

Table 2: Maximum Base Shear

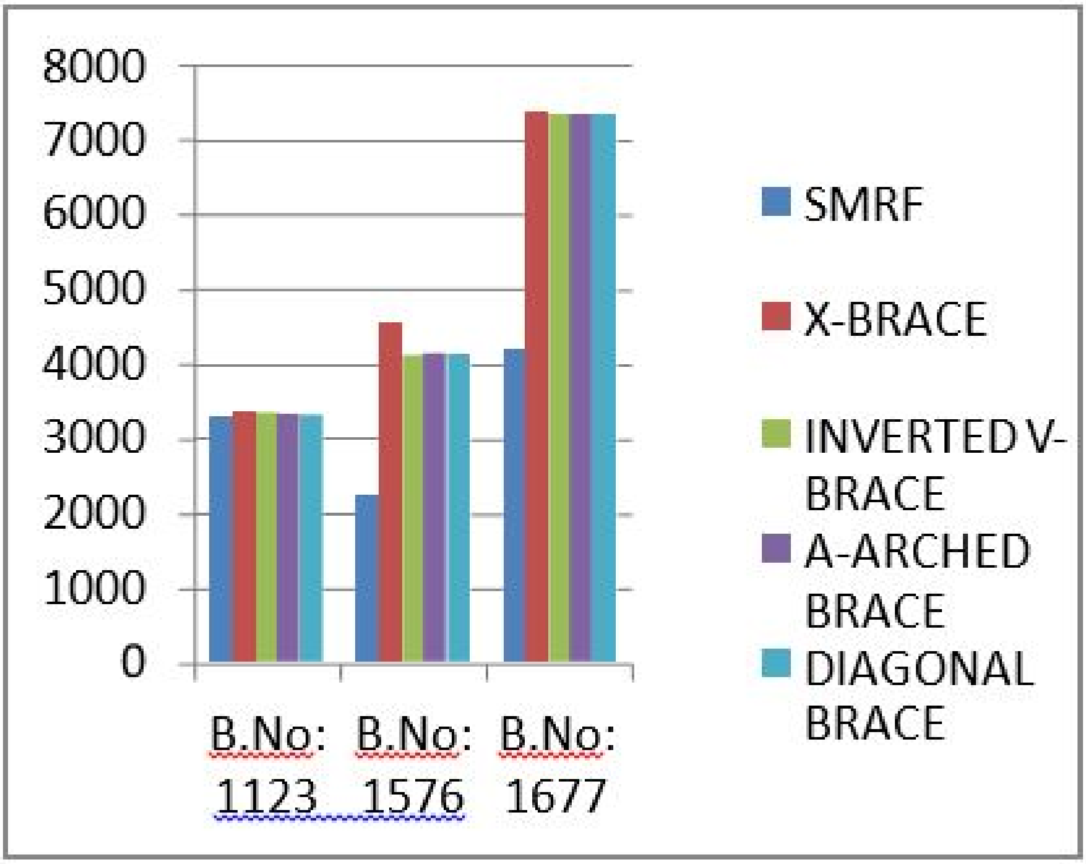

Figure 7: Base Shear

Table 3: Maximum Axial Force

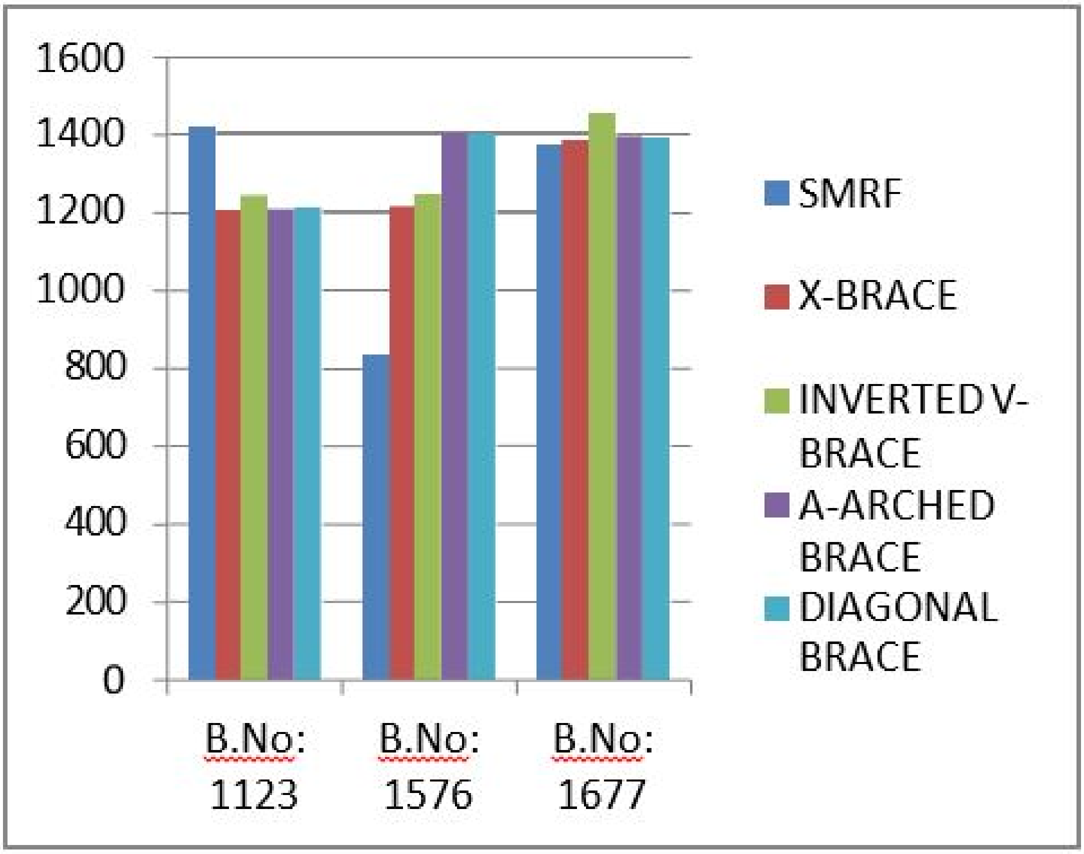

Figure 8: Axial Force

The above passage discusses a study that examines the structural performance of different building structures. The study measures three key factors - displacement, base shear, and axial force - to evaluate how each structure responds to stress. The study finds that incorporating a bracing system can enhance the base shear of a building due to an increase in its lateral stiffness. To compare the effectiveness of bracing systems, the study evaluates models both with and without four types of bracing - X-bracing, Inverted V-bracing, A-arch bracing, and diagonal bracing. By comparing the performance of these different models, the study aims to determine which type of bracing system is most effective in enhancing the structural performance of building structures.

Based on the data presented in the previous tables, the inclusion of bracing systems in building structures has been found to have a substantial impact on their structural performance. Specifically, incorporating a bracing system can significantly decrease the displacement of the building while simultaneously improving its resistance to axial force and base shear.

Furthermore, the study reveals that out of the four types of bracing systems evaluated-X-bracing, Inverted V-bracing, A-arch bracing, and diagonal bracing - the X- bracing system demonstrates superior performance compared to the other two types. In other words, incorporating an X- bracing system in building structures may be the most effective way to enhance their overall structural stability and reduce the likelihood of damage or collapse under stress.

The X-braced system stands out as the most effective among other bracing systems, based on the data presented. It significantly improves the structural performance of building structures by reducing displacement and increasing resistance to axial force and base shear.

Moreover, one key advantage of incorporating a bracing system in low-rise constructions is that it allows for the elimination of columns that obstruct open space. This is because the bracing system provides lateral support to the building structure, thereby reducing the need for additional vertical supports such as columns.

As a result, architects and designers can create more spacious and open interiors without compromising the structural stability of the building. This not only enhances the aesthetic appeal of the building but also improves its functionality and practicality for various uses. Therefore, implementing an X-braced system or any effective bracing system can be a valuable design consideration for low-rise constructions seeking to maximize space and structural stability.

Conclusion

The seismic characteristics of base shear and storey displacement are compared in this research for various braced buildings. Based on the analysis, the following conclusions are summarized:

The factors of strength and stiffness are especially significant in high-rise constructions. As a result, bracing systems are used to improve both of these properties. MRF buildings demonstrated more story displacement, indicating that they are weaker than other braced buildings and thus more vulnerable to earthquake damage.

The use of braces was found to enhance the structural performance of the building, thereby increasing its ability to withstand external forces and resist deformation.

The use of X-braces provides greater protection against the occurrence of structural failure or collapse under loading conditions and can be attributed to their ability to effectively dissipate energy and resist deformation, thereby ensuring that the building remains stable and secure even when subjected to significant external forces.

The use of X bracings instead of other bracings can result in a reduction of storey drift.

The use of steel bracings in buildings can help to reduce storey displacement caused by lateral loads. Therefore, for optimal results, it is recommended to use X-bracing systems where possible in steel braced buildings to minimize storey displacement and improve overall building performance under lateral loads.

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