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RESEARCH ARTICLE

COMPARATIVE SEISMIC PERFORMANCE AND MATERIAL EFFICIENCY ANALYSIS OF G+10 AND G+20 RCC MOMENT-RESISTING FRAME BUILDINGS WITH VARIOUS BRACING CONFIGURATIONS

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ABSTRACT

The need for adequate resistance against seismic forces is particularly highlighted as a consequence of the rapid urbanization and the demand for high rise structures. Although Reinforced Cement Concrete (RCC) moment-resisting frame (MRF) buildings are very popular in the construction industry due to their strength, durability and architectural flexibility, they are generally too flexible in respect of lateral stiffness for seismic safety in tall buildings. Various systems of bracing are used in RCC frames for improving structural stability and control of the lateral displacements. The purpose of this comparative seismic analysis is to demonstrate that the G+20 RCC moment resisting frame structure outperforms the G+10 structure under Seismic Zone III loading conditions as specified in IS 1893 (Part 1):2002. The analysis was carried out using STAAD.Pro software and included four different bracing configurations: center, corner, horizontal (HZ), and zigzag. The structural response was evaluated in terms of lateral displacement, storey drift, storey shear, stiffness, base shear, and material consumption. The results reveal that the Zigzag and HZ bracing systems considerably improve lateral stiffness while reducing displacement and drift in comparison to the conventional bracing systems. Using STAAD, four distinct bracing configurations—Center, Corner, Horizontal (HZ), and Zigzag—were examined. Advanced program. We looked at the structural response in terms of material consumption, stiffness, base shear, lateral displacement, storey drift, and storey shear.

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INTRODUCTION

Greater urbanization and population expansion in recent decades have prompted the construction of an increasing number of skyscrapers and other multi-story structures [1]. The influence of lateral forces, like wind loads and earthquakes, are more significant in the design of taller buildings [2]. Structures' stability, serviceability, and security can be compromised by vibrations, storey drift, lateral displacement, and other stresses caused by these lateral forces. Serious structural damage or even collapse can occur in seismically active areas when structures are not adequately resistant to lateral loads. For this reason, designing high-rises with adequate lateral stiffness and stability is now a top priority [3]. Bracing systems transfer lateral loads through axial action of bracing members and thereby reduce bending stresses in beams and columns. Different bracing arrangements such as Center bracing, Corner bracing, HZ bracing, and Zigzag bracing influence the structural response differently depending on building height, geometry, and loading conditions [4]. The effectiveness of these bracing configurations must therefore be carefully evaluated to determine the most suitable arrangement for seismic resistance and material efficiency [5].

METHODOLOGY

The methodology adopted for research objective is presented in a systematic way in this chapter. In the study, the sizes of structural sections are determined and material properties are specified,

structural models are developed and analysis procedures are applied to buildings of G+10 RCC MRFs by different bracing types and G+20 RCC MRFs by different bracing types. Using STAAD, structural examination and design was performed. As per Indian Standard codes, Pro Software. The software reliability and accuracy were tested against previous benchmark studies such as the work by Yaseen Ahmad (2023) who conducted seismic examination of RC framed building by different bracing systems with the same software and standard. The comparison indicated that there was a good agreement between the two important parameters: displacement, drift and base shear, thus the appropriateness of STAAD.Pro (present study) [13-14]. In the present study, two moment resisting frame buildings, G+10 and G+20 are considered and the seismic performance of various bracing system configurations (Table 1) are evaluated. The plan dimensions for both buildings were the same, 24 m × 15 m and the height of the storeys was also the same, 3 m. The heights of buildings, as 36 m and 66 m for the G+10 and G+20 models, respectively, were selected. For the comparatively tall G+20 structure, comparatively large beam and column dimensions were used for the structural frame in order to provide appropriate strength and stiffness, according to the building height and loading requirements [15]. The following important structural reaction metrics are compared and studied: lateral displacement, storey shear, storey drift, according to the applicable Indian codes of practice, the loading details were distributed. According to IS 875 (Part 1), dead load included the weight of the structural components, loads on the walls, and loads on the floor finish. When creating the models, we

considered the unit weights of the following materials: RCC, masonry, mortar, and flooring. The live loads for residential areas, such as rooms, balconies, hallways, staircases, kitchens, and restrooms, were taken into account in accordance with IS 875 (Part 2) and IS 8888: 1977. In STAAD, the loading parameters are now present. Suitable for building seismic evaluations. It used these building designs and loading details to create a standard against which to compare the bracing systems' efficacy in mitigating lateral displacement, storey drift, stiffness, and seismic performance [16].

fifteen meters, and each bay is spaced three meters apart. In order to increase the structure's resilience to earthquake and wind loads, decrease displacement, and improve lateral stiffness, the 3D models show different configurations of diagonal bracings. The overall stability and seismic performance of buildings are improved by these bracing methods [19].

Design steps: The structural design procedure starts with preparing the architectural plan and grid system in STAAD.Pro using the

Table 1. Combined Building and Loading Details

Parameter	G+10 Building	G+20 Building
Height of Superstructure (m)	33	63
Depth of Substructure (m)	3	3
Height of Each Floor (m)	3	3
Total Height of Building (m)	36	66
Length along Z-direction(m)	15	15
Length along X-direction(m)	24	24
Slab Thickness(mm)	150	150
Aspect Ratio (Ly/Lx)	1.6	1.6
Column Size	300 × 550	400 × 600
Beam Size(mm)	230 × 450	300 × 500
Self-Weight	Considered automatically in STAAD.Pro	Considered automatically in STAAD.Pro
External Wall Load (kN/m)	13	13
Internal Wall Load (kN/m)	6.5	6.5
RCC Unit Weight (kN/m ³)	22.75–26.50	22.75–26.50
Floor Finish Load (kN/m ²)	1.235	1.235
Brick Partition Wall Load (kN/m)	1.91	1.91
Brick Masonry Unit Weight (kN/m ³)	18.85	18.85
Vitrified Tile Load (kN/m ²)	0.215	0.215
Cement Mortar Unit Weight (kN/m ³)	20.40	20.40
Live Load – Toilets & Bathrooms (kN/m ²)	2.0	2.0
Live Load – Rooms & Kitchens (kN/m ²)	2.0	2.0
Live Load – Corridors & Staircases (kN/m ²)	3.0	3.0
Live Load – Balconies (kN/m ²)	3.0	3.0

Table 2. Combined Seismic Parameters and Load Combinations for G+10 and G+20 RC Buildings

Parameter / Load Combination	G+10 Building	G+20 Building
Seismic Zone	Zone III	Zone III
Response Reduction Factor (R)	5	5
Importance Factor (I)	1.0	1.5
Zone Factor (Z)	0.16	0.16
Damping Ratio	5%	5%
Soil Type	Medium Soil	Medium Soil
Topography Factor	Category IV	Category IV
0.9 DL ± 1.5 (ELx ± 0.3ELy)	Considered	Considered
1.2 (DL + LL ± (ELx ± 0.3ELy))		
1.5 (DL ± (ELx ± 0.3ELy))		
0.9 DL ± 1.5 (ELy ± 0.3ELx)		
1.2 (DL + LL ± (ELy ± 0.3ELx))		
1.5 (DL ± (ELy ± 0.3ELx))		
Soil Pressure Increase Check		
Vertical Seismic Effect		

Seismic load: In accordance with IS 1893 (Part 1):2002 (Seismic Zone III), the MRF buildings G+10 and G+20 underwent seismic study. In this analysis, the impacts of earthquake forces acting in both HZ directions were taken into account when examining the structures. Compulsory perpendicular loading equal to 30% of the total design seismic load was applied in accordance with the stipulations of the code. In order to assess the structural reaction during severe seismic events, suitable combinations of dead load (DL), live load (LL), and earthquake load (EL) were taken into consideration. The study also considered vertical earthquake effects for structures located on medium soil conditions, having greater heights, and possessing possible irregularities or long-span characteristics. The response of all three seismic components was accounted for by including 30% of the effects of the remaining two components conditions. The earthquake parameters adopted for both building models are summarized in the combined table below. The building in figure 1 is a multi-story reinforced concrete structure with several bracing methods shown in both the plan and three-dimensional perspectives. The layout is made up of eight bays running in the X-direction and five bays running in the Z-direction. The overall dimensions are twenty-four meters by

Structure Wizard, where a frame model with 8 bays in X-direction and 5 bays in Z-direction is generated with uniform 3 m spacing and total building heights of 33 m for G+10 and 63 m for G+20 structures. After generating the 3D frame, material properties and section dimensions are defined by assigning M25 grade concrete and Fe415 steel reinforcement to beams, columns, slabs, and bracings. The property definition menu is used to assign the following dimensions: beam sections of 0.45 m × 0.23 m, column sections of 0.55 m × 0.30 m, slab thickness of 0.15 m, and steel bracing section ISA 110 × 110 × 12. Then, various load cases are applied in accordance with the requirements of IS 875 and IS 1893. The dead load includes self-weight, floor finish, wall, and partition loads, while the live load is determined by using floor load intensity values appropriate for residential floors and roofs. Seismic loads are defined in both the X and Z directions by specifying seismic parameters such as zone factor, soil type, importance factor, and response reduction factor, as per IS 1893 (Part-1): 2016. Then, appropriate load combinations are created. The next step is to apply the various load situations outlined in IS 875 and IS 1893, including dead load, live load, and seismic load. The floor finish, walls, and partitions all contribute to the dead

load, while the floor load intensity values that are appropriate for residential floors and roofs are used to assign the live load. In accordance with IS 1893 (Part-1): 2016, seismic factors including zone factor, soil type, importance factor, and response reduction factor are specified before appropriate load combinations are created, allowing for the definition of seismic loads in both the X and Z directions. After assigning all loads, structural analysis is carried out using the Run Analysis command in STAAD.Pro, and the output is checked for errors and warnings. Finally, concrete design is performed as per IS 456:2000 by defining design parameters including concrete grade, steel grade, clear cover, and reinforcement limits. The axial load and uniaxial/biaxial bending moments are considered when designing columns, whereas flexure, shear, torsion, and deflection are included when designing beams. Then, for both G+10 and G+20 structures, the whole performance is assessed using metrics such as base shear, lateral displacement, storey drift, and stiffness [20].

Software Modelling of G+10 and G+20 R.C Moment Resistance by Using Various Locations and Parameters: When a building experiences HZ movement due to lateral forces like wind or earthquakes, this is called lateral displacement. Tall buildings are more prone to this movement due to their greater height and flexibility. Excessive lateral displacement can reduce structural stability and damage non-structural elements like walls, glass panels, and cladding systems [21]. Therefore, design codes limit the maximum permissible displacement, generally to about H/500 to H/600 of the total building height.

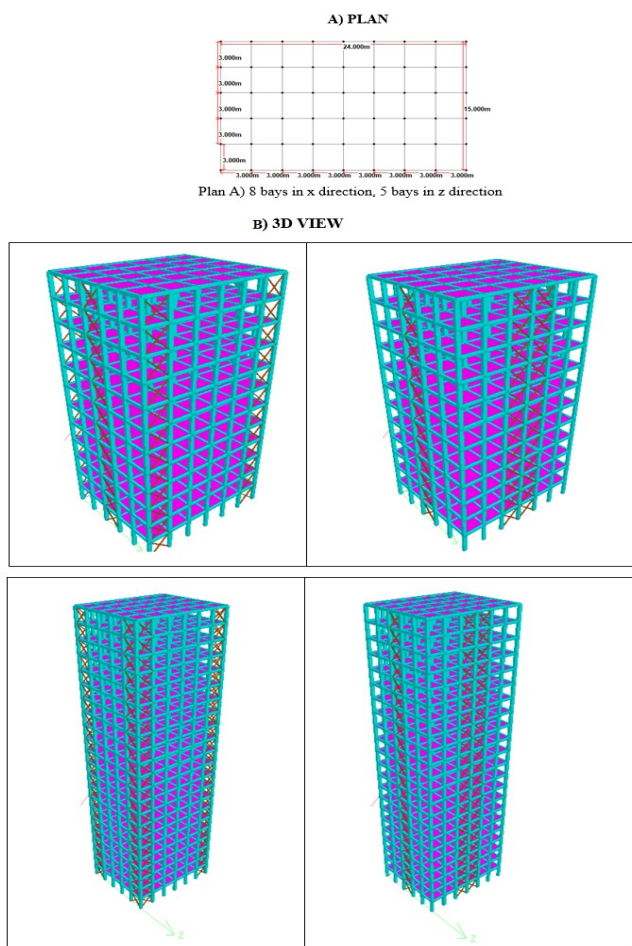


Figure 1. Modelling of buildings

As per location of bracing for 10 floors : Bracing system effectiveness changes with building height and loading direction (Figure 2), with zigzag bracing being the most effective in one scenario and center bracing providing the most stiffness and least displacement in taller buildings, followed by corner and HZ bracing. While zigzag bracing is the most effective in one situation for X-direction lateral displacement, corner and HZ bracing offer the most

rigidity and the least amount of displacement in taller buildings. For the Z-direction, on the other hand, the center bracing indicates the least displacement and is the most effective in resisting lateral sway, whereas corner, HZ and zigzag bracing indicate moderate displacement and effectiveness in resisting lateral sway. As a regular characteristic of tall buildings exposed to lateral loads, the amount of lateral displacement increases as the number of storeys increases, regardless of the bracing configuration. According to the findings, centrally located bracing systems significantly improve stability in the X and Z dimensions while simultaneously decreasing structural drift.

Storey drift: In addition to the relative vertical displacement of floors, there is also some relative HZ displacement among two consecutive floors that occurs due to lateral forces, which is called storey drift or inter-storey drift [22]. This is a significant design parameter as too great a drift can result in structure damage, P-Delta effects, and failure of non-structural components like walls, windows, and cladding. The maximum allowable storey drift in RC buildings is given as 0.004 times storey height (H/250), from IS 1893 (Part 1): 2016. In seismic zones and tall buildings, the lateral stiffness is low, which can cause a higher drift in bare RC moment resisting frames. X-type bracing offers a considerable lateral stiffness and its use provides almost 50-70% reduction in storey drift compared to the bare frames due to its axial resistance to loads. The use of X-bracing typically reduces drift in G+10 buildings within acceptable limits and in G+20 buildings, as the lateral forces and overturning effects increase as building height increases, the reduction can become more critical.

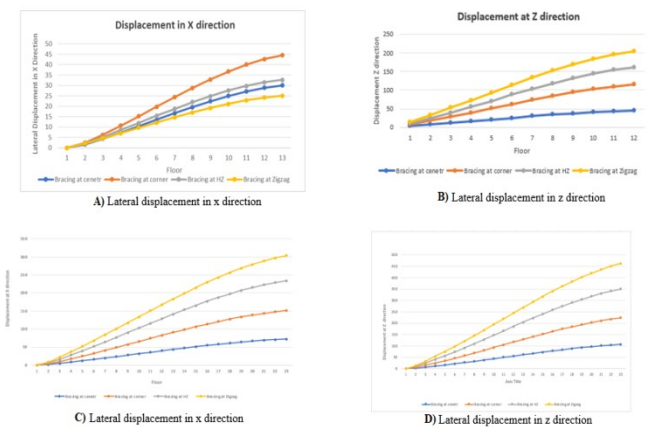


Figure 2. Location of bracing for 10 floors

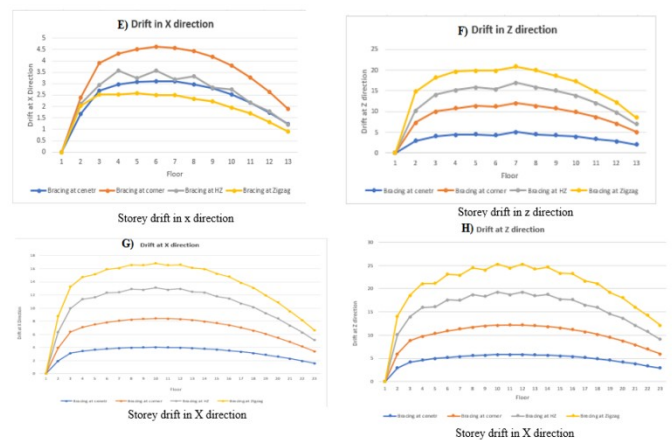


Figure 3. Storey drift

The storey drift results show that the effectiveness of bracing systems varies with loading direction and building height. For the G+13 building, Zigzag bracing provides the minimum storey drift in X-direction with a peak value of about 2.6 units, followed by Center and Corner bracing, while in the Z-direction Center bracing performs best with the lowest drift of nearly 5 units, followed by Corner and HZ bracing (Figure 3). For the G+20 building under Seismic Zone III

loading, drift increases from the base, reaches maximum values at the middle storeys, and then decreases towards the roof. In the X-direction, Center bracing shows the least drift (about 5–6 mm), followed by Corner, HZ, and Zigzag bracing, which gives the highest drift. Similarly, in the Z-direction, Center bracing again provides the best control with minimum drift values of about 6–7 mm, whereas Zigzag bracing shows the highest drift of nearly 25–26 mm. All drift values stayed under the allowed limit of 0.004 times storey height, as stated in IS 1893 (Part 1):2002, and the results showed that center bracing was the most effective solution for minimizing inter-storey drift in tall structures.

Storey Shear: The term "storey shear" refers to the overall HZ force that lateral loads like earthquakes and wind have on a multi-storey building's individual floor. It increases from the top storey towards the base because each floor transfers the accumulated lateral forces from the upper floors to the lower levels. During seismic events, these forces are transmitted through beams, columns, bracings, and shear walls to the foundation. Factors that affect storey shear include building height, stiffness distribution, and lateral load-resisting system type and placement. This study made use of the STAAD model. According to the Indian standard codes, storey shear analysis was conducted using Pro V8i under static and response spectrum analysis for various bracings, including center bracing, corner bracing, HZ bracing, and zigzag bracing. At the base of a tall building, where shear forces are greatest, shear control is essential for the building's stability and safety.

Storey Shear in X and Z direction for G+10 & G+20 structure

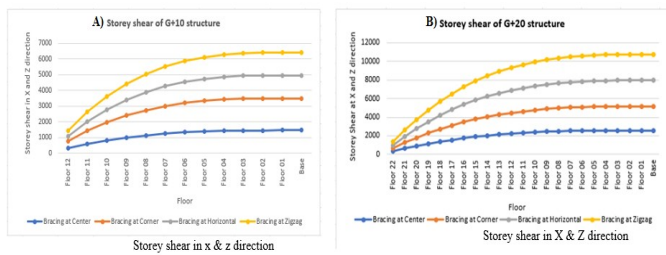


Figure 4. Storey Shear in X & Z direction for G+10 structure

The storey shear distribution for X and Z directions has been calculated for the G+10 building with Seismic Zone III as per IS 1893 (Part 1) and is found to be inverted triangular in nature as shown in the figures below, where the maximum shear in both directions is at the base and minimum shear is at the roof. The different bracing configurations exhibit the highest storey shear, Zigzag bracing (with a base shear in the range of 6300 – 6500 units), followed by HZ bracing, Corner bracing, and Center bracing (Figure 4) which has the lowest shear values indicating that it has less lateral stiffness and less resistance to force. The outcomes specify that storey shear decreases gradually from ground level up to upper level with greatest differences seen in the middle storeys. The high shear ranges from the center to Zigzag account for the high dependence of the force attraction and stiffness of the structure on bracing location and pattern. Zigzag and HZ bracing provide increased lateral resistance and lateral drift control, but increase shear forces in structural members and therefore should be considered in seismic design and ductile detailing. Storey shear distribution in X and Z direction is seen to be in the inverted triangular pattern for G+20 building, for Seismic Zone III, with maximum shear at the bottom and decreases towards the top. Based on the results, Zigzag bracing configuration has the highest storey shear and lateral stiffness with base shear values between approximately 10,500 – 11,000 units, followed by HZ bracing, Corner bracing and Center bracing, which has the lowest shear values. This decrease in shear is greater in the lower floors where the total contribution of mass is greater. Zigzag bracing has a shear that is nearly four times higher than center bracing, indicating that bracing location and configuration greatly impact seismic force distribution and structural rigidity. For seismic safety, it is important to consider the increased shear demands that come with zigzag or HZ

bracing when designing members, ductile details, and connections, as well as the increased stiffness and drift control that they provide [23].

Stiffness: When it comes to earthquake performance, lateral stiffness is a key component that impacts multi-storey buildings. This value determines things like fundamental time period, inter-storey drift, distribution of inert forces, and energy dissipation [24]. In G+10 and G+20 construction, the increase in building height also means that there is a greater demand for stiffness as a result of increased mode effects, P-delta effects and drift demands. In accordance with IS 1893 (Part 1): 2016, seismic forces can be calculated by equivalent static technique and the bracing systems increase the stiffness by making the frame as a truss like structure wherein the lateral load is resisted by axial action. Where buildings are G+10, bracing may be sufficient to keep drift within acceptable limits and in buildings of G+20 or more, the distribution of bracing is more important to ensure that the building is not too flexible, that drift is not concentrated at the top and that soft-storey effects are avoided (Figure 5).

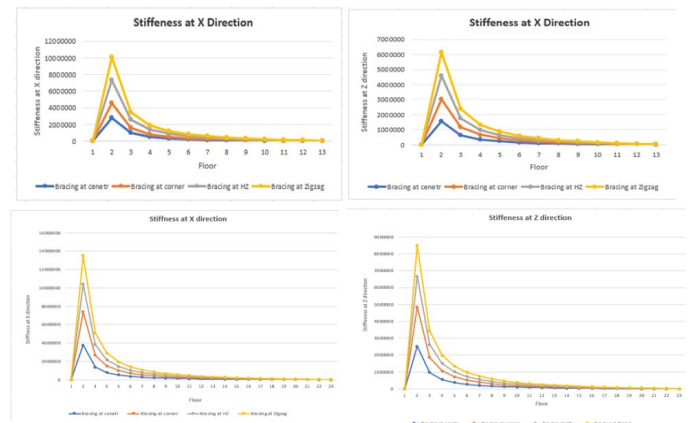


Figure 5. Stiffness for G+10 & G+20 structure

The results of story stiffness for G+10 and G+20 buildings under seismic loadings as per IS 1893 indicate that stiffness will be maximum at lower levels of building and will decrease considerably with the height in all the bracing arrangements under study. The Zigzag bracing is the stiffer of all the bracings in both X and Z directions, followed by HZ bracing, Corner bracing and Center bracing which has the lowest values. The difference is most notable at Floor 2, where Zigzag bracing offers almost 3.5–4 times the stiffness as Center bracing. In G+20 buildings, stiffness values are very high in the lower levels and then they drop off sharply, and become almost constant in the higher levels. The results show that bracing systems with Zigzag and HZ bracing systems have better performance on improving the lateral stiffness and seismic resistance, especially at the bottom stories where the seismic force is the largest.

Base Shear: Table 3 shows that in Seismic Zone III, the base shear of G+10 RC and G+20 RC buildings increases with height because to the relationship between building weight and flexibility. Base shear values for G+10 structures is the highest for Corner Bracing followed by Zigzag and HZ bracing [25].

Table 3. Base shear results for G+10 and G+20 RC buildings

Building Model	Bracing Type	Base Shear (kN)
G+10	Center	1462.68
G+10	Corner	2040.06
G+10	HZ	1461.52
G+10	Zigzag	1453.25
G+20	Center	2575.17
G+20	Corner	2574.52
G+20	HZ	2795.74
G+20	Zigzag	2797.58

The base shear values in G+20 buildings are the highest in Zigzag and HZ bracing and lowest in Center and Corner bracing due to their high

lateral stiffness. In general, this means that base shear is higher in taller buildings, as number of storeys has been increased from G+10 to G+20. While the increased stiffness and drift control from Zigzag and HZ bracing result in greater seismic forces to be considered in structural design and ductile detailing, they are beneficial.

Material Consumption: Table 4 indicates the amount of concrete remains same for all the bracing approaches in the case of G+10 & G+20 RC moment resisting frame buildings and amount of reinforcement and bracing steel varies with the bracing approach. To minimize the amount of bracing steel required in both building heights, HZ bracing is found to be the most economical system; Center and Corner bracing generally tend to require greater reinforcement and quantity of steel in their design. The results show that the overall material economy and structural efficiency of the building are greatly influenced by selecting a proper bracing system [26].

RESULTS & DISCUSSION

This research aims to study seismic performance of G+10 & G+20 RC moment resisting frame structures in Seismic Zone III with various bracing system like Center bracing, Corner bracing, HZ bracing and Zigzag bracing as per IS 1893 (Part 1):2002. The evaluation takes into account crucial structural factors including material consumption, base shear, lateral displacement, storey drift, storey shear, storey stiffness, and storage conditions under seismic load. Stiffness, drift control, force demand, and material efficiency are some of the structural performance metrics that are affected by building height and bracing setup, as shown in the results. All things considered, the research is useful for determining which bracing solutions are best for tall buildings in moderate seismic zones in terms of safety, stability, economy, and efficiency.

Table 4. Material Consumption

Building	Bracing Type	Concrete (m ³)	Reinforcement (Tonne)	Bracing Steel (Tonne)
G+10	Center	659.4	57.73	16.00
G+10	Corner	659.4	60.61	16.00
G+10	HZ	659.4	59.34	8.00
G+10	Zigzag	659.4	57.34	13.01
G+20	Center	1746.5	148.44	29.37
G+20	Corner	1746.5	143.92	25.86
G+20	HZ	1746.5	151.45	14.68
G+20	Zigzag	1746.5	147.20	24.69

Maximum Storey Displacement: A multitude of factors impact the degree to which an upper floor of a tall structure can sway, such as the building's height, seismic zone, soil condition, reinforcing, and lateral stiffness. With poor lateral stiffness, seismic loading results in greater displacement. H/250 of the building's total height is the maximum permissible top displacement according to IS 1893 (Part 1):2016. Structures having a G+10 RC MRF and a 36 m overall height are permitted to have a displacement no more than 144 mm. The highest Z-direction seismic displacement and X-direction seismic displacement that were recorded were 130.66 mm and 97.03 mm, respectively, and were within the permissible range. The G+20 building, which is 66 meters tall, also has a maximum permissible displacement of 264 millimeters. In addition, the dimensions that are allowed include an X-direction displacement of 219.74 mm and a Z-direction displacement of 263.72 mm. However, the wind displacement in the Z-direction slightly exceeds the limit, indicating that the G+20 model may require further structural modification for practical use. HZ and Center bracing is intermediate. The zigzag bracing decreases roof displacement by almost 40-50% from the Corner bracing. While Zigzag bracing provides the greatest amount of displacement control, HZ bracing is determined to be the most economical, with a good level of stiffness and displacement control and least material used.

Maximum Storey Drift: An essential serviceability characteristic in earthquake resistant design is inter-storey drift, which is the HZ

motion between storeys under seismic loading. Building services, cladding, and partitions are all susceptible to damage from drifting, which can also cause P-delta effects and make occupants uncomfortable. The standard for drift, as stated in IS 1893 (Part 1):2002, is 0.004 of the storey height. Different seismic zone III load routes (Center, Corner, HZ, and Zigzag) were examined in this study, along with a variety of G+10 & G+20 RC buildings. The data shows that the drift profile is steepest at the bottom, widest in the middle, and narrowest at the top of the building. When it comes to G+10 & G+20 buildings, the bracing types with the highest drift values are Zigzag and HZ. The bracing types with the lowest and best drift control are Center and Corner, respectively. There is less stiffness in the Z-direction since drift is usually greater in that direction compared to the X-direction. The research confirms that drift is significantly affected by the proper bracing design and that all models adhere to the maximum drift limits set out in IS 1893.

Maximum Storey Shear: Designing beams, columns, and bracing members with storey shear—the total of all HZ seismic forces at each floor level—in mind is essential. Seismic Zone III structures were analyzed in this work using IS 1893 (Part 1):2002. The buildings in question were G+10 RC moment resisting frames with varying bracing configurations and G+20 RC moment resistant frames with varying bracing configurations. Seismic forces are plotted in all models with a typical inverted triangular distribution with the highest storey shear at the base and gradually reducing towards the roof. A Center bracing system has the lowest value of storey shear, followed by Zigzag and HZ bracing systems. These systems offer better drift control and lateral resistances, and result in more demanding design requirements for the members, but higher shear. The difference between systems is highest at lower levels, with Zigzag bracing resulting in almost 300–350% more shear than Center bracing. Likewise, for the G+20 building, Zigzag bracing has the highest storey shear ($S = \sim 10,500 - 11,000$) followed by HZ, Corner, and Center bracing. The variation is most significant at the base, where Zigzag bracing attracts nearly 4 times higher shear than Center bracing. Overall, Zigzag and HZ bracing provide better seismic resistance, but require stronger member and connection design to safely resist the increased shear forces.

Maximum Stiffness: When buildings are subjected to seismic stresses, their lateral resistance and deformation behavior are significantly impacted by the storey stiffness. This study examined buildings in Seismic Zone III that were designed with G+10 & G+20 RC MRFs and included Center, Corner, HZ, and Zigzag bracing, in accordance with IS 1893 (Part 1):2002. In all models, the results demonstrate that the stiffness is greatest on the lowest floors and drastically reduces as one moves up the building. Maximum stiffness for the G+10 building is at Floor 2, with Zigzag bracing having the highest stiffness values in both X and Z directions, followed by HZ, Corner, and Center bracing. The stiffness variation between the systems is the highest at the lower floors and then tends to be uniform at the upper storeys. In the same way, within the G+20 building, the peak stiffness is evident at the lower levels with a swift decrease towards the upper levels with regards to all bracing systems. Zigzag bracing is the stiffest overall, particularly in the Z-direction, and HZ and Corner bracing are intermediate in stiffness. The findings are consistent with the observation that Zigzag bracing system is maximum effectual approach to achieve higher lateral stiffness and enhance seismic performance in tall structures.

Maximum Base Shear: The structures in Seismic Zone III that have been analyzed according to IS 1893 (Part 1):2002 are G+10 and G+20 moment resisting frames with various combinations of bracing, including center, corner, HZ, and zigzag. The results show that base shear increases with building height; the G+20 models, which account for more mass and seismic forces, show base shear that is 70–90% higher than the G+10 models. Although Zigzag and HZ bracing systems attract higher base shear because of their increased stiffness, they also provide better lateral resistance, reduced displacement, and improved drift control. For the G+10 building, Zigzag bracing shows the lowest base shear (1453.25 kN), closely followed by HZ and Center bracing, while Corner bracing records the highest base shear

(2040.06 kN), nearly 40% greater than the other configurations. In the G+20 building, Zigzag bracing shows the highest base shear (2797.58 kN), followed closely by HZ bracing, whereas Center and Corner bracing show comparatively lower and similar values (about 2575 kN). The results indicate that Zigzag and HZ bracing systems increase seismic force attraction due to greater stiffness, but they remain effective and suitable for improving seismic performance of high-rise RC structures when proper ductile detailing and member design are provided.

Material Consumption: The material consumption analysis of G+10 & G+20 RC MRF buildings with Center, Corner, HZ, and Zigzag bracing shows that the quantity of concrete remains constant for all bracing configurations, with 659.4 m³ for G+10 and 1746.5 m³ for G+20 buildings. This indicates that the bracing pattern has little effect on concrete volume, as member sizes are mainly governed by gravity loads and code requirements. However, noticeable variation is observed in reinforcement and bracing steel consumption depending on the bracing arrangement. Among all configurations, HZ bracing is the most economical system for both G+10 & G+20 buildings, as it requires the least amount of bracing steel and lower reinforcement consumption while still providing good seismic performance. The zigzag bracing is also effective and second most economical of materials. Whereas, the quantity of reinforcement and bracing steel needed is typically greater for center and corner bracing. The study indicates that the economical and efficient RC framed buildings in Seismic Zone III can be achieved by using HZ bracing, which can save about 15–20% of steel consumption due to the selection of bracing configuration.

CONCLUSION

Seismic Zone III buildings constructed using G+10 & G+20 RCC moment resisting frames and braced in different ways (Center, Corner, HZ, and Zigzag) are compared in this study using the criteria laid down in IS 1893 (Part 1):2002. The structural response was evaluated using STAAD. Important considerations including material utilization, stiffness, base shear, storey drift, storey shear, and lateral displacement are accounted for by professional software. Adding bracing systems to multi-story RCC buildings significantly improves their seismic behavior and lateral stability, according to all the data. By controlling displacement, reducing storey drift, and lowering storey shear values, the center X-bracing configuration outperformed all other configurations investigated in terms of total seismic performance. However Zigzag and HZ bracing systems gave the highest storey stiffness & better resistance to lateral forces. The systems were stiffer than other systems and had higher base shear, but all structural parameters were still within code limits. Based on material consumption analysis, it was found that HZ bracing is the economical configuration as it consumes less reinforcement and bracing steel along with it. In general, the study suggests that the HZ bracing is a more efficient and cost-effective solution in medium- and high-rise RCC buildings, and the center bracing is most effective in terms of seismic safety and stability of the structure.

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