SEISMIC RESPONSE OF RE-ENTRANT CORNER BUILDING WITH UNDER TUBULAR BRACING

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Abstract

The recent seismic activities reported the potential vulnerability of buildings with irregular configurations to earthquake-induced damages. The irregularities in building plans also complicate the seismic structural design. The re-entrant corners create discontinuities; they cause sudden changes in stiffness and introduce amplified torsional effects in the structure, hence, increasing the level of stress concentration. It is therefore crucial to carry out constructive research on the building with re-entrant corners and other torsional irregularities to design seismic response demands and avert correlated damages. The aim of the study is to find effect of bracing in 20 storey re-entrant corner building under linear and nonlinear dynamic seismic conditions as per Indian standard IS 1893 (Part - 1):2016. Time history of 2001 Bhuj earthquake motion is considered as nonlinear dynamic function, i.e. time history function. For each building configuration three dimensional buildings are modelled in ETABS. The results from the linear dynamic analysis are discussed in terms of time period, maximum storey displacement, storey accelerations and storey stiffness. For nonlinear dynamic analysis absolute accelerations, drift and overturning moments are discussed and compared for unbraced and braced re-entrant building. The numerical results shows that bracing in re-entrant corner building are effective in controlling seismic parameters which leads to economical and safe design.

Keywords:
Re-entrant Corner Building, Steel Bracing, irregular, modelling

I. Introduction

Re-entrant corner buildings in the form of high-rise constructions are becoming more and more popular in Indian cities due to natural urban densification caused by population growth. Such architectural types represent one of the new trends in structural engineering and urban planning due to double aesthetic purposes of becoming a part of the city’s view and optimal use of space. High-rise buildings are widely used in Mumbai, Bengaluru, and Delhi to meet natural population growth, increasing the demand for commercial and living areas through the modern innovative architectural approach . Seismic analysis of re-entrant corner buildings with steel bracing is crucial due to the high earthquake risk in regions like India[1]. Seismic analysis of high-rise re-entrant corner buildings is an essential part of structural engineering due to the various seismic zones in India. Seismic activity often amplified forces and caused irregular distribution of the load on buildings, causing re-entrant corner overstressed and vulnerable. Building material, structural design, foundation type, and local seismic activity are among factors to be taken into the designers consideration. Seismic analysis of buildings with re-entrant corners reveals the vulnerability of the building as a result of plan irregularities. The varying A/L ratios affect the seismic behavior of the structure, with optimal shear wall placement being critical in ensuring structural integrity [2]. Seismic analysis of buildings with re-entrant corners in various seismic zones reveals increased vulnerability on account of torsion and stress concentrations, which can widely damage these buildings [3]. Steel bracing systems have a pivotal role in improving the seismic performance of buildings by reducing lateral displacement and supporting elements [4][5]. Different bracing configurations, such as X-bracing and diagonal bracing, have varying impacts on structural stability and performance [6]. Additionally, the use of bracings in structures helps resist lateral loads during seismic events, as demonstrated in studies comparing different bracing configurations using software like ETABS [7]. Seismic analysis of steel building with re-entrant corners and bracing enhances performance, reducing plastic hinge formation and improving structural safety under various seismic actions [9]. Figure 1 shows condition for re-entrant corner building as per IS IS 1893 (Part - 1):2016. As per IS Code 1893(Part 1):2016[9] the building is said to have a re-entrant corner when its structural configuration in the plan has a projection of size greater than 15% of the overall plan in the same direction. The objective of the the study is to discuss the effect of 20 storey re-entrant corner building with and without bracing. Comparison of seismic response is also been done for braced and unbraced building.

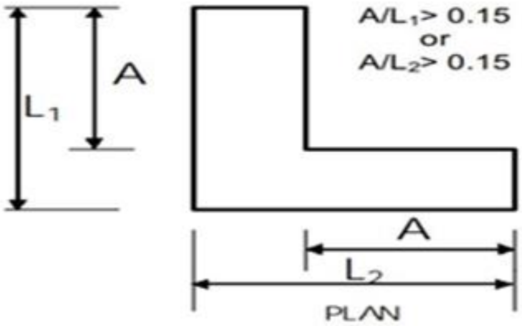

Figure 1: Re-entrant Corner Building

II. Methodology

20 storey re-entrant corner building plan dimensions are shown in table 1. As the A/L1 ration is greater than 15%, therefore selected building is fulfilling re-entrant corner building conditions as per Indian standard codes.

Table 1: A/L1 Criteria for Model Selection

Case	*A*	*L_1 or L_2*	*A/L_1*
1	20 m	30 m	0.66

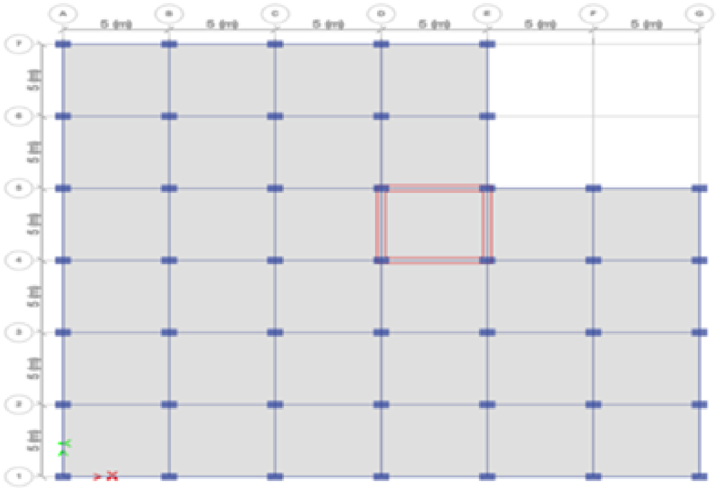

Figure 2. Plan of 30 x 20 m (A/L1 = 0.66)

The geometric details are given in table 2. The beam sizes and column sizes are determined by the hit and trial method until the safe design is achieved. Bracing member is selected as per clause 8.5.2.2 of IS 15988.2013[11] the specification of bracing member is shown in table 3.

Table 2. Geometrical Properties

Description	**Specification**
Number of Stories	20
Story Height	3.5 m

Grid Spacing	5 m
Concrete Grade	M40
Size of Beam	400 mm x 750 mm
Size of Column	500 mm x 750 mm
Thickness of Slab	200 mm
Core Wall Thickness	400 mm
Seismic zone	IV
IS Codes	IS 456 :2000[10], IS 1893 :2016[9]

Table 3. Tubular Section Criteria

Bracing	***Out-to-out width/wall thickness***
ISB172×92×5.4	17.03

The linear and nonlinear dynamic analysis is performed on braced and unbraced 20 storey re-entrant corner building. Selected re-entrant corner conventional and braced frame building have been modelled and analysed by linear dynamic analysis method for zone 4 and nonlinear dynamic analysis i.e. time history analysis. The results so obtained in the analysis of such structure have been studied and compared to understand the extent of response of structure under bracing conditions. Time history graph for Bhuj Earthquake (India) is shown in figure 3.

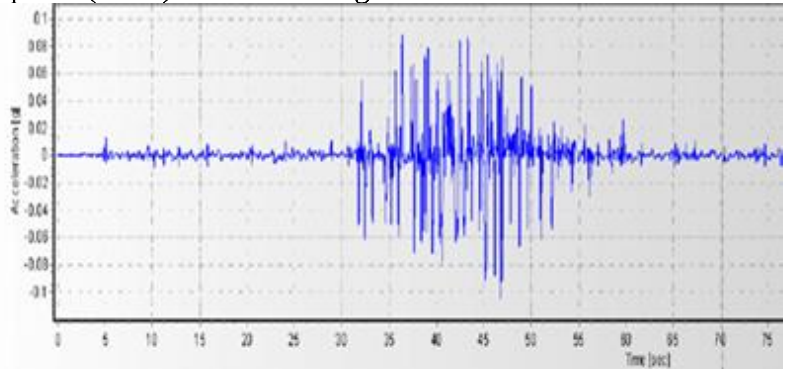

Figure 3. Time History Graph for Bhuj Earthquake (India)

III. Results and Discussion

3.1 Linear Dynamic Analysis

Response spectrum analysis results are discussed in this section.

3.1.1 Time Period

Time period comparison for conventional and braced building is shown in figure 4. For braced building, time period decreased by 7% as comparison to conventional non braced structure. Application of bracing results into reduction in time period.

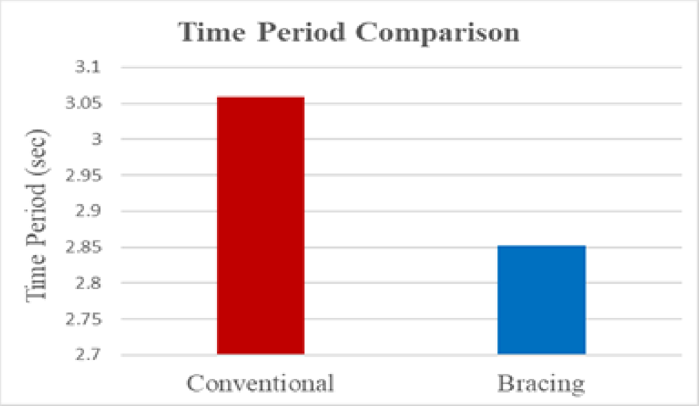

Figure 4. Time Period Comparison

3.1.2 Maximum Roof Displacement

Maximum Roof Displacement comparison for conventional and braced building for X and Y directions is shown in figure 5. For braced building, maximum roof displacement decreased by 5% in X and 6% in Y directions as comparison to conventional non braced structure. Decrease in maximum roof storey displacement shows that on using bracings the seismic behaviour in terms of storey displacement enhances.

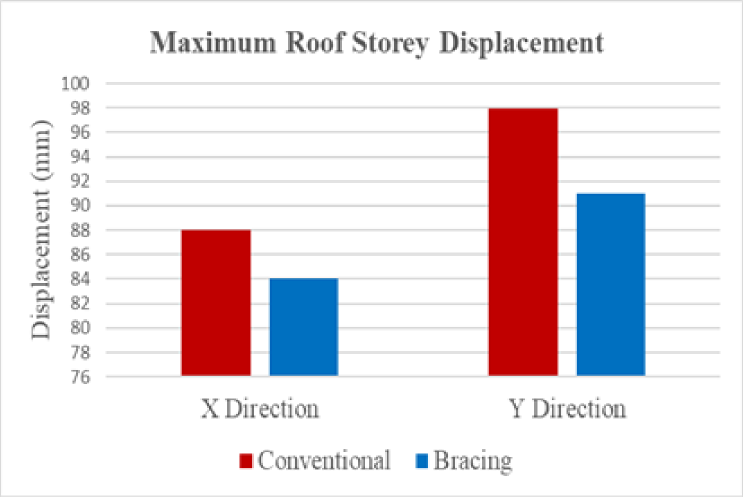

Figure 5. Maximum Roof Displacement Comparison

3.1.3 Storey Accelerations

Storey accelerations for conventional and braced building is shown in figure 6. It is observed in case of conventional re-entrant corner building values change of storey accelerations at different storey levels is very large, while on considering braced re-entrant corner building storey accelerations changes gradually at different storey levels and also it is less than as compared to conventional building.

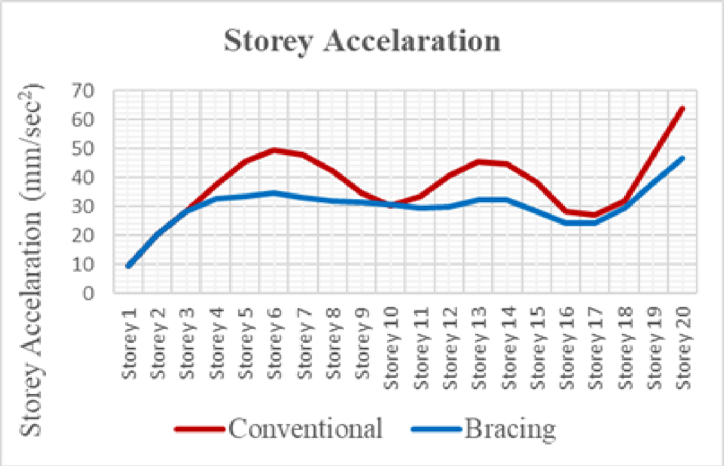

Figure 6. Storey Acceleration Comparison

3.1.4 Storey Stiffness

Storey stiffness for conventional and braced building is shown in figure 7. From the analysis it is found that on considering bracing, the storey stiffness at top stories enhanced by 10%, similar enhancement is also found at other storey levels.

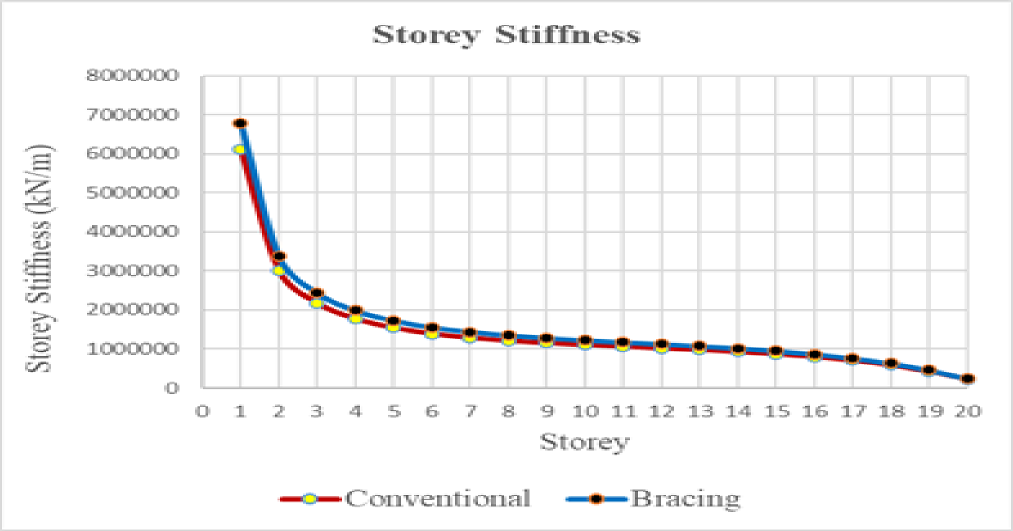

Figure 7. Storey Stiffness Comparison

3.2 Non - Linear Dynamic Analysis

3.2.1 Absolute Acceleration

Absolute accelerations result for conventional and braced buildings are shown in figure 8 and 9 respectively. It was found that absolute accelerations at top storey is reduced by 10% in braced entrant corner building. It is also found that at other storey levels also the absolute accelerations reduced by significant amount, which leads to optimize design during seismic design.

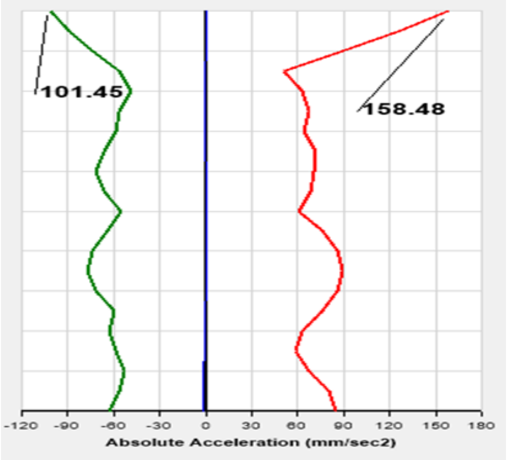

Figure 8. Absolute Acceleration for Conventional Building

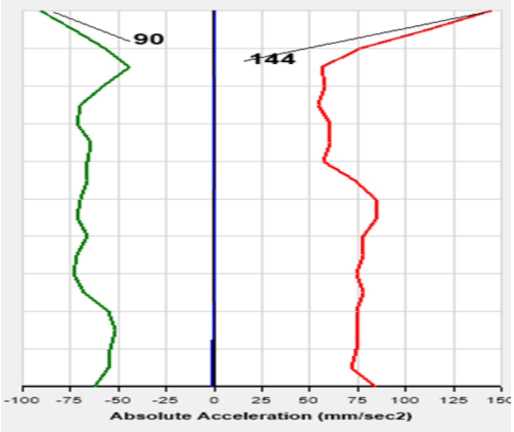

Figure 9. Absolute Acceleration for Braced Building

3.2.2 Drift

Drift results for conventional and bracing buildings are shown in figure 10 and 11 respectively. As per Indian standard, Criteria for earthquake resistant design of structures, IS 1893(Part 1): 2016, the storey drift in any story shall not exceed 0.004 times storey height. Overall reduction in drift is observed at different levels although the in both the structures drift is within the permissible limit of 0.004 times height of storey. But as braced structure attracts less drift due to which cladding and sheeting will affect less and their design can be optimized as compare to conventional building.

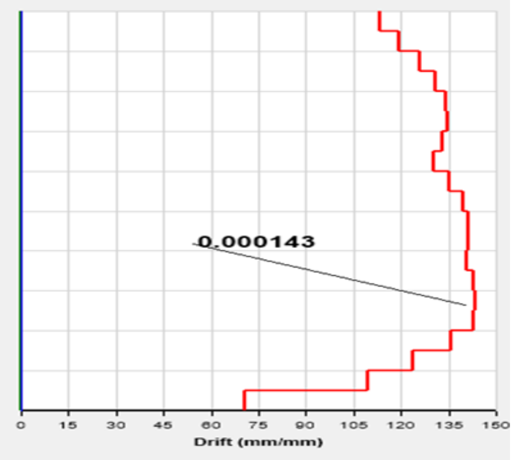

Figure 10. Drift for Conventional Building

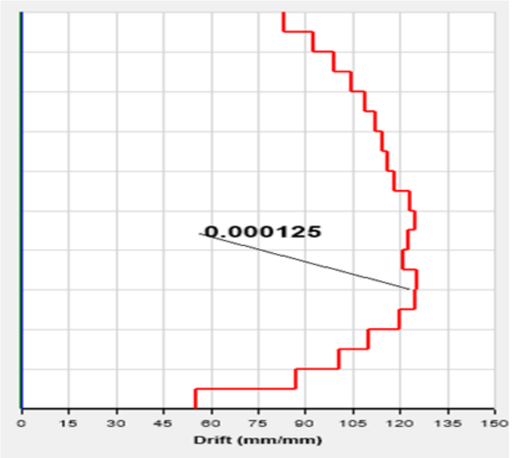

Figure 11. Drift for Braced Building

3.2.3 Overturning Moment

Overturning moments for conventional and braced buildings are shown in figure 12 and 13 respectively. Using bracing in re-entrant building, overturning reduces significantly by 15%. As overturning moment decreases which will directly affects the seismic design of lower stories structural members and foundation.

Figure 12. Overturning Moment for Conventional Building

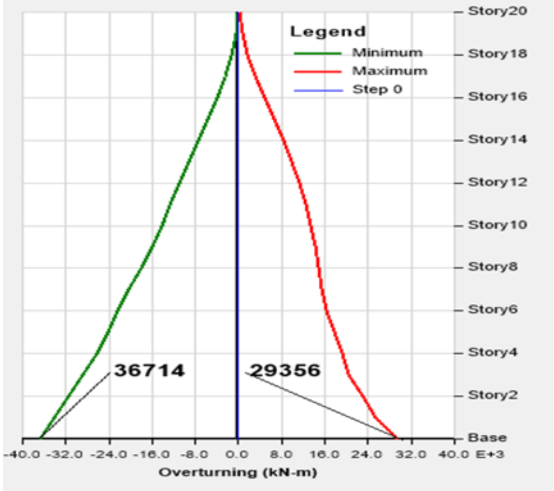

Figure 13. Overturning Moment for Braced Building

IV. Conclusion

In this study, 20- storey re-entrant corner building is studied for unbraced and braced conditions. Seismic analysis method opted for this study is linear dynamic (Response Spectrum) and non-linear dynamic (Time History). Results are discussed for linear dynamics analysis and non-linear dynamic analysis. The conclusions of the study are as follows –

1. For 20-storey re-entrant corner building having A/L1 ratio as 0.66, the tubular bracing systems building shows that seismic behaviour of the building enhances.
2. It is found that time period, maximum roof displacement and storey accelerations reduces significantly in braced frame building which leads to the more optimized and safe building design. Storey stiffness enhances using tubular bracing which makes column design more economical.
3. Nonlinear analysis shows the seismic response of building with respect to time. On analyzing both buildings for time history graph of Bhuj earthquake, it is observed that with the use of bracing the absolute acceleration and drift reduces at different time durations and levels.
4. Reduction in overturning moments at base of the building in braced building shows that, on using bracing building is more restrained against overturning moment at bottom of the building and also it leads to optimized design of columns and foundations.

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