



Time Period Analysis of Reinforced Concrete Building with and Without Influence of Steel Bracings

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Abstract: This study summarizes the seismic performance evaluation of RC building consisting of low rise, medium rise and high rise building frames. These building frames are designed for gravity load combinations as per IS 456-2000 which is located in severe seismic zones of India. For the study of seismic performance of building by increasing number of storey with bracings are considered in order to increase the stiffness and to control drifts and displacement. As the effect of steel bracings in different storeys of RC framed buildings is considered, the loading and storey stiffness have been maintained constant. The aim of this present study is to find out the possible effective earthquake mitigation system by adopting steel bracings for the above said low, medium and high rise buildings. Also the study highlights the building performance by obtaining the natural time period and the corresponding results shows that the reinforced concrete building with steel bracing system performs better than any other normal building under severe earthquake zones of India. Based on the study undertaken the project aims to determine the extent of possible changes in the seismic performance of low medium & high rise RC framed buildings. This research involves the various analysis techniques to determine the lateral forces ranging from purely linear to non-linear inelastic analysis. The entire process of modeling, analysis and design of all the primary elements for all the models are carried out by using ETABS 9.7.0 nonlinear version software and its software implementation. In India the Standardized method of analysis is followed by using a code – IS1893 (Part 1):2002 – “Criteria for Earthquake resistant design of structures”

Key words: Time period, Static analysis, Response spectrum analysis, Steel bracing, Seismic vulnerability assessment

1.Introduction: The magnitude and intensities of earthquakes are varies from place to place causing low to severe destructive powers on engineered properties as well as giving rise to great economic losses and life threat. To overcome this issue several countries over the world started monitoring the records of ground motions in their regions and converting these data into seismic zone maps in terms of PGA (Peak ground accelerations), which will be helpful for creation of safe and economical earthquake resistant structures^[1]. An ideal multistory building designed to resist lateral loads due to earthquake would consist of symmetric distribution of mass and stiffness in plan at every storey and a uniform distribution along the height of the building^[2]. In general steel braced building is designed to satisfy certain basic structural and functional requirements. The structural requirements are strength, stiffness and stability^[3].

Rigid frames have been used in the past for tall buildings and are still used up to certain heights^[4]. However, they are not so efficient for lateral loads and are being replaced by steel bracings^[5]. As a result, the need to identify the seismic performance of the built environment through the development of various analytical procedures, which ensure the structures to withstand during frequent minor earthquakes and produce enough caution whenever subjected to major earthquake events^[6]. So that can save as many lives as possible. There are several guidelines all over the world which has been repeatedly updating on this topic. The method of analyzing the structure varies from linear to nonlinear. The linear procedures are more applicable to the buildings that have sufficient strength to remain nearly elastic when subjected to the design based earthquakes and if the inadequacy of the design is limited to a few primary elements, it is possible to reanalyzed and evaluated to determine

if acceptable performance is predicted. But, if the analysis indicates only limited inadequacy, the use of a nonlinear procedure may demonstrate acceptable performance. This is because the nonlinear procedure provides more accurate estimates of demands than do linear procedures^[7].

1.1. Bracing Systems

Steel bracing is a highly efficient and economical method of resisting horizontal forces in a frame structure^[3]. Bracing has been used to stabilize laterally the majority of the world’s tallest building structures as well as one of the major retrofit measures. Bracing is efficient because the diagonals work in axial stress and therefore call for minimum member sizes in providing stiffness and strength against horizontal shear. A number of researchers have investigated various techniques such as infilling walls, adding walls to existing columns, encasing columns, and adding steel bracing to improve the strength and/or ductility of existing buildings. A bracing system improves the seismic performance of the frame by increasing its lateral

stiffness and capacity^[3]. Through the addition of the bracing system, load could be transferred out of the frame and into the braces, bypassing the weak columns while increasing strength.² Steel-braced frames are efficient structural systems for buildings subjected to seismic or wind lateral loadings. Therefore, the use of steel-bracing systems for retrofitting reinforced-concrete frames with inadequate lateral resistance is attractive. The first approach is realized with the introduction of steel braces in steel structures and of RC shear walls in RC structures. However, the use of steel bracing systems for RC buildings may have both practical and economic advantages. In particular, this system offers advantages such as the ability to accommodate openings and the minimal added weight of the structure. Furthermore, if it is realized with external steel systems (External Bracing) the minimum disruption to the full operability of the building is obtained. There are two types of bracing systems, Concentric Bracing System and Eccentric Bracing System are shown in figure I.

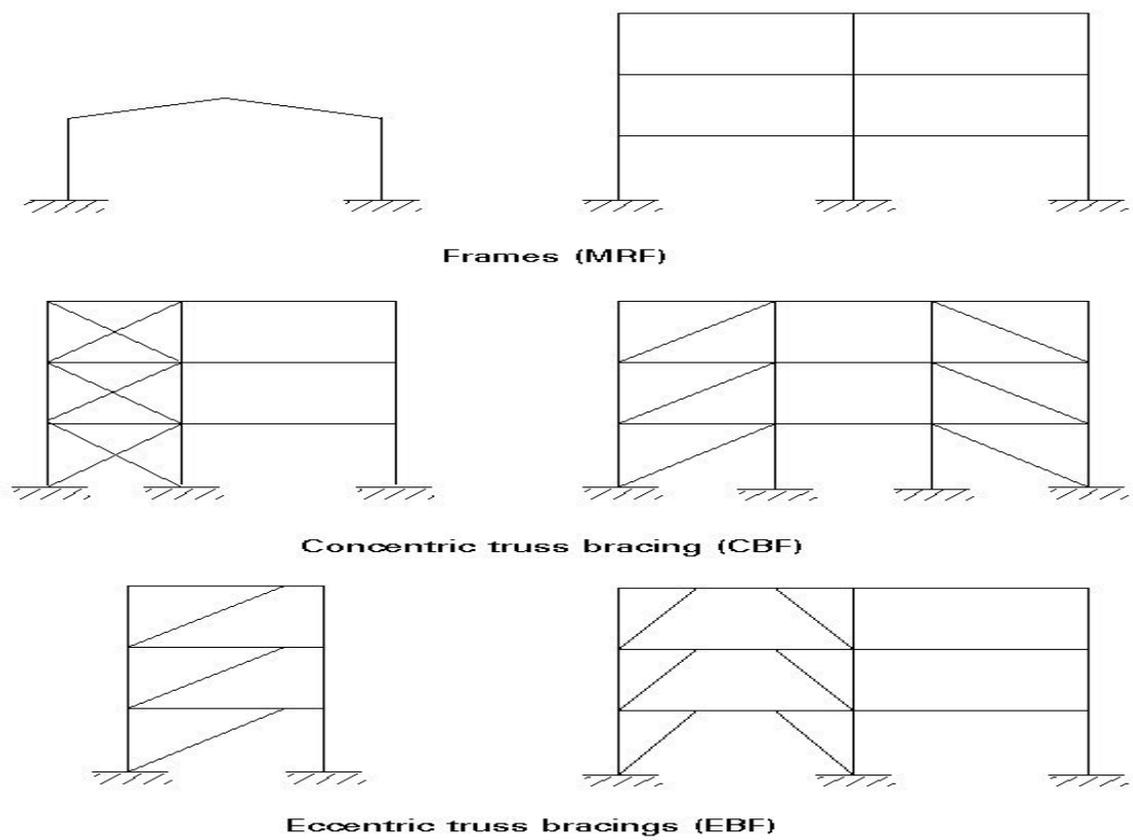


Figure I. Seismic response of different buildings

The steel braces are usually placed in vertically aligned spans. This system allows obtaining a great increase of stiffness with a minimal added weight, and so it is very effective for existing structure for which the poor lateral stiffness is the main problem.

The concentric bracings increase the lateral stiffness of the frame, thus increasing the natural

frequency and also usually decreasing the lateral drift. However, increase in the stiffness may attract a larger inertia force due to earthquake. Further, while the bracings decrease the bending moments and shear forces in columns, they increase the axial compression in the columns to which they are connected. Since reinforced concrete columns are

strong in compression, it may not pose a problem to retrofit in RC frame using concentric steel bracings. Eccentric Bracings reduce the lateral stiffness of the system and improve the energy dissipation capacity. Due to eccentric connection of the braces to beams, the lateral stiffness of the system depends upon the flexural stiffness of the beams and columns, thus reducing the lateral stiffness of the frame. The vertical component of the bracing forces due to earthquake cause lateral concentrated load on the beams at the point of connection of the eccentric bracings.

1.2. Seismic Design Philosophy

The design philosophy adopted in the seismic code is to ensure that structures possess at least a minimum strength to

- i. Resist minor earthquakes (Design Basis Earthquake-DBE), which may occur frequently without damage.
- ii. Resist moderate earthquake (DBE) without significant structural damage through some non-structural damage.
- iii. Resist major earthquake (Maximum Considered Earthquake-MCE) without collapse.

Design Basis Earthquake (DBE) is defined as the maximum earthquake that reasonably can be expected to experience at the site once during lifetime of the structure. The earthquake corresponding to the ultimate safety requirements is often called as maximum considered earthquake (MCE). Generally, DBE is half of MCE.

2. Analytical Methods

Analysis methods are broadly classified as linear static, linear dynamic, nonlinear static and nonlinear dynamic methods. In these the first two methods are suitable when the structural loads are small and no point the load will reach to collapse load and are differs in obtaining the level of forces and their distribution along the height of the structure. Whereas the nonlinear static and dynamic analysis are the improved methods over linear approach. During earthquake loads the structural loading will reach to collapse load and the material stresses will be above yield stresses. So in that case material nonlinearity and geometrical nonlinearity should be incorporated into the analysis to get better results. These methods also provide information on the strength, deformation and ductility of the structures as well as distribution of demands.

2.1. Linear Static Analysis or Equivalent Static Analysis

Here the total design lateral force or design base shear along any principal direction is given in terms of design horizontal seismic coefficient and seismic weight of the structure. Design horizontal seismic coefficient depends on the zone factor of the site, importance of the structure, response reduction factor of the lateral load resisting elements and the fundamental period of the structure. The procedure generally used for the equivalent static analysis is explained below:

- (i) Determination of fundamental natural period (T_a) of the buildings $T_a = 0.075h^{0.75}$
Moment resisting RC frame building without brick infill wall

$T_a = 0.085h^{0.75}$ Moment resisting steel frame building without brick infill walls

$T_a = 0.09h/\sqrt{d}$ All other buildings including moment resisting frame with brick infill walls.

Where,

h - is the height of building in m

d - is the base dimension of building at plinth level in m, along the considered direction of lateral force.

- (ii) Determination of base shear (V_B) of the building

$$V_B = A_h \times W$$

Where,

$A_h = \frac{Z I S_a}{2 R g}$ is the design horizontal seismic

coefficient, which depends on the seismic zone factor (Z), importance factor (I), response reduction factor (R) and the average response acceleration coefficients (S_a/g). S_a/g in turn depends on the nature of foundation soil (rock, medium or soft soil sites), natural period and the damping of the structure.

- (iii) Distribution of design base shear

The design base shear V_B thus obtained shall be distributed along the height of the building as per the following expression:

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{i=1}^n W_i h_i^2}$$

Where, Q_i is the design lateral force, W_i is the seismic weight, h_i is the height of the i^{th} floor measured from base and n is the number of stories in the building.

3. Results and Discussions:

3.1. Natural Periods

The natural time periods obtained from seismic code IS 1893 (Part 1) -2000 and analytical

(ETABS v 9.1.1) are given in Table I. Codal and analytical values do not tally with each other. It can be observed that models with equivalent diagonal struts significantly affects fundamental natural period, which is a function of mass, stiffness and damping characteristics of the building.

Table I :Codal and Analytical Fundamental Natural Periods for Building Models

Building	Models	Seismic analysis in sec	
		CODE	Analysis
G+2	Bare Frame	0.483	1.6892
	Braced Frame	0.483	0.9613
G+3	Bare Frame	0.5858	1.7563
	Braced Frame	0.5858	1.2627
G+4	Bare Frame	0.6825	1.9204
	Braced Frame	0.6825	1.3562
G+5	Bare Frame	0.7748	2.1233
	Braced Frame	0.7748	1.4676
G+6	Bare Frame	0.8635	2.1954
	Braced Frame	0.8635	1.7285
G+7	Bare Frame	0.9493	2.2533
	Braced Frame	0.9493	1.6921
G+8	Bare Frame	1.0326	2.2545
	Braced Frame	1.0326	1.7192

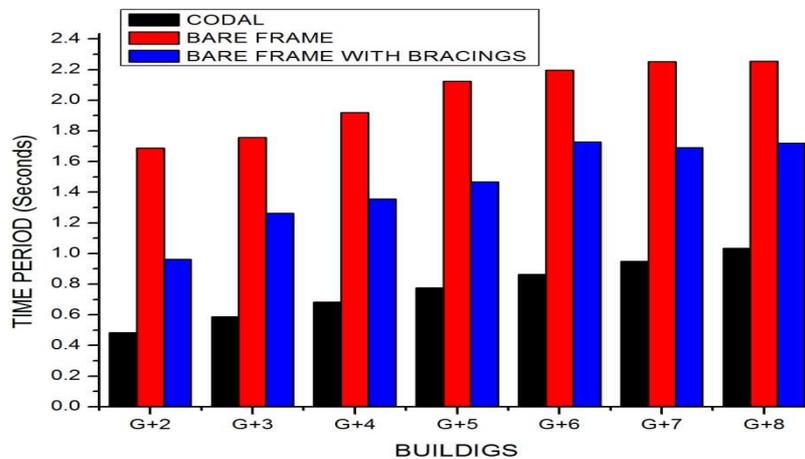


Figure 2 Natural time period profile for all Storey building for gravity and seismic combination

4. Conclusion

From the present analytical investigation, the main aim is to focus on the study of seismic performance of buildings consisting of low rise, medium rise & high rise buildings, which are located in seismic zone – V of IS - 1893-2002 (part – II) i.e. Medium soil using various analytical methods. The performances were reported in terms of time period. The project aims to identify correct load pattern which can regulate its effect on seismic performance. For the entire performance study the forward braced building system perform better than that of other type braced systems. Bracings are

introduced to make the structure stiff and hence there is a dramatic reduction in the structural response of buildings.

The fundamental natural periods obtained for the seismic designed building models is plotted in figure 2. From the plot it is very clear that, stiffness of the building is directly proportional to its natural frequency and hence inversely proportional to the natural period. That is, if the stiffness of building is increased the natural period goes on decreasing. And as the natural frequency of the taller buildings is low due to the less stiffness, the natural period goes on increasing for nine story buildings. The comparison

of natural period presented in the table or plot shows that, the code IS 1893 (part-I) 2002 uses empirical formula to calculate natural period which is directly depends on the height of the building. Whereas the analytical procedure calculates the natural period on the basis of mass and stiffness of the. With this code doesn't consider the irregular effects on the natural period of vibration of the building. Bracings system can be effectively used as an earthquake mitigating system to make structure stiff

5. Scope of Future Study

1. Parametric studies of these structures can be done considering the effect of brick infill.
2. Present study can be carried to further level by applying nonlinear method of structural analysis.
3. Also the structures can be analyzed by adopting multiple stiffness systems like shear wall with bracings.
4. Time history analysis also can be performed by the above structures with different method of structural analysis.

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