Analysis of Time Period of Reinforced Concrete Building with and without Steel Bracings

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Abstract— The aim of this present study is to find out the possible effective earthquake mitigation system by adopting steel bracings for the low, medium and high raise 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 2016 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: Bare Frame, High Rise Building, Time Period, Steel Bracings, Seismic Performance

I. Introduction

Bracing is a very effective global upgrading strategy to enhance the global stiffness and strength of steel and composite frames. It can increase the energy absorption of structures and/or decrease the demand imposed by earthquake loads. Structures with augmented energy dissipation may safely resist forces and deformations caused by strong ground motions. Generally, global modifications to the structural system are conceived such that the design demands, often denoted by target displacement, on the existing structural and non-structural components, are less than their capacities. Lower demands may reduce the risk of brittle failures in the structure and/or avoid the interruption of its functionality. The attainment of global structural ductility is achieved within the design capacity by forcing inelasticity to occur within dissipative zones and ensuring that all other members and connections behave linearly. Bracing may be inefficient if the braces are not adequately capacity-designed. Braces can be aesthetically unpleasant where they change the original architectural features of the building.

This paper address the effect of bracing on the seismic response of high and low rise structure. The results are compared in terms of time period for structure storey varying from G+3 to G+10.

II. Bracings

Braced-frames virtually eliminate the columns and girder bending factors and thus improve the efficiency of the pure rigid frame actions. By the addition of truss members such as diagonals (between the floor systems) this can be achieved effectively. These diagonals carry the lateral loads and transfers the axial loads to the columns, which is an effective structural system.

Steel bracing is a highly efficient and economical method of resisting horizontal forces in a frame structure. 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.

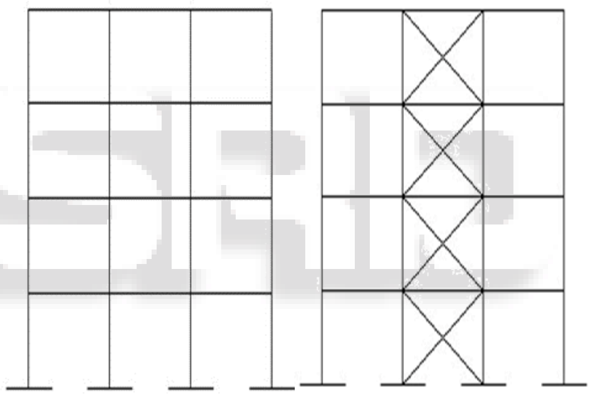

Fig.1: On the left side is Bare RCC portal frame and to the right is RCC Portal frame with double way steel bracing.

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.

III. Analytical time period

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:

1) Determination of fundamental natural period (Ta) 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.
$T_a=0.09h/d^{1/2}$ 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.

2) Determination of base shear (VB)n of the building

$$V_B = A_h * W$$

Where,

$$A_h = \frac{Z}{2}\frac{I}{R}\frac{S_a}{g}$$

A_h 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.

3) 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, hi is the height of the i[th] floor measured from base and n is the number of stories in the building.

Generally time period is related to stiffness of the structure as follows:

$$Time\ Period \propto \frac{1}{Stifness}$$

IV. STRUCTURAL MODELING

A G+3 to G+10 storey models have been made in Etabs 2016. Models are 18m x 18m in plan having 3 x 3 bay each 6m wide. Height of each storey is 3m in all the cases. Beam having size of 300x450 mm and column having size of 450x450 mm have been provided. Slab of 150mm thickness have been provided. The design dead load and live load on floor slab are 1.5 kN/m2 and 2.5 kN/m2 respectively. Loads due to outer walls of 14.82 kN/m have been applied onto outer beams and for inner beams load of 7.41 kN/m have been applied.

The design earthquake load is computed based on Zone factor 0.36, Soil type II, Importance factor 1, Response reduction factor 5 as per IS 1893-2002.

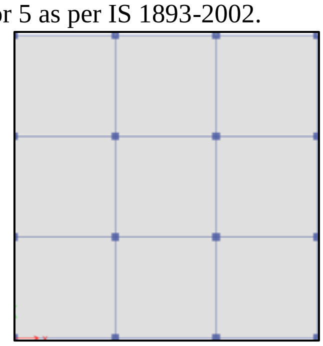

Fig. 2: On the left side is RCC portal frame and to the right is RCC portal with corner shear wall.

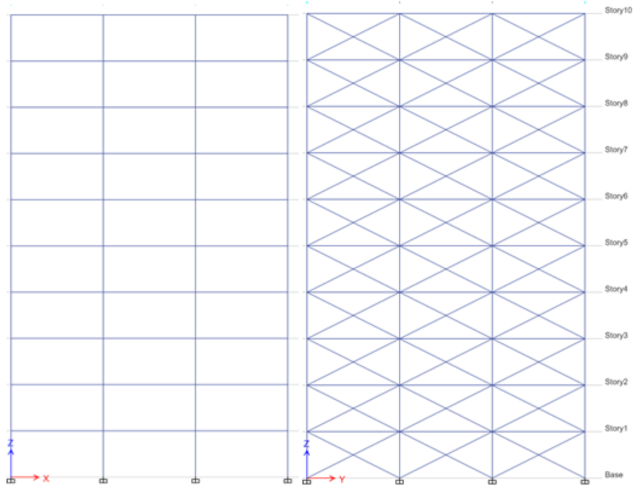

Fig. 3: On the left side is Portal frame outer shear walls and to the right is Portal with shear wall at center bay.

An G+3, G+4, G+5, G+6, G+7, G+8, G+9, G+10 bare as well as steel braced RCC portal frames have been modeled in Etabs 2016 analysis software. Bracing of steel I section having flange and web size of 250mm each with flang and web thickness of 15mm having a fillet size of 5mm has been provided. The time period computed by this analysis softwares has been taken for the first mode of vibration provided by the model analysis done in Etabs 2016. Time period of modes other then the mode 1 has been not taekn into consideration in this analysis paper.

V. ANALYSIS RESULTS

The natural time periods obtained from seismic code IS 1893 (Part 1) -2000 and analytical (ETABS 2016) are given in Table 1 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.

Storey	Time Period (sec) (As per IS code)	Time Period (sec) (Bare frame)	Time Period (sec) (With 2-way bracing)
4	0.212	0.411	0.106
5	0.251	0.554	0.139
6	0.288	0.698	0.174
7	0.323	0.844	0.211
8	0.357	0.99	0.251
9	0.31	1.136	0.294
10	0.422	1.284	0.339
11	0.453	1.432	0.388

Table 1: Time period values for different stories as per IS code, bare frame, with 2-way bracing.

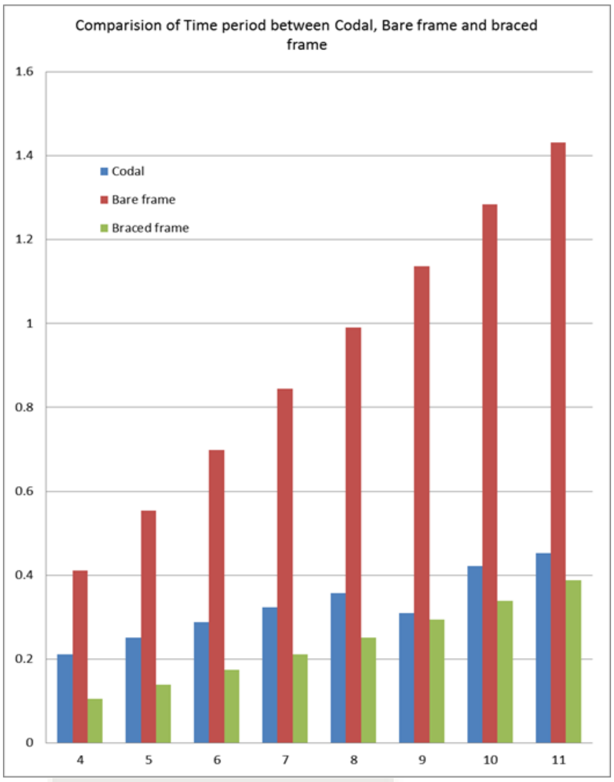

Fig 4: Comparison of time period values of bare and 2 way braced models with time period as per IS code.

VI. 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 8.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.

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