Analysis of steel braced symmetrical RCC building with designed I-sectional rubber base isolator

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Abstract – *A seismic isolation is one of the most popular and effective methods of protecting structures under strong dynamic excitations. Structures which are located in high seismic areas are having larger amount of risk and causes severe damage to the structures. The steel bracing system with base isolation is efficient under these conditions. The main advantage of providing steel bracing and base isolator is bracing works diagonal for axial stresses and base isolator gives minimum earthquake response to the structures. In this research, study of X type steel braced symmetrical building without and with rubber base isolators at different sections are provided and behavior of the structure is analyzed using Response spectrum analysis.*

Key Words: **X-Bracing, Base isolator design, Response spectrum method, Base shear, Storey Displacement, Storey drift.**

1. INTRODUCTION

Earthquake resistant structures are structures designed to withstand earthquakes. While no structure can be entirely free from damage of earthquakes, the goal of earthquake-resistant construction is to erect structures that fare better during seismic activity. According to building codes, earthquake-resistant structures are intended to withstand the largest earthquake of a certain probability that is likely to occur at their location. This means the loss of life should be minimized by preventing collapse of the buildings for rare earthquakes. Earthquakes are occasional forces on structure that may occur during the lifetime in seismic region. As seismic waves move through the ground, they create series of vibrations. These movements are translated into dynamic or inertial forces causing damage to structure. Base isolation, also known as seismic base isolation or base isolation system, is one of the most popular means of protecting a structure against earthquake forces. Base isolation is one of the most powerful tools of earthquake engineering resisting to the passive structural vibration. It is meant to enable a building to survive a potentially seismic impact through a proper initial design. In some cases, application of base isolation can raise both seismic performance and sustainability of structure. As popular belief base isolation does make a building earthquake proof.

1.1 Base Isolation

Base isolation separates upper structure from base or from down structure by changing of fixed joint with flexible one. Increasing of flexibility is done by the insertion of additional elements in structure, known as isolators. Usually, these isolators are inserted between upper structure and foundation. Seismic isolation system absorbs larger part of seismic energy. Therefore, vibrations of soil to upper structure are drastically reduced. But in case of isolated building as the ground moves, inertia tends to keep structure in place resulting in the imposition of structure with large displacement in different stories. For base isolation structure the situation is quite different. In such cases, the whole upper structure gets a displacement (which naturally remains in limits) and the relative displacement of different stories is so small that the structure can withstand a comparatively high seismic tremor with a low seismic loading in safe, efficient and economic manner.

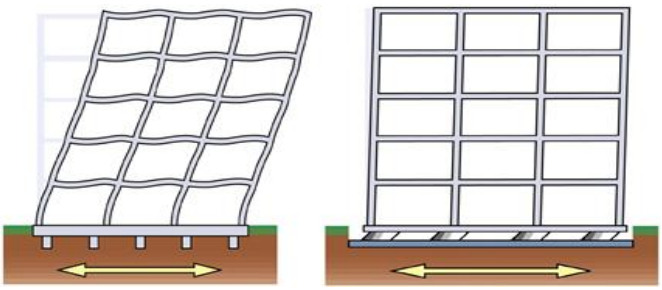

Fig. 1:- Behaviour of building with and without base isolators during earthquake

2. METHODOLOGY

Following methodology is adopted for analysis work:-

1. Decide symmetrical structure symmetry in plan with bracing parameter.

2. Prepare software model on ETABS software and analysis of model.

3. Response spectrum analysis is carried out using ETABS software model.

4. Design the I-section shaped base isolators.

5 Analysis of model with base isolators.

6 . Comparison of results.

3. PROBLEM STATEMENT

The following table no. 1 showing the details for the structural modeling of building on ETABS software. The load cases considered according to IS:1893(Part 1)-2002.

Table 1 :- Problem Statement

Type of building	R.C.C.
No. of story	G+15
Plan area	400 m^2
Plan Dimensions	20m X 20m
Height of building	45 m
Height of each floor	3
Type of building	Residential
Seismic zone	IV
Importance factor	1
Response reduction factor	5
Type of soil	Medium
Dimensions of beam	230mm X 400mm
Dimensions of column	300mm X 450mm
Slab thickness	150mm
Grade of concrete	M25
Grade of steel	Fe415
Live Load	2 kN/m^2

4. CRITERIA FOR SELECTION OF SUITABLE STEEL BRACING SECTION

The effective slenderness ratio of brace should be kept relatively low so that the brace are effective in compression as well as tension. The maximum slenderness ratio allowed for steel bracing in earthquake and wind is 350. (As per clause IS 800 table no.3 page no 30)

According to this, concrete column – 300mm X 450mm Size of steel bracing (Steel angle section) - 100x100x10mm

Slenderness ratio, $\lambda = \frac{Kl}{r_{min}}$

For building column, λ= **5.77,** For steel bracing, λ=**51.546**

Also, Stiffness of steel column and bracing calculated for 1m member,

For concrete column = $K = \frac{12EI}{l^3} = 6.834X10^6$ N/mm

For steel bracing= $K = \frac{AE(\cos\theta)^2}{1000}$

$K_1 = \frac{19.03X10^2X2X10^5X(\cos 30.96)^2}{1000} = 0.279X10^6$N/mm

$K_2 = \frac{19.03X10^2X2X10^5X(\cos 59.04)^2}{1000} = 0.100X10^6$N/mm

The stiffness for steel column is more than steel bracing which thus give better resistance to failure as compared to steel bracing, From the above results, size of steel bracing is taken as **100x100x10mm.**

5. STRUCTURAL MODELING AND ANALYSIS

To study the seismic response of Steel structure, G+15 multi-storied building is considered. The modeling and analysis of work is done by using ETABS software. ETABS is powerful and completely incorporated research software for analysis of RCC and Steel structure. The X-type bracing arrangements are provided in zigzag pattern. Following figures shows modeling of structure as plan elevation and three dimensional view of building model.

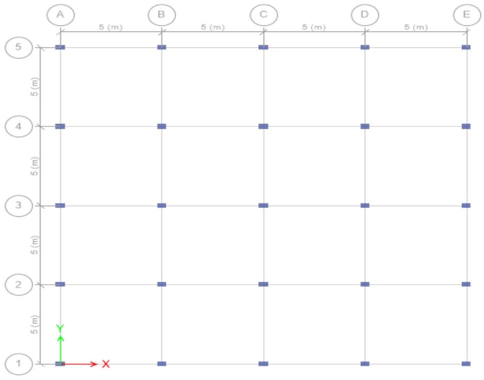

Fig. 2 :- Plan of Building

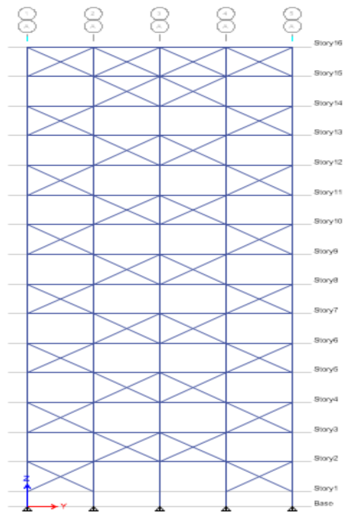

Fig. 3. :- Elevation of building with bracing provision

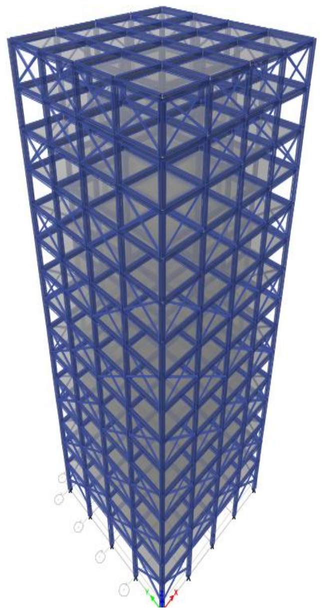

Fig. 4. :- 3D view of building with bracing provision

6. DESIGN OF I- SECTION TYPE BASE ISOLATOR

1. Calculate design displacement (D_d) :-- Assume design time period = T_D = 2 sec. and damping = 5% ,
   So $D_d = \frac{g}{4\pi^2} X \frac{C_{vd}.T_D}{B}$
2. Effective stiffness of isolator $K_{eff} = \frac{W}{g} X (\frac{2\pi}{T_D})^2$
3. Energy dissipated per cycle(W_D):-
   $W_D = 2\pi.K_{eff}.(D_D)^2.B_{eff}$
4. Force at design displacement characteristic strength
   $Q_d = \frac{W_D}{4xD_D}$
5. Stiffness in rubber (Horizontal Stiffness) $K_1 = K_{eff} - \frac{Q_d}{D_d}$
6. Yield Displacement $D_y = \frac{Q_d}{K_1 - K_2}$
7. Calculation of $Q_{d(Req)} = \frac{W_D}{4x(D_D - D_y)}$
8. Revised stiffness of rubber $K_{eff(Req)} = K_{eff} - \frac{Q_{d(Req)}}{D_d}$
9. Total thickness of rubber isolator $T_r = \frac{D_d}{V}$
10. Area of isolator $A_{RB} = \frac{K_{eff(Req)} x T_r}{G}$
11. Now here we consider section types of rubber isolators as I-Section
12. Shape factor $S = \frac{\text{Lateral Diamension}}{\text{4x Thickness}}$
13. Compression Modulus $E_c = 6GS^2(1-\frac{6GS^2}{K})$
14. Horizontal stiffness (K_H) of isolator $K_H = \frac{\text{Gx Area}}{T_r}$
15. Vertical stiffness (K_V) = $\frac{E_c \text{ x Area}}{T_r}$

From above design, the summary of I-section base isolator as shown in table no. 2

Table 2 :- Design summary of I –section base isolator

Design displacement (D_d)	0.268m
Effective stiffness of isolator K_{eff}	1826.03kN/m
Energy dissipated per cycle(W_D	41.20 kN.m
Force at design displacement characteristic strength Q_d	38.43 kN
Stiffness in rubber(Horizontal Stiffness) K_1	1682.63kN/m
Yield Displacement D_y	0.00254m
$Q_{d(Req)}$	38.80 kN
Revised stiffness of rubber $K_{eff(Req}$	1681.25 kN/m
Total thickness of rubber isolator T_r	0.3 m
Area of isolator A_{RB}	0.7 m^2

From this above design parameters the details of designed I-section type of base isolators as shown in table no. 3

Table 3 :- Details of I-section base isolator

Type of shape	I-section
Size of isolator	Top and bottom web 0.3x0.3x0.075m and flange 0.1x1.5x0.3m
Area provided	1.53 m^2
Thickness of each layer	0.01m
S	7.5
steel plates at ends of thickness	0.04m
Total height of square isolator	0.38m
Mass of square rubber isolator	23.28 kN
E_C	208.34×10^6 N/m^2
K_H	3570 kN/m
Nonlinear K_H	35700 kN/m
K_V	1062534 kN/m

After design the base isolators the designed properties of such isolators was given to ETABS software model. The following figure shows the isolator provision for I-section isolators and response spectrum analysis was carried out.

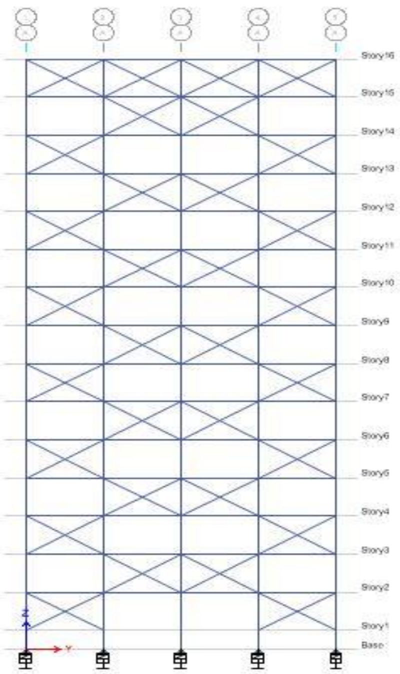

Fig. :- Elevation of model with isolator

7. RESULTS

After analyzing the building models with fixed base that is without base isolator and with I-section base isolators, the results were obtained. The results were compared with and without base isolators. The storey displacements, base shear and storey drift are parameters used for comparison of models. The results are shown in figure no. 5 to 7

7.1 Displacements

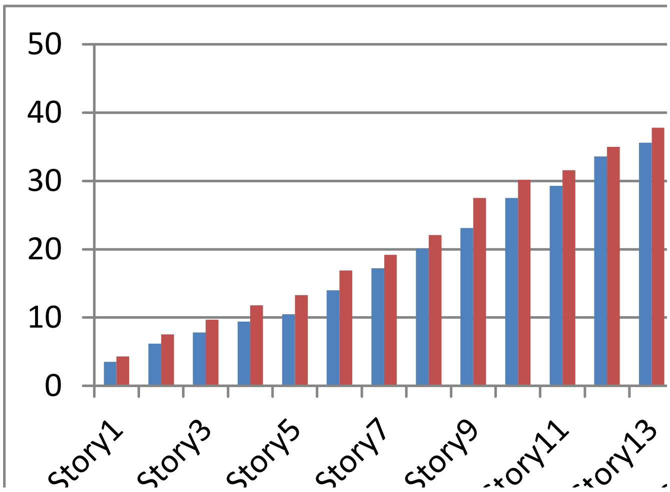

Fig.5 :-Displacements of different stories

The results shows the variations displacements of fixed base building with bracing is moderated and with i-section type of base isolator is very low.

7.2 Storey Drift

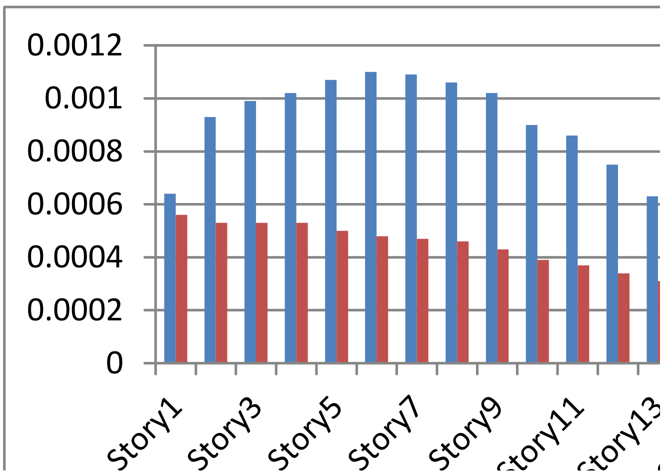

Fig. 6:- Storey drift at different stories

From above figure shows the i-section type base isolated model storey drift is reduced by 70% as compared to fixed base model.

7.3 Base Shear

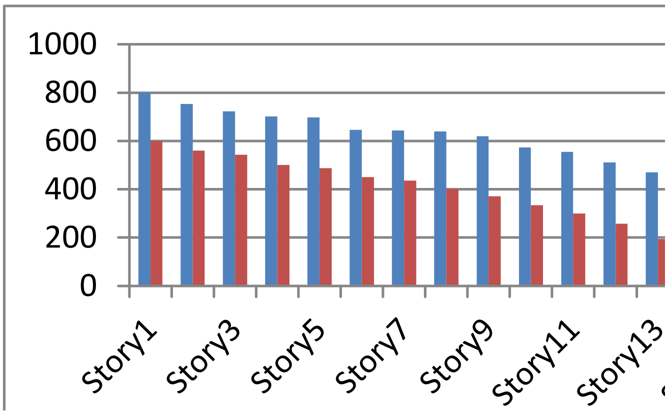

Fig. 7:- Base Shear at different stories

From the above figure the base shear of I-section type of base isolator model is reduced by 40% as compared to fixed base model.

8. CONCLUSIONS

The steel braced symmetrical structures with and without base isolator are analyzed on ETabs software. The displacement is reduced by use of base isolators and the maximum displacement reduced by I- Section of rubber isolator. Therefore it reduces the seismic effect on building. The base shear is increased by use of base isolators and the maximum base shear found by I- Section of rubber isolator, which makes structure make stable during earthquake occurrence. The maximum storey drift is reduced by use of base isolators and the maximum storey drift reduced by I-Section of rubber isolator making the superstructure flexible which is better for building resistance. Therefore, from this it is advantageous that the possibility of damage to building by earthquake is highly reduced by use of bracing and base isolators to the structures. It is also minimizes the reinforcement of the structure hence it becomes economic too.

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