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Seismic Analysis of Asymmetric Building with Different Base Isolation Systems

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Abstract— ***The base isolation is a technique which decouples the structure from its foundation[1], which reduces the impact of the vibration caused by the earthquake. It is most used system for the reduction of the damage caused by vibration of the structure. In the current study, G+4 Asymmetric building is considered for seismic analysis. Response Spectrum Analysis is performed on the Etabs software[2]. The study is performed by using the Lead Rubber Bearing (LRB) and Fixed Base and the results are compared in terms of time period, displacement and base shear[3]. The LRB is designed by using International Building Code (2005) and seismic analysis is done by IS1893:2016. It shows that the time period of the structure increases in the base isolated structure[3]. Base shear is reduced by 57% in LRB than fixed base and deflection of the structure increases.***

Index Terms— Fixed Base, Lead Rubber Bearing (LRB), Response Spectrum Analysis, Software (ETabs 2018).

I. INTRODUCTION

Now a days there are various techniques which are followed for the seismic resistance to the structure and the research also going on the new methods for earthquake resistance[4]. As the Asymmetric structures are more vulnerable to the earthquake, they are very prone to the severe damage to the structures[5]. **An asymmetric structure is a building or a structure that lacks symmetry in its structural dimensions, load distribution, or overall design configuration.** This structure does not have a well distribution of mass, stiffness, or other structural properties. But in today's time this type of structures is designed as it gives the best aesthetic view to the structure[1], [6], [7][8]. So, it is necessary to check the earthquake resistance of the structure. There are too many methods to make structure earthquake resistant, among them Base Isolation method is suitable for any type of the structure and also effective for the earthquake resistant[9]. However, base isolation does not save the structure from the damage entirely[10]. It is still necessary to consider other earthquake-resistant design techniques and also the consideration of the maintenance of the base isolator[11].

Base Isolation is a device which are placed between the structure and the foundation[12]**.** It divides the entire structure into the two parts and allow to move independently. It reduces the vibrations caused by the seismic waves thus the damage to the structure gets reduced[13]. Also, this are cost effective which gives the improved safety to the structure[14]. There are various types of base isolator Lead Rubber Bearing, High Damping Rubber Bearing and Friction Pendulum Bearing[6].

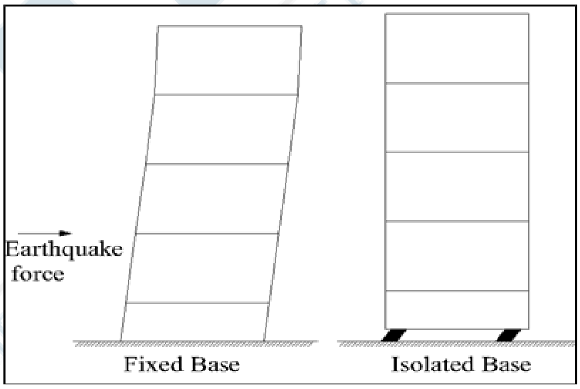

Figure 1- Base Isolation System

II. PROPOSED STUDY

The current study focuses on the seismic behaviour of the Asymmetric building with base isolation. The G+4 structure which is asymmetric in plan is considered for the analysis with Fixed Base and Lead Rubber Bearing (LRB) provided under each column. The models are tested for Linear Dynamic Analysis (RSA) and results are obtained for Fixed Base and Isolated Base.

III. OBJECTIVES OF PROPOSED WORK

- To design the Lead Rubber Bearing (LRB) by using International Building Code (2005)
- To differentiate seismic behaviour of the structure with fixed base and isolated base in terms of time period, deflection and base shear.

IV. METHODOLOGY

- G+4 Asymmetric model creation in ETabs 2018 Software.
- Define materials, section properties.
- Assign sections and loads on section.
- Perform Response Spectrum Analysis on fixed base structure.
- Determine Maximum Load on column.
- Design Lead Rubber Bearing by taking maximum load.
- Perform Response Spectrum Analysis on base isolated structure.
- Compare results of fixed base and LRB building.

V. EXAMPLE BUILDING AND DESIGN OF BASE ISOLATION

In the current study the 5-storey building with isolator at base is considered for the seismic analysis. The LRB is used as a base isolation for the Asymmetric building located in a Seismic zone IV. Plan and 3D view of the building is shown in figure 2. Height of storey is 3.6m. Average size of the column is 450mm x 650mm and size of beam is 450mm x 450mm. The thickness of the slab is 125mm. The grade of concrete is M30 and Fe500 steel is used.

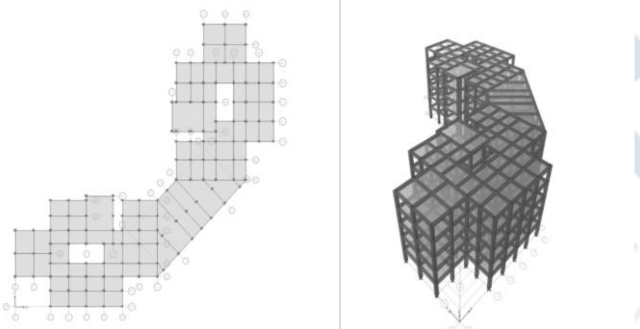

Figure 2- Plan and 3D view of Building

The following equations estimate various design parameters for this model.

- Design Displacement

$D_D = (g/4\pi^2) * (S_{D1} * T_D / B_D)$[15]

g - gravitational acceleration.

SD1 - spectral coefficients, available from the maps shown in Fig.4.12accompanying the IBC-2000

TD - isolated period,

BD - damping coefficients corresponding to the DBE level responses shown in Table 1623.2.21 of IBC 2000

- The effective stiffness of rubber is given by

$KH = (w/g) * (2\pi/T)^2$,[15]

- Area of Rubber can be calculated from

$A = k_H * T_r / G$[7]

K_H- Effective Horizontal stiffness of Rubber

T_r- Thickness of Rubber

G- Shear modulus of Rubber

w – Max. Support Reaction

DAMPING COEFFICIENT, B_D or B_M	
EFFECTIVE DAMPING, β_D OR β_M (PERCENTAGE OF CRITICAL)	B_D OR B_M FACTOR
≤ 2%	0.8
5%	1.0
10%	1.2
20%	1.5
30%	1.7
40%	1.9
≥ 50%	2.0

a. The damping coefficient shall be based on the effective damping of the isolation system determined in accordance with the requirements of Section 1623.8.4.2.

b. The damping coefficient shall be based on linear interpolation for effective damping values other than those given.

Table 1 - Values of BD or BM factor (Table 1623.2.21 of IBC: 2000)

- Energy dissipated per cycle, WD

$WD = 2\pi \times k_{eff} \times ß \times D^2$[16]

- Characteristics strength, Q;
-

$Q = WD / (4(D - Dy))$[16]

- Post-yield stiffness of the isolator, k_2;

$K_2 = k_{eff} - (Q/D)$
[16]

- Yield displacement, Dy is given by;

$Dy = Q / (k_1 - k_2)$[16]

- Yield strength, Fy[16]

$Fy = Q + kd. Dy$[16]

VALUES OF SITE COEFFICIENT F_v AS A FUNCTION OF SITE CLASS AND MAPPED SPECTRAL RESPONSE ACCELERATION AT 1 SECOND PERIOD (S_1)[a]

SITE CLASS	MAPPED SPECTRAL RESPONSE ACCELERATION AT 1 SECOND PERIOD				
	$S_1 \le 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 \ge 0.5$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	Note b
F	Note b	Note b	Note b	Note b	Note b

a. Use straight line interpolation for intermediate values of mapped spectral acceleration at 1-second period, S_1.

b. Site-specific geotechnical investigation and dynamic site response analyses shall be performed to determine appropriate values.

Table 2- Values of site Coefficient Fy (Table 1615.1.2(2) of IBC: 2000)

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Table 3 shows the properties of the LRB,

Horizontal Stiffness (Kh)	6837.56 kN/m
Vertical stiffness (*KV*)	241197 kN/m
Effective damping (*βeff*)	5%
Yield strength of rubber (*Fy*)	43.58 kN
Effective stiffness (*Keff*)	897.31 kN/m
Post-yield stiffness ratio	0.1
Compression modulus of rubber (*Ec*)	251171.9 kN/m2

Table 3- Properties of LRB

VI. RESULTS

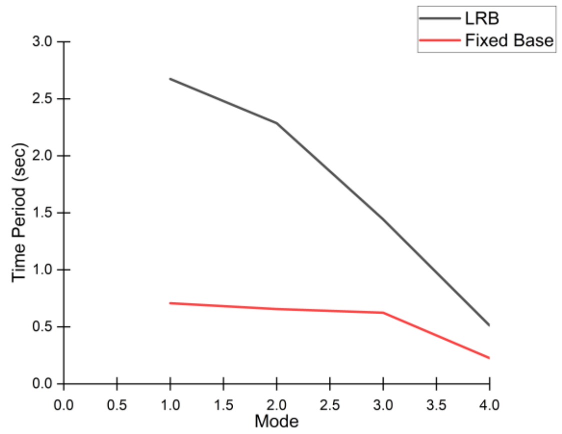

Figure 3- Time Period

As shown in Figure 3, time period is increased for lead rubber bearing by almost 4 times than fixed base.

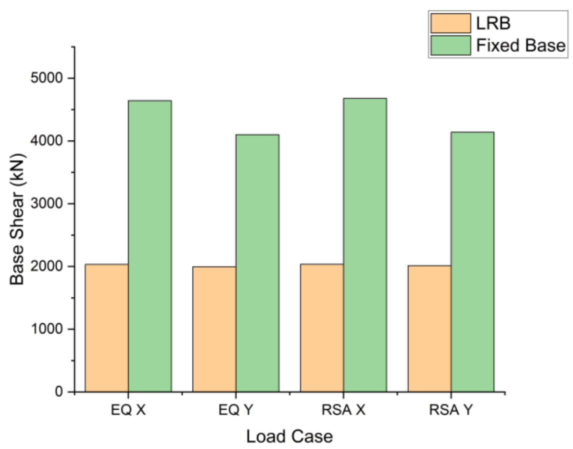

Figure 4- Base Shear

As shown in Figure 4, base shear is reduced for the Lead Rubber Bearing.

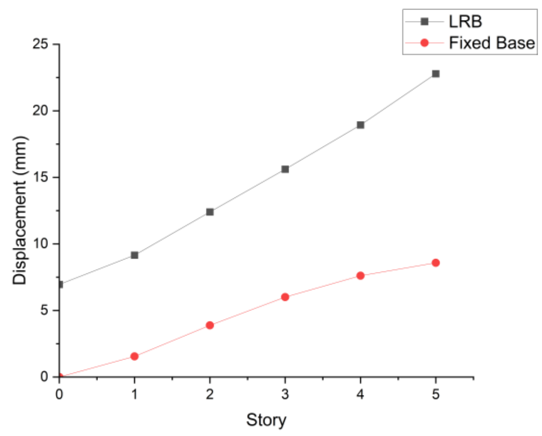

Figure 5- Deflection

As shown in Figure 5, deflection is increased for lead rubber bearing (LRB) than fixed base.

VII. CONCLUSION

From the result, time period for the structure with lead rubber bearing (LRB) is increased by 3.78 multiple times the time period for fixed base structure. Base reaction in X-direction is reduced by 57% for Lead Rubber Bearing than Fixed base structure and it is reduced by 52% for LRB in Y-direction. Maximum deflection for fixed base is 9.154mm and 27.948mm for LRB is less than the 72 mm (H/250), it shows that the structure with base isolation is flexible than fixed base structure.

By considering the above values it states that base isolation is effective for damage reduction of the structure but not completely stop the earthquake damage. It gives stability to the structure and enhances serviceability of the structure.

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