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Comparision of Fixed Base and Base Isolation Reinforced Concrete Structure for Seismic Response

Yagneshkumar Patel[1],Pradeep Kumar Pandey[2]

[1]*PG Student, Civil Engineering Department, School of Engineering,R.K. University, Rajkot*
[2]*Assistant Professor, Civil Engineering Department, School of Engineering, R.K. University, Rajkot*

Abstract - *Seismic hazards are a major concern in many populous regions of the world. Performance-based seismic design has brought about new technological advances and introduced an innovative approach to constructing seismic-resistant buildings. Base isolation is one of the most powerful tools of earthquake engineering pertaining to the passive structural vibration control technologies. The application of the base isolation techniques to protect structures against damage from earthquake attacks has been considered as one of the most effective approaches and has gained increasing acceptance during the last two decades.Design of base isolation bearing is taken from International Building code IBC-2000In order to verify the effect of base isolation system, two different structures are presented (7 stories symmetrical and non-symmetrical school buildings) in which the seismic responses of the 'fixed-base' and 'base-isolated' conditions have been compared using Etabs (a well-known computer program).The high damping rubber isolation system has been used and devices have been installed at the foundation level. Response Spectrum Analysis has been performed using Indian Standard Code IS-1893(Part-1):2002. Comparing the results of the base-isolated condition with those obtained from the fixed-base condition has shown that the base isolation system reduces the base shear force and storey drifts, whilst also increasing the displacement.*

Keywords*-Base isolation, Rubber, Response Spectrum, Base Shear, Displacement*

I. INTRODUCTION

Seismic base isolation is a well-defined building protection system against earthquakes. Earthquakes are one of nature’s greatest hazards; throughout historic time they have caused significant loss of life and severe damage to property, especially to man-made structures. On the other hand, earthquakes provide architects and engineers with a number of important design criteria foreign to the normal design process. From well established procedures reviewed by many researchers, seismic isolation may be used to provide an effective solution for a wide range of seismic design problems. The application of the base isolation techniques to protect structures against damage from earthquake attacks has been considered as one of the most effective approaches and has gained increasing acceptance during the last two decades. This is because base isolation limits the effects of the earthquake attack, a flexible base largely decoupling the structure from the ground motion, and the structural response accelerations are usually less than the ground acceleration. In this paper, the effect of base isolation system on seismic responses of structures is studied. Two different structures are presented (regular and irregular 7-storey school buildings) in which the seismic responses of the fixed-base condition and HDR isolation condition have been compared using the well-known computer program Etabs. Response Spectrum Method of analysis shall be performed by IS 1893(Part1):2002 in Etabs.Acar [10] studied the effect of HDR isolation on the seismic responses of different structures using IBC2000 and FEMA design codes and concluded that the site condition where earthquake data is recorded has a great influence on the design parameters of the structure.

II. TYPES OF BASE ISOLATION BEARING

The successful seismic isolation of a particular structure depends on the appropriate choice of the base isolation devices. The basic features of an isolation system are identified as:

- An increased flexibility so that the natural period of the structure is increased sufficiently to shift the frequency of the structure out of the range of dominant frequency of earthquake.
- A capacity for dissipating earthquake energy for resisting excessive horizontal displacement at the base of the building.

2.1. Elastomeric Bearing

Elastomeric bearings are constructed of alternating rubber layers bonded to intermediate reinforcing plates that are typically steel as illustrated by the schematic of a deformed bearing shown in Figure 1. The total thickness of rubber provides the low horizontal stiffness need to achieve the period shift whereas the spacing of the steel shim plates controls the vertical stiffness of the bearing for a given shear modulus and bonded rubber area. [12]

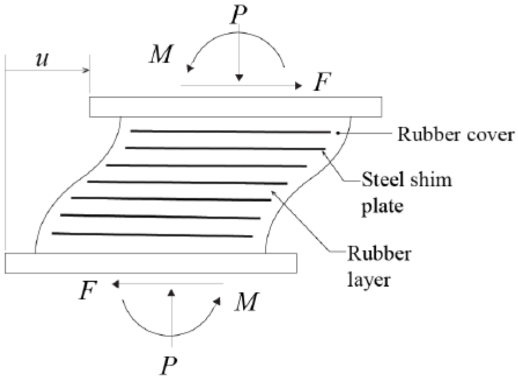

Figure 1.Elastomeric Bearing in the laterally deformed configuration

2.2. High Damping Rubber (HDR) Bearing

The energy dissipation in high-damping rubber bearings is achieved by special compounding of the elastomeric. Damping ratios will generally range between 8% and 20% of critical. The shear modulus of high-damping elastomeric generally ranges between 0.34 MPa and 1.40 MPa. The material is nonlinear at shear strains less than 20% and characterized by higher stiffness and damping, which minimizes the response under wind load and low-level seismic load. Over the range of 20-120% shear strain, the modulus is low and constant. At large shear strains, the modulus and energy dissipation increase. This increase in stiffness and damping at large strains can be exploited to produce a system that is stiff for small input, is fairly linear and flexible at design level input, and can limit displacements under unanticipated input levels that exceed design levels. High damping rubber bearing is shown in Figure 2.[12]

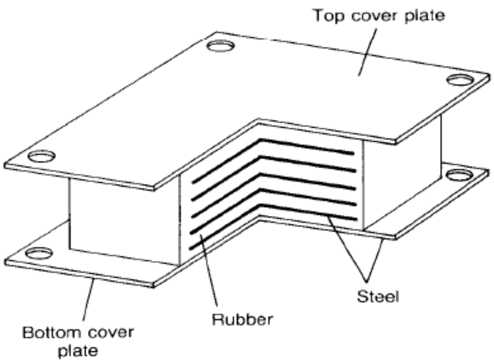

Figure 2. High Damping Rubber Bearing

2.3. Lead Rubber Bearing (LRB)

Lead-plug bearings are generally constructed with low-damping elastomers and lead cores with diameters ranging 15% to 33% of the bonded diameter of the bearing as shown in Figure 3. Laminated-rubber bearings are able to supply the required displacements for seismic isolation. By combining them with a lead-plug insert which provides hysteretic energy dissipation, the damping required for a successful seismic isolation system can be incorporated in a single compact component.[12]

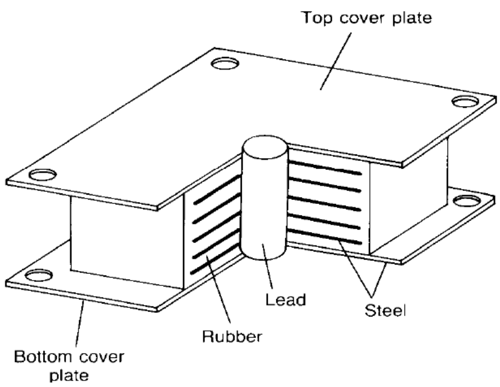

Figure 3. Lead Rubber Bearing

2.4. Friction Pendulum Sliding (FPS) Bearing

The concept of sliding bearings is also combined with the concept of a pendulum type response, obtaining a conceptually interesting seismic isolation system known as a friction pendulum systemas shown in Figure 4. In FPS, the isolation is achieved by means of an articulated slider on spherical, concave chrome surface.[12]

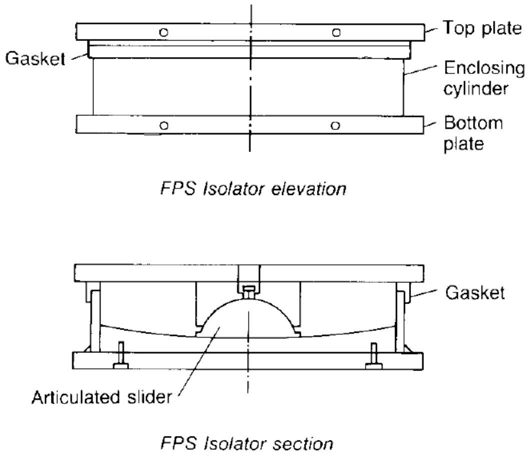

Figure 4. Friction Pendulum Sliding Bearing

III. MODEL AND ANALYSIS

In this research work two different structure are use in this study symmetrical and non-symmetrical. Compression of fixed base and base-isolated structure for seismic response is performed.

3.1 The symmetrical structure

7-Stories (G+6) Symmetric Reinforced School Building with High Damping Rubber Bearing (HDR) Base Isolation. The Slab thickness is 0.16 m, the Column Sections is 0.55 × 0.55 m, the Beam Sections is 0.30 × 0.70 m and each Floor height is 3.0 m. Building location is Bhuj, India.

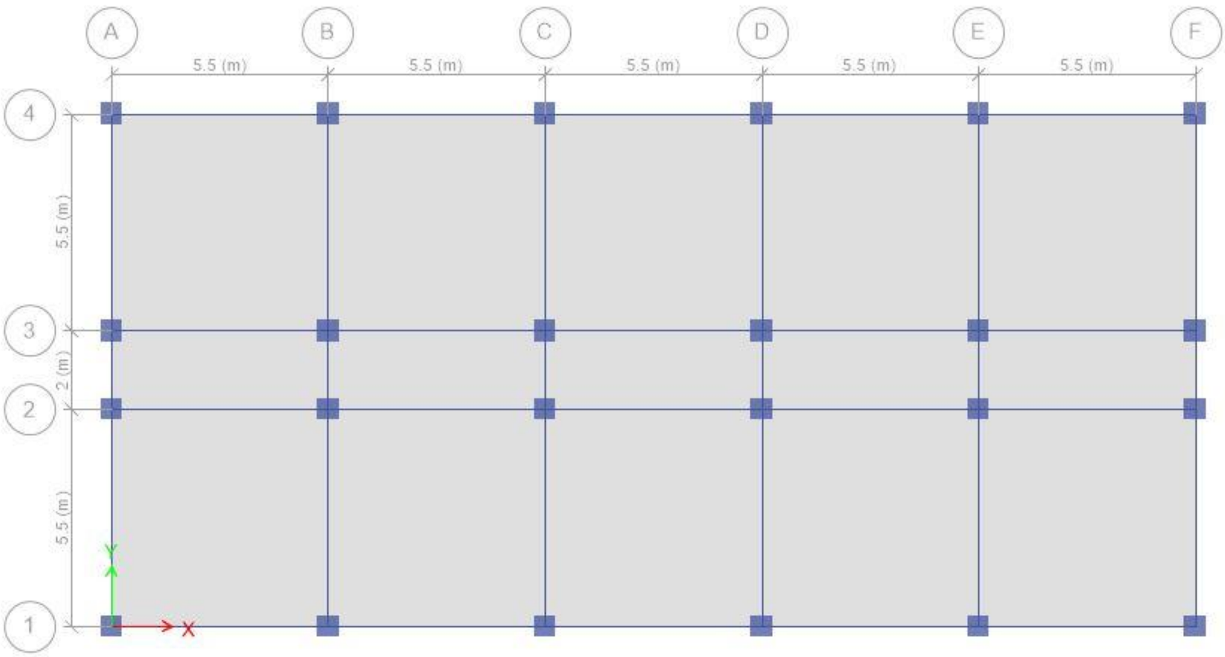

Figure 5. Plan of the Symmetric Building

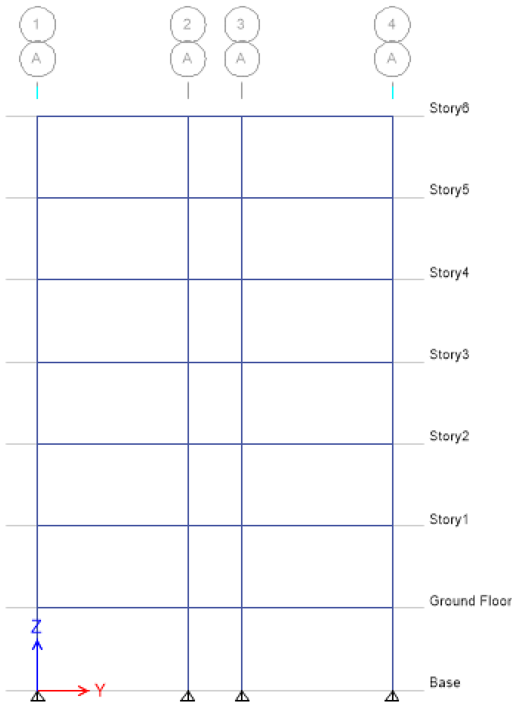

Figure 6. Elevation of the Symmetric Building

For isolating the structure, 24 units (HDR) are used. The basic structural data to be used for the design is as follows:
Target period for 'Design Level' earthquake T_D = 2.10 Second
Target period for 'Max. Capable Level' earthquake T_M = 2.50 Second
Shear modulus of HDR G = 550 kN/m^2
Small shear strain G = 700 kN/m^2
Bulk modulus K = 20,00,000 kN/m^2
Damping ratio of isolator β = 15%
Shear Strain γ_{max} = 150% = 1.5
Acceleration of gravity g = 9.81 kN/m^2
Seismic load Reduction factor for special RC moment resisting frame (SMRE) R = 5.0 [16]

3.1.1 Design 5% damped spectral acceleration at 1-second Period S_{D1}

The mapped spectral acceleration for a 1-second period S_1
Seismic Zone Factor Z for Bhuj, India (Zone-V) = 0.36 [16]
So, S_1 = 0.36

Table 1. Values of site coefficient F_v as a function of site class and mapped spectral response acceleration at 1 second period (S_1)[15]

Site Class	$S_1 \leq 0.1$	S_1=0.2	S_1=0.3	S_1=0.4	$S_1 \geq 0.1$
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

Site Coefficient F_V, from table 1,
For a stiff soil Profile, take site class 'D'
For S_1 = 0.36,
Interpolation, $\frac{1.8-1.6}{0.4-0.3} = \frac{F_v-1.6}{0.36-0.3}$, F_v =4.2

Maximum considered earthquake spectral response acceleration parameters [15]
$S_{M1} = F_v S_1 = 4.2 \times 0.36 = 1.512$

Design 5% damped spectral acceleration at 1-second Period [15]

$$S_{D1} = \frac{2}{3} S_{M1} = \frac{2}{3} \times 1.512 = 1.008$$

3.1.2 Total weight of the structure
Weight of typical slab= (27.5×13) × SW × 7= (27.5×13) × (0.16×25) × 7 = 10010 kN

Weight of longitudinal beams= [20 Nos × (5.5-0.55) × ((0.30×0.70) × 25)] × 7= 519.75 × 7= 3638.25 kN

Weight of Transverse beams
= [12 Nos × (5.5-0.55) × ((0.30×0.70) × 25)] + [6 Nos × (2-0.55) × ((0.30×0.70) × 25)] × 7
= (1311.85 + 45.675) × 7= 2502.675 kN

Weight of Column= [24 Nos ×3× ((0.55×0.55) × 25)] × 7= 544.5 × 7= 3811.5 kN

Total = 10010 + 3638.25 + 2502.675 + 3811.5 = 19962.425 kN = 19963 kN

3.1.3 Lateral stiffness of Base isolators
For Design Level Earthquake [15]

$$T_D = 2\pi \sqrt{\frac{W}{k_h \times g}}$$

$$2.10 = 2\pi \sqrt{\frac{19963}{k_{total} \times 9.81}}$$

$$\sqrt{k_{total}} = 134.97$$

$$k_{total} = 18216.90 \text{ kN/m}$$

For one bearing

$$k_h = \frac{18216.90}{24} = 759.04 \text{ kN/m}$$

For Maximum Capable Earthquake [15]

$$T_M = 2\pi \sqrt{\frac{W}{k_h \times g}}$$

$$2.50 = 2\pi \sqrt{\frac{19963}{k_{total} \times 9.81}}$$

$$\sqrt{k_{total}} = 113.37$$

$$k_{total} = 12853.95 \text{ kN/m}$$

For one bearing,

$$k_h = \frac{12853.95}{24} = 535.58 \text{ kN/m}$$

3.1.4 Estimation of Lateral Displacement
The displacement of isolation system to the 'Design level earthquake' [15]

$$D_D = \left(\frac{g}{4\pi^2}\right) \frac{S_{D1} T_D}{B_D}$$

Table 2. Damping Coefficient B_D [15]

Effective Damping β_D (percentage of critical)	**B_D factor**
≤ 2%	0.8
5%	1
10%	1.2
20%	1.5
30%	1.7
40%	1.9
≤ 50%	2

So, B_D for 15% Damping, from table 2, By Interpolation, $\frac{1.5-1.2}{20-10} = \frac{B_D-1.2}{15-10}$, $B_D = 1.35$

$$D_D = \left(\frac{9.81}{4\pi^2}\right)\frac{1.008 \times 2.10}{1.35} = 0.39\text{m}$$

The displacement of isolation system to the 'Maximum capable earthquake' [15]

$$D_M = \left(\frac{g}{4\pi^2}\right)\frac{S_{D1}T_M}{B_D} = \left(\frac{9.81}{4\pi^2}\right)\frac{1.008 \times 2.50}{1.35} = 0.46\text{m}$$

3.1.5 Estimation of Disc dimensions

Maximum shear strain, [12]

$$\gamma_{max} = \frac{D_D}{t_r}$$

So, Thickness of the Disc

$$t_r = \frac{D_D}{\gamma_{max}} = \frac{0.39}{1.5} = 0.26\text{m} = 26\text{cm}$$

Horizontal stiffness [12]

$$k_h = \frac{GA}{t_r}$$

So,

$$A = \frac{k_h t_r}{G}$$

$$A = \frac{759.04 \times 0.26}{550} = 0.359\text{m}^2$$

Now, Diameter

$$A = \frac{\pi}{4}\Phi^2$$

$$0.359 = \frac{\pi}{4}\Phi^2$$

$$\Phi = 0.676\text{m} = 67.6\text{cm} = 676\text{mm}$$

3.1.6 Bearing Detail

Compression Modulus [12]

$$E_c = \left(\frac{1}{6GS^2} + \frac{1}{K}\right)^{-1}$$

Where,

E_c = Compression Modulus

S = Shape factor ($5 < S < 30$)

K = Bulk Modulus (1000MPa < K < 2500MPa)

G = Shear Modulus (0.5MPa < G < 2.5MPa)

$$E_c = \left(\frac{1}{6 \times 700 \times 8^2} + \frac{1}{2000000}\right)^{-1}$$

$$E_c = 236953\ \text{kN/m}^2$$

So, Total Vertical Stiffness [12]

$$k_v = \frac{E_c A}{t_r} = \frac{236953 \times 24 \times 0.359}{0.26} = 7852257.877\ \text{kN/m}$$

For one bearing,

$$k_v = \frac{7852257.877}{24} = 327177.41\ \text{kN/m}$$

Total stiffness for one bearing

$$k = k_h + k_v = 759.04 + 327177.41 = 327936.45\ \text{kN/m}$$

For circular pad Shape factor, [12]

$$S = \frac{\Phi}{4t_0}$$

So, thickness of single layer rubber

$$t_0 = \frac{\Phi}{4S} = \frac{676}{4 \times 8} = 21.125\text{mm} \approx 22\text{mm}$$

Number of layer is 10
$n \times t_0 = 10 \times 22 = 220mm$

Assume, The end plates are 25mm thick and the steel shims are 2mm each
Total Height h = (2×25) + (10×22) + (9×2) = 281mm
The steel shims will have a diameter Φ_s = 676mm, giving 5mm cover

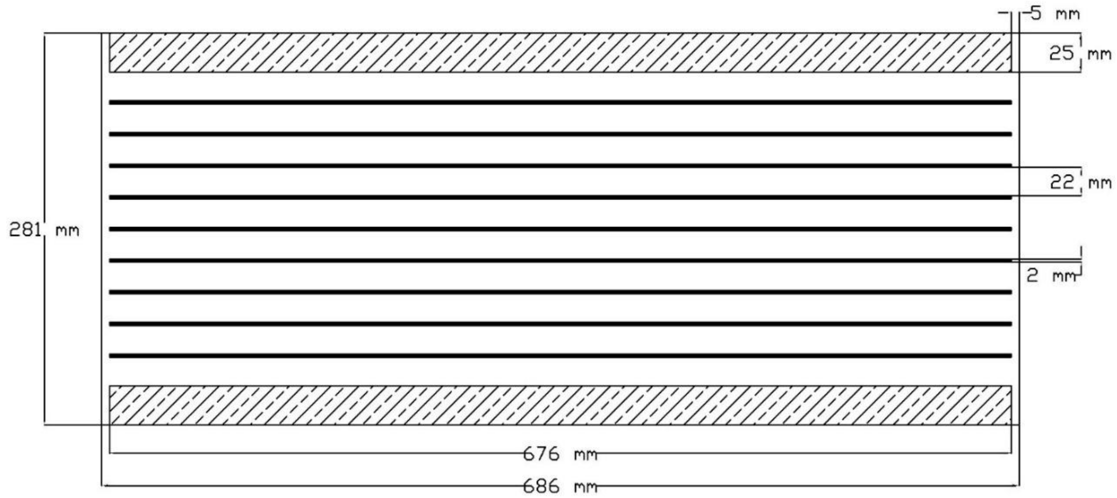

Figure 7. Detail design of isolator for the Symmetric Building

3.2The Non-Symmetric structure
7-Stories (G+6) Non-Symmetric Reinforced School Building with High Damping Rubber Bearing (HDR) Base Isolation. The Slab thickness is 0.16 m, the Column Sections is 0.55 × 0.55 m, the Beam Sections is 0.30 × 0.70 m and each Floor height is 3.0 m. Building location is Bhuj, India.

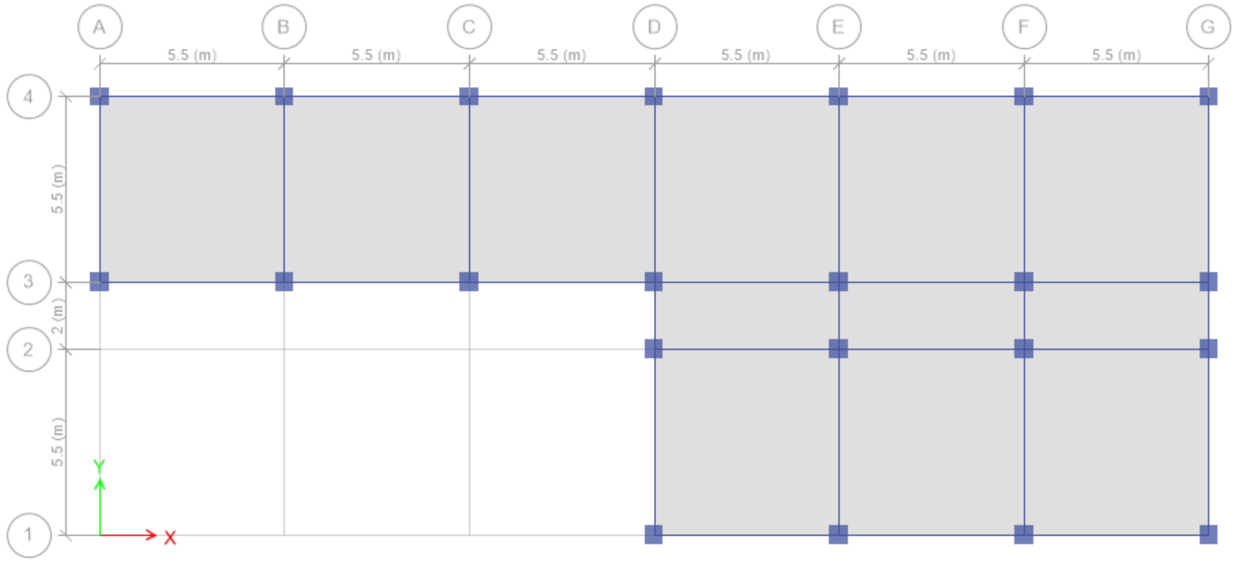

Figure 8. Plan of the Non-Symmetric Building

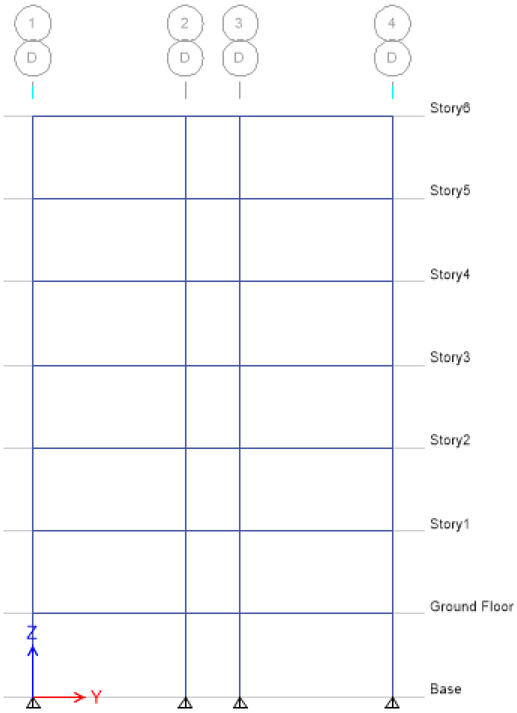

Figure 9. Section of the Non-Symmetric Building

For isolating the structure, 22 units (HDR) are used. The basic structural data to be used for the design is as follows:
Target period for 'Design Level' earthquake T_D = 2.10 Second
Target period for 'Max. Capable Level' earthquake T_M = 2.50 Second
Shear modulus of HDR G = 550 kN/m^2
Small shear strain G = 700 kN/m^2
Bulk modulus K = 20,00,000 kN/m^2
Damping ratio of isolator β = 15%
Shear Strain γ_{max} = 150% = 1.5
Acceleration of gravity g = 9.81 kN/m^2
Seismic load Reduction factor for special RC moment resisting frame (SMRE) R = 5.0 [16]

3.2.1 Design 5% damped spectral acceleration at 1-second Period S_{D1}
The mapped spectral acceleration for a 1-second period S_1
Seismic Zone Factor Z for Bhuj, India (Zone-V) = 0.36 [16]
So, S_1 = 0.36
Site Coefficient F_V, from table 1,
For a stiff soil Profile, take site class 'D'
For S_1 = 0.36,
Interpolation, $\frac{1.8-1.6}{0.4-0.3} = \frac{F_V-1.6}{0.36-0.3}$, F_v =4.2

Maximum considered earthquake spectral response acceleration parameters [15]
$S_{M1} = F_v S_1 = 4.2 \times 0.36 = 1.512$

Design 5% damped spectral acceleration at 1-second Period [15]
$S_{D1} = \frac{2}{3} S_{M1} = \frac{2}{3} \times 1.512 = 1.008$

3.2.2 Total weight of the structure
Weight of typical slab = (33×13) × SW × 7 = (33×13) × (0.16×25) × 7 = 12012 kN

Weight of longitudinal beams = [18 Nos × (5.5-0.55) × ((0.30×0.70) × 25)] × 7 = 467.775 × 7 = 3274.425 kN

Weight of Transverse beams = [11 Nos × (5.5-0.55) × ((0.30×0.70) × 25)] + [4 Nos × (2-0.55) × ((0.30×0.70) × 25)] × 7 = (285.8625 + 30) × 7= 2211.0375 kN
Weight of Column = [22 Nos ×3× ((0.55×0.55) × 25)] × 7 = 499.125 × 7 = 3493.875 kN

Total = 12012 + 3274.425 + 2211.0375 + 3493.875 = 20991.3375 kN = 20992 kN

3.2.3 Lateral stiffness of Base isolators
For Design Level Earthquake [15]

$$T_D = 2\pi\sqrt{\frac{W}{k_h \times g}}$$

$$2.10 = 2\pi\sqrt{\frac{20992}{k_{total} \times 9.81}}$$

$$\sqrt{k_{total}} = 138.40$$

$$k_{total} = 19156.04 \text{ kN/m}$$

For one bearing

$$k_h = \frac{19156.04}{22} = 870.73 \text{ kN/m}$$

For Maximum Capable Earthquake [15]

$$T_M = 2\pi\sqrt{\frac{W}{k_h \times g}}$$

$$2.50 = 2\pi\sqrt{\frac{20992}{k_{total} \times 9.81}}$$

$$\sqrt{k_{total}} = 116.26$$

$$k_{total} = 13516.50 \text{ kN/m}$$

For one bearing,

$$k_h = \frac{13516.50}{22} = 614.38 \text{ kN/m}$$

3.2.4 Estimation of Lateral Displacement
The displacement of isolation system to the 'Design level earthquake' [15]

$$D_D = \left(\frac{g}{4\pi^2}\right)\frac{S_{D1}T_D}{B_D}$$

So, B_D for 15% Damping, from table 2,
By Interpolation, $\frac{1.5-1.2}{20-10} = \frac{B_D-1.2}{15-10}$, $B_D = 1.35$

$$D_D = \left(\frac{9.81}{4\pi^2}\right)\frac{1.008 \times 2.10}{1.35} = 0.39\text{m}$$

The displacement of isolation system to the 'Maximum capable earthquake' [15]

$$D_M = \left(\frac{g}{4\pi^2}\right)\frac{S_{D1}T_M}{B_D} = \left(\frac{9.81}{4\pi^2}\right)\frac{1.008 \times 2.50}{1.35} = 0.46\text{m}$$

3.2.5 Estimation of Disc dimensions
Maximum shear strain, [12]

$$\gamma_{max} = \frac{D_D}{t_r}$$

So, Thickness of the Disc

$$t_r = \frac{D_D}{\gamma_{max}} = \frac{0.39}{1.5} = 0.26\text{m} = 26\text{cm}$$

Horizontal stiffness [12]

$$k_h = \frac{GA}{t_r}$$

So,

$$A = \frac{k_h t_r}{G}$$

$$A = \frac{870.73 \times 0.26}{550} = 0.412\text{m}^2$$

Now, Diameter

$$A = \frac{\pi}{4}\Phi^2$$

$$0.412 = \frac{\pi}{4}\Phi^2$$

$$\Phi = 0.724\text{m} = 72.4\text{cm} = 724\text{mm}$$

3.2.6 Bearing Detail

Compression Modulus [12]

$$E_c = \left(\frac{1}{6GS^2} + \frac{1}{K}\right)^{-1}$$

Where,

E_c = Compression Modulus

S = Shape factor ($5 < S < 30$)

K = Bulk Modulus (1000MPa < K < 2500MPa)

G = Shear Modulus (0.5MPa < G < 2.5MPa)

$$E_c = \left(\frac{1}{6 \times 700 \times 8^2} + \frac{1}{2000000}\right)^{-1}$$

$$E_c = 236953 \text{ kN/m}^2$$

So, Total Vertical Stiffness [12]

$$k_v = \frac{E_c A}{t_r} = \frac{236953 \times 22 \times 0.412}{0.26} = 8260546.123 \text{ kN/m}$$

For one bearing,

$$k_v = \frac{8260546.123}{22} = 375479.36 \text{ kN/m}$$

Total stiffness for one bearing

$$k = k_h + k_v = 870.73 + 375479.36 = 376350.09 \text{ kN/m}$$

For circular pad Shape factor, [12]

$$S = \frac{\Phi}{4t_0}$$

So, thickness of single layer rubber

$$t_0 = \frac{\Phi}{4S} = \frac{724}{4 \times 8} = 22.625\text{mm} \approx 23\text{mm}$$

Number of layer is 10

$$n \times t_0 = 10 \times 23 = 230\text{mm}$$

Assume, The end plates are 25mm thick and the steel shims are 2mm each

Total Height h = (2×25) + (10×23) + (9×2) = 298mm

The steel shims will have a diameter Φ_s = 724mm, giving 5mm cover

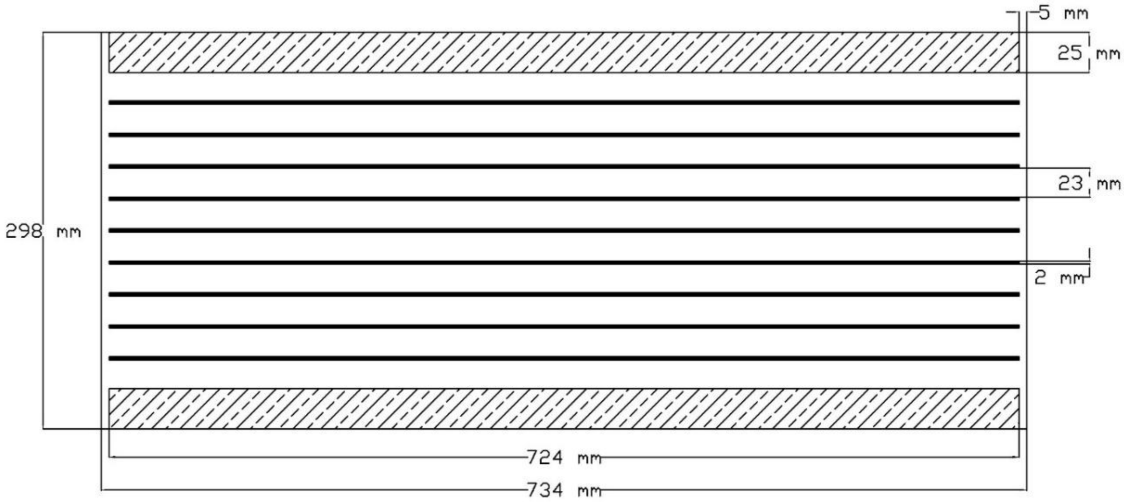

Figure 10. Detail design of isolator for the Non-Symmetric Building

IV. ANALYSIS AND RESULT

Response spectrum analysis is carried out to find seismic response of structures using Etabs software [14].
To calculate scale factor for response spectrum analysis,

$$\text{Scale factor} = \frac{\text{I g}}{\text{R}} = \frac{1 \times 9806.65}{5} = 1961.33$$

Where,
I= Importance Factor = 1
g = acceleration due to gravity = 9.80665 m/s^2 = 9806.65 mm/s^2
R = Seismic load Reduction factor for special RC moment resisting frame (SMRE) = 5.0 [16]

4.1 The symmetrical structure result

The seismic responses of the fixed-base condition and base-isolated condition have been compared using the well-known computer program Etabsthrough Response Spectrum method. The comparison about Time Period, Base shear force, Base moment, Storey Drifts Ratio and Displacements.

Table 3. Time period for the Symmetric Building

Number	Mode shape	Time period (Sec.) Fixed Base	Time period (Sec.) HDR Isolation Base
1	Mode	0.729	8.657
2	Mode	0.722	3.864
3	Mode	0.661	2.279
4	Mode	0.226	0.979
5	Mode	0.222	0.827
6	Mode	0.204	0.316
7	Mode	0.121	0.137
8	Mode	0.12	0.137
9	Mode	0.11	0.125
10	Mode	0.079	0.092
11	Mode	0.079	0.091
12	Mode	0.072	0.082

Table 4. Base shear, Base moment for the Symmetric Building

	Fixed base	HDR Isolation Base
Base Shear in X Direction (kN)	2567.3641	502.4521
Base Shear in Y Direction (kN)	2519.5431	516.516
Base Moment in X Direction (kN.m)	34230.652	6053.9367
Base Moment in Y Direction (kN.m)	34651.8018	6636.5074

Table 5. Storey Drifts Ratio of the Symmetric Building

Storey	X Direction - Fixed	X Direction - HDR	Y Direction - Fixed	Y Direction - HDR

	Base	Isolation Base	Base	Isolation Base
6	1.002	1	1.002	1
5	1	1	1.001	1
4	1	1	1.001	1
3	1	1	1.001	1
2	1.001	1	1.001	1
1	1.002	1.001	1.002	1
Ground Floor	1.001	1.02	1.001	1.004

Table 6. Displacement for the Symmetric Building

Floor	X Direction Displacement - Fixed Base (m)	X Direction Displacement - HDR Isolation Base (m)	Y Direction Displacement - Fixed Base (m)	Y Direction Displacement - HDR Isolation Base (m)
6	0.02233	0.12511	0.022939	0.636662
5	0.021553	0.113005	0.021884	0.555606
4	0.020145	0.100805	0.020213	0.474339
3	0.01811	0.088534	0.017965	0.392884
2	0.015502	0.07623	0.015211	0.311279
1	0.012347	0.063936	0.012013	0.229587
Ground Floor	0.008268	0.051606	0.008032	0.147806

- The Base shear in X-direction is equal to 502.4521 kN for the base isolated condition while it is equal to 2567.3641 kN in fixed base condition for building.
- The Base shear in Y-direction is equal to 516.516 kN for the base isolated condition while it is equal to 2519.5431 kN in fixed base condition for building.
- The Base moment in X-direction is equal to 6053.9367 kN for the base isolated condition while it is equal to 34230.652 kN in fixed base condition for building.
- The Base moment in Y-direction is equal to 6636.5074 kN for the base isolated condition while it is equal to 34651.8018 kN in fixed base condition for building.
- The Internal storey drift ratio in X-direction is 1 for the base isolated condition while it is 1 for the fixed-base condition. In Y-direction is 1 for the Base Isolated condition while it is 1.001 for the fixed base condition.

5.4 The Non-Symmetric Building Result

Table 7. Time period for the Non-Symmetric Building

Number	Mode shape	Time period (Sec.) Fixed Base	Time period (Sec.) HDR Isolation Base
1	Mode	0.76	8.534
2	Mode	0.71	3.261
3	Mode	0.687	2.159
4	Mode	0.234	0.904
5	Mode	0.218	0.731
6	Mode	0.212	0.377
7	Mode	0.123	0.142
8	Mode	0.119	0.135
9	Mode	0.113	0.13
10	Mode	0.082	0.093
11	Mode	0.08	0.09
12	Mode	0.078	0.087

Table 8.Base shear, Base moment for the Non-Symmetric Building

	Fixed base	HDR Isolation Base
Base Shear in X Direction (kN)	2291.9391	518.714
Base Shear in Y Direction (kN)	1933.2633	478.4729
Base Moment in X Direction (kN.m)	26293.3362	5334.5476
Base Moment in Y Direction (kN.m)	30934.0034	6896.7976

Table 9. Storey Drifts Ratio of the Non-Symmetric Building

Storey	X Direction - Fixed Base	X Direction - HDR Isolation Base	Y Direction - Fixed Base	Y Direction - HDR Isolation Base
6	1.037	1.012	1.259	1.01
5	1.031	1.013	1.25	1.01
4	1.029	1.014	1.254	1.01
3	1.028	1.014	1.258	1.011
2	1.029	1.015	1.27	1.011
1	1.031	1.014	1.281	1.013
Ground Floor	1.022	1.018	1.219	1.015

Table 10. Displacement for the Non-Symmetric Building

Floor	X Direction Displacement - Fixed Base (m)	X Direction Displacement - HDR Isolation Base (m)	Y Direction Displacement - Fixed Base (m)	Y Direction Displacement - HDR Isolation Base (m)
6	0.023199	0.143664	0.032672	0.619552
5	0.022373	0.127871	0.03115	0.538935
4	0.020889	0.112062	0.028773	0.458169
3	0.018754	0.096275	0.025541	0.377199
2	0.016026	0.080601	0.021539	0.296031
1	0.01273	0.065199	0.016769	0.214671
Ground Floor	0.00847	0.050288	0.010696	0.133217

- The Base shear in X-direction is equal to 518.714 kN for the base isolated condition while it is equal to 2291.9391 kN in fixed base condition for building.
- The Base shear in Y-direction is equal to 478.4729 kN for the base isolated condition while it is equal to 1933.2633 kN in fixed base condition for building.
- The Base moment in X-direction is equal to 5334.5476 kN for the base isolated condition while it is equal to 26293.3362 kN in fixed base condition for building.
- The Base moment in Y-direction is equal to 6896.7976 kN for the base isolated condition while it is equal to 30934.0034 kN in fixed base condition for building.
- The Internal storey drift ratio in X-direction is 1.014 for the base isolated condition while it is 1.028 for the fixed-base condition. In Y-direction is 1.011 for the Base Isolated condition while it is 1.258 for the fixed base condition.

V. CONCLUSION

The results of the study show that the response of the structure can be reduced by using Base isolation.Comparing the results of the base-isolated condition with those obtained from the fixed base condition has shown that the base isolation system reduces the Base shear force, Base moment and Storey drifts.

Comparing the results between fixed base and base isolated building show that in base isolated building increasing the displacement in building so prove that base isolated building is more flexible than fixed base building.So, we should use bracing system, shear wall to reduce the displacement of the building.

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