EFFECT OF THICKNESS OF HIGH DAMPING RUBBER ON THE DESIGN OF BASE ISOLATOR FOR RCC BUILDING

M.Parvez Alam[1], Garima Arora[2], Manisha Bhati[3]

ABSTRACT

As the earthquake effects are very dangerous and hazardous to all types of structures whether it is a residential building, Commercial or any other property along with the life of the people. They all need to be designed safely and according to earthquake resistant criteria so as to counter effects of earthquake vibration produced.

In this paper, the main focus of projection is toward how to reduce the total design displacement in the building structures by using passives types of control system for the building structures. For the same, five different rubber bearing are used to design the base isolator and checked how the design displacement varies accrodingly.

Keywords : Passive Control System, High Damping Rubber, Base Isolator, Design displacement, UBC

INTRODUCTION

Earthquakes are perhaps the most unpredictable and devastating of all natural disasters. They not only cause great destruction in terms of human casualties, but also have tremendous economic impact on the affected locality. The concern about seismic hazards has led to an increasing awareness and demand for structures designed to withstand seismic forces. In such a scenario, lies on the designers, architects, and engineers who conceptualize these structures. Codes and recommendations, postulated by the relevant authorities, study of the behaviour of structures in past earthquakes, and understanding the physics of earthquakes are some of the factors that help in the designing of an earthquake-resistant structure.
The need of control system are hence nowadays more important in the consideration of seismic resistant design of the structure. Base isolation amongst them is widely used and acceptable in almost every country.

Control systems family consists of various types of control systems depending on the basis of their functionality of control system. A large numbers of technique have been tried to produce

IJAER

better control against wind and earthquake excitation. These can be classified into four broad categories: passive control, active control, semi-active control and hybrid control.

In the present study, the design displacement is controlled by various rubber typically HDRB i.e High damping rubber bearing having different thickness and also the frequency also manipulated for the different types of rubbers

SEISMIC BASE ISOLATION

It is an old concept for the same, and has wider applications with advanced technology. It is based on the principle of decoupling the structure or part of it, or even of equipment placed in the structure, from the damaging effects of vibrations caused by seismic forces or ground accelerations. Seismic isolation objectives:

(i) To alter the fundamental frequency
(ii) To control the displacement by addition of adequate amount of damping .

Period shift of structure reduces the acceleration transmitted to the isolated structure. In its effective form the structure approaches near stationary state whereas the supporting ground vibrates under excitation. But increase in time period also increases the displacement. The displacement is controlled by inclusion of damping material in isolators such as lead. The base isolators inserted at founding level or at first floor level filter the horizontal components of the seismic vibrations from soil, which are most dangerous when entering the structure.

TYPE OF BASE ISOLATOR BEARING

Elastomeric (rubber) bearings

Rubber bearings are formed of horizontal layers of natural or synthetic rubber in thin layers bonded between steel plates. The steel plates prevent the rubber layers from blown up or busting. In such mechanism the bearing is capable to support higher vertical loads with only smaller deflection (typically 1 to 3 mm under full gravity load).

HDRB is one type of elastomeric bearing. This type of bearing consist of thin layers of high damping rubber and steel plates built in alternate layers . The vertical stiffness of the bearing is several hundred times the horizontal stiffness due to the presence of internal steel plates. Horizontal stiffness of the bearing is controlled by the low shear modulus of elastomer while steel plates provides high vertical stiffness as well as prevent bulging of rubber. High vertical stiffness of the bearing has no effect on the horizontal stiffness. The damping in the bearing is increased by adding extra-fine carbon block, oils or resins and other proprietary fillers. The dominant features of HDRB system are the parallel action of linear spring and viscous damping.

IJAER

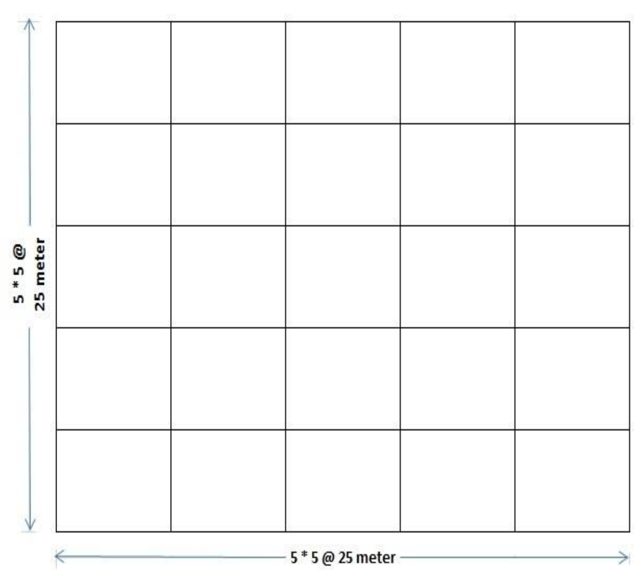
DESCRIPTION

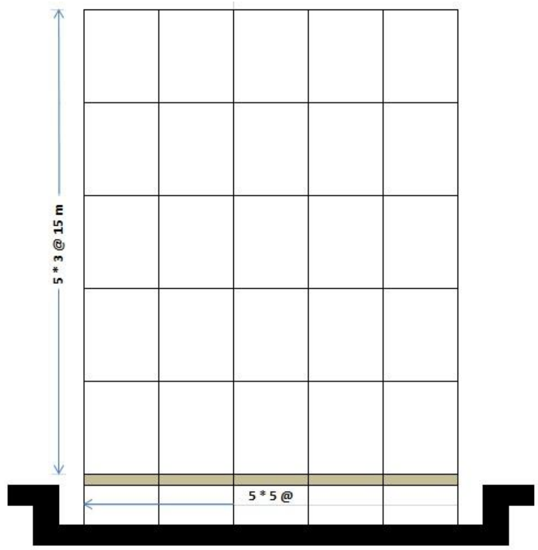
DESCRIPTION OF PROBLEM

The Plan and elevation is shown in figure as below

No. of stories	:	G + 4
Total No. of floors	:	5
Plan Dimensions	:	25 m * 25 m
No. of bays	:	5
Size of bays	:	5 m in each direction
Height of floor	:	3.0 m
No. of Exterior Column	:	20
Size of Exterior Column	:	0.45 m * 0.45 m
No. of Interior Column	:	16
Size of Interior Column	:	0.45 m * 0.45 m
No. of Beams	:	60
Size of Beams	:	0.30 m * 0.55 m
Concrete Mix design	:	M-30
Modulus of Elasticity	:	32000 MPa
Location of Building	:	Delhi
Zone of Location	:	Zone 4
Zone Factor	:	0.4 (Table-16-I UBC97)
Soil Profile Type	:	Rocky
Nearest Fault	:	Shivalik
Nearest distance of fault and location	:	300 Km
Degree of Freedom	:	3

IJAER





DESCRIPTION OF AN ISOLATOR

Type of Isolator : High Damping Rubber Bearing

Diameter of rubber bearing : 0.5 m

Exterior Column Rubber Denoted by : HDR-A

Interior Column Rubber Denoted by : HDR-B

Shear Modulus of Rubber for HDR-A : 0.5 MPa

Shear Modulus of Rubber for HDR-B : 1.0 MPa

Different designing thicknesses of Rubber Bearing

t_{r1} : 0.10 m

t_{r2} : 0.15 m

t_{r3} : 0.20 m

t_{r4} : 0.25 m

Damping ratios of HDR-A, β_D^{HDR-A} : 0.10

Damping ratios of HDR-B, β_D^{HDR-B} : 0.15

DESIGN PROCEDURE OF AN ISOLATOR

In this designing, we have to determine various parameters for rubber following the designing consideration of UBC97. All these parameters are based on the weight of the structure of building.

Following are the designing procedure of an Isolator:

IJAER

Step 1: Calculate the designed weight of structure;
Step 2: Check for magnitude of earthquake which can cause Class A seismic source from Table-16-U of UBC97;
Step 3: Determine Seismic Coefficient (C_{VD}) from Table-16-R of UBC97 depending on seismic Zone factor and Soil Profile Type;
Step 4: Calculate Horizontal Stiffness through formula;

$$K_D = \frac{G.A}{t_r}$$

where, K_D = Horizontal stiffness of an individual rubber isolation bearing,
G = Shear modulus of the Rubber,
A = Cross sectional area of rubber, = [π * D ^{2} / (4)]
t_r = Thickness of rubber.

Step 5: Calculate total effective stiffness of an isolation system;

$$\sum K_D = 20\ K_D^{HDR-A} + 16\ K_D^{HDR-B}$$

Step 6: Calculate Effective Isolation Period;

$$T_D = 2\pi\sqrt{\frac{W}{g.\sum K_D}}$$

where, g = Acceleration due to gravity = 9.81 m/s^2
W = Total weight of structure.

Step 7: Calculate design level damping ratio of the isolation system;

$$\beta_D = \frac{\sum K_D^{HRD-A}\beta_D^{HRD-A} + \sum K_D^{HRD-B}\beta_D^{HRD-B}}{\sum K_D}$$

Step 8: Calculate the design displacement of the isolation system along each main horizontal axis at design basis earthquake (DBE) level is calculated according to the UBC97;

$$D_D = \frac{\left(\frac{g}{4\pi^2}\right)C_{VD}T_D}{\beta_D}$$

Step 9: Calculate total design displacement including additional displacement due to accidental torsion is calculated according to the UBC97 as follows:

IJAER

$$D_{TD} = D_D\left(1 + y\frac{12e}{b^2 + d^2}\right)$$

Step 10: Check whether total design displacement calculated above satisfies the UBC97 minimum criteria; $D_{TD} > 1.10*D_D$. If does not satisfy then redesign isolator for another thickness.

CALCULATION FOR ISOLATORS

CALCULATION OF TOTAL WEIGHT OF STRUCTURE

Specific density of Reinforced Concrete Cement (R.C.C.) = 25 KN/m^2

Weight of Columns (Wc) = 30 * 0.45* 0.45 * (3.0 – 0.25) * 25 = 417.66 KN

Weight of Beams (W_b) = 60 * 0.30 * 0.55 * 5 * 25 = 1237.5 KN

Weight of slabs (Ws) = 5 * 25 * 25 * 0.25 * 25 = 19531.25 KN

Total Weight of building structure (W) = Wc + W_b + Ws

= 417.66 + 1237.5 + 19531.25 = 21186.41 KN

CALCULATION OF SEISMIC FACTORS AND COEFFICIENTS

Seismic coefficient (C_{VD}) = C_V

Cv = 0.4 * N_V

= 0.4 * 1.0 = 0.4

CALCULATION FOR HRD PARAMETRS

Cross sectional area of area, A = [π * (D^2 /4)]

=[π *(0.5^2 /4)]

= 0.19635 m^2

Horizontal stiffness for exterior Columns, k_D^{HDR-A} = [500 * (0.19635 / 0.25)]

= 392.7 KN/m

Horizontal stiffness for interior Columns, k_D^{HDR-B} = [1000 * (0.19635 / 0.25)]

= 785.4 KN/m

Total Effective stiffness of isolation system, $\sum k_D = 20 * k_D^{HDR-A} + 16 * k_D^{HDR-B}$

= 20 * 392.7 + 16 * 785.4

= 20420.4 KN/m

Effective Isolation Period,

$$T_D = 2\pi\sqrt{\frac{W}{g.\sum K_D}} \qquad = 2.04 \text{ s}$$

Damping ratio,

$$\beta_D = \frac{\sum K_D^{HRD-A}\beta_D^{HRD-A} + \sum K_D^{HRD-B}\beta_D^{HRD-B}}{\sum K_D} \qquad = 0.769$$

For this the value of $\beta_D = 0.8$ (From Table A-16-C of UBC97)

Now, Design Displacement of isolation system,

$$D_D = \frac{\left(\frac{g}{4\pi^2}\right)C_{VD}T_D}{\beta_D}$$

= 0.2534 m

Again, total design displacement including additional displacement due to accidental torsion is calculated according to the UBC97 as follows:

$$D_{TD} = D_D\left(1 + y\frac{12e}{b^2 + d^2}\right)$$

y = b /2 = d/2 (shortest of plan dimension)
y = 25 / 2 = 12.5 m

e = *A*ctual eccentricity plus the accidental eccentricity which is taken as 5 percent of the maximum building dimension perpendicular to the direction of force under consideration;

e = 0.05 * 25
= 1.25 m

So, D_{TD} = 0.2914 m

Checking that $D_{TD} > 1.10 * D_D$
Hence checked that 0.2914 > 1.10 * 0.2534
0.2914 > 0.2787

IJAER

Isolator design is correct. Hence it can be used for the structure.

In this way, we have calculated all parameters for the other thicknesses also and calculated there values in a tabulated form.

S. No.	Weight of Structure (W)	Thickness of Rubber (t_r)	Total effective stiffness $\sum K_D$	Effective period T_D (sec)	β_D	D_D(m)	D_{TD} (m)
1	21186.41 KN	0.10 m	511051 KN/m	1.29	0.769	0.1603	0.1843
2	21186.41 KN	0.15 m	34034 KN/m	1.58	0.769	0.1963	0.2257
3	21186.41 KN	0.20 m	25525 5KN/m	1.827	0.769	0.2268	0.261
4	21186.41 KN	0.25m	20420.4 KN/m	2.04	0.769	0.2534	0.2914

CONCLUSION

From the above problem and parameters , we conclude the following points

As the thickness of rubber increases,

i. the total effective stiffness decreases
ii. the total effective period/isolation of the system also increases
iii. the total design displacement increases

Based on the simulations carried out, it is concluded that seismic base isolation is a successful technique that can be used in earthquake-resistant design.

High damping rubber bearings are composed of rubber layers and thin steel sheets. The damping is increased by adding oils, resins, or other fillers and a damping around 10%~15% can be obtained. The stiffness of the bearing is high in case of small displacements and low in case of

IJAER

high displacements. This is very advantageous since large movements are prevented under wind load. On the other hand long periods and therefore isolation under strong ground motion are obtained.

REFERENCES

1. Cenk Alhana And Metin Altun , (2009). PERFORMANCE OF NON-LINEAR BASE ISOLATION SYSTEMS DESIGNED ACCORDING TO UNIFORM BUILDING CODE, *5th International Advanced Technologies Symposium (IATS'09), May 13-15, 2009, Karabuk, Turkey*

2.Kelly, J.M. (1997). *Earthquake Design With Rubber*, Springer-Verlag, Inc.

2.Kelly, J.M. (1999). The Role Of Damping In Seismic Isolation, *Earthquake Engineering And Structural Dynamics*, 28, Pp. 3-20.

3.Kelly, J.M. (1999). The Current State Of Base Isolation In United States, *Proceedings Of The 2nd World Conference On Structural Control*, Kyoto, Japan, 1, 1043-1052

4.Kelly, J.M. (2004), Chapter 11, *Seismic Isolation, In Earthquake Engineering*, Borzognia & Bertero (Eds), CRC Press LLC.

5.UBC97 Is Strictly Followed.

IJAER