Static Analysis of Asymmetric Reinforced Concrete Structure with Lead Rubber Bearing

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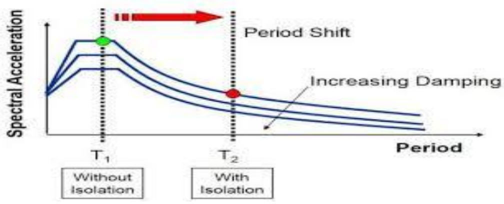
Abstract: *In the present work, "static analysis of asymmetric reinforced concrete structure with lead rubber bearing". The configuration of buildings are G+4 and G+9 with storey height is 3m taken. static analysis and lateral load for response spectrum analysis is done as per UBC 1997 and the modelling approach includes the development of model, used ETABs 2016 and compile all the result in the term of of displacements, height, drift, shear and plot the graphs between storey displacement vs storey height, storey drift vs storey height, storey shear vs storey height and observed that use of LRB isolation system average drift for 5 storey structure reduces to almost 53% while in case of 10 storey structure it reduces to 26% only w.r.t. fixed base structure. Average percentage reduction in storey shear of LRB building w.r.t. fixed base building is 48.765% and 70.37% in 5 and 10 storey building respectively.*

KEYWORD:- Seismic Zones, Base Isolation, Lead Rubber Bearing, Static Analysis, Etabs Software.

I-Introduction

Base Isolation

In seismic zones and high risk areas for constructing bridges, flyovers and buildings Base isolation is being commonly used in the past few years. There are many projects made and many are under construction in which base isolation is applied. At the time of earthquake the movement of the ground occurs laterally and disrupt the structure. So there is a need to bifurcate the structure from the ground by inserting flexible isolation system between the structure and the foundation and therefore the after effects and shocks of the earthquake will be minimised by doing this. Thus the stability of the structure remains for longer period because of low seismic energy is transmitted in the structure. The prime factors which are being used in maintaining the flexibility of structure are Rubber bearing and Lead Rubber. These helps in increasing the usual period of the structure as a whole and base displacement is greater than the prearranged limit. The time period shift is shown in the Fig

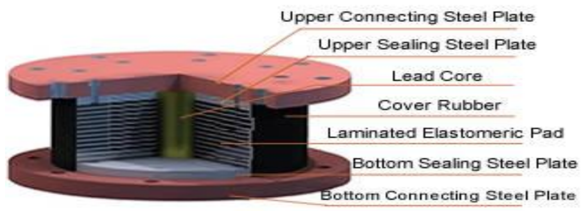


Effect of base isolation on spectral acceleration

Lead Rubber Bearing (LRB)

New Zealand was the first country to use Lead Rubber Bearing in year 1975 afterwards it was used in New Zealand, Japan and United States at a large scale. To support the structure and provide ground flexibility to the structure one or more lead plugs are installed in the bearing.

With the lead core with diameter ranging from 15% to 33% of bonded diameter and low damping elastomers the LRB is constructed as shown in fig.



Lead Rubber Bearing (LRB)

II-Literature Review

Avinash A.R, Rahul N.K, Kiran Kamath studied the impact of height changing of a base isolated structure on torsional response has been explore. For the analysis of structure are base isolated by lead rubber bearing (LRB). The elevation of the structure is changed trumphant and subjected to two direction seismic excitation. The maximum diminishion in torsional movement by LRB isolator is 92.315% for twelve story building for Chi-Chi earthquake. It is 91.625% for twelve story building in Kobe and 73.091% for eleven story building in El-Centro seismic.

Sonali Anilduke1, Amay Khedikar2. Studied that All over chronical time seismic are one of the natural threat that obtain due to instant vicious vibration of earth's surface which causes destroyed to field, mainly to man-made building . Base isolation is one of the most equipment of seismic engineering pertaining to the passive structural movement restrict technologies. . This paper recent three dimensional nonlinear time history analysis is presentation on r/c structure the use of computer program SAP 2000 v12.0.0. The dynamic study of the building has been used and the presentation of the structure with and without isolator is analysis.

Shirol and Kori(2017), contemplate a G6 storey dummy with and without masonary infill. Lead rubber bearing and abrasion type isolators were used. The infill was modelled as single bevelled swagger. The static and response spectrum analysis are implement using ETABS-2016. From the analysis it was culminate that equipping of isolators escalate the natural time period which abolish the prospect of sonority. The base shear and the storey drifts got diminished noteworthy while the deracination escalate which is due to the pliability transmitted to the buildings. The deliberation of infill operation escalate the base shear while the deracination and inter storey drifts showed diminished bias. The base shear diminished by 50% for bare fixture dummy and 70% for models with masonry infill in static method. The base shear diminished by 46 % and 42% in bare fixture and by 71% and 65% for infill buildings for rubber isolator and abrasion isolator discretely by response spectrum method. The escalate in deracination at foundation is 19.38 mm and 14.48mm for LRB and FPS isolator for response.

Rastandi J. I. et al (2018), Initiate the disparity of length of wings in L-shaped structure. Lead rubber bearing (LRB) with damping ratio 27% was preowned for base isolation. Six dummy were provinced as office sticture in 6-story high; three fixed foundation dummy are designed with twofold procedure and another three isolated dummy were delineation using linear dissemination horizontal forces pursuant to ASCE 7-16 code. 3D nonlinear time history analysis for isolated dummy is execute and will presume seven couples of ground movement, which are contest to MCER ambition variety of Jakarta in soft soil circumstances. Finally it was initiate that the non-linear dynamic major reaction of isolated buildings may impart superior and flowless outcome. In inclusion, evaluate cost for design phase of pre-framework can be done by the computaion of rebar ratio and comparable thickness of concrete, known from the outcomes of this analysis. The base shear deliberate from the NLTHA is harmonious lofty than RSA on fastened foundation. The distinction of both utility is 34.23%% for L1 dummy; 33.31% for L2 dummy; and 36.75% for L3 dummy. The isolated buildings offer the miniature drift story rate of not more than 0.2% for each story, elude any destruction to non-structural component interior the structure. It can be culminates that foundation isolation can guide to the retrenchment attempt i.e. rebar by 7-15% and concrete by 3%.

III-METHODOLOGY& MODELLING APPROACH

Methodology

In this attempt, following major cases will be analysed:

1. An extensive survey of the literature on the response of base isolation to seismic loading is performed.
2. Provisions related to seismic analysis of base isolationare presented.
3. Modelling of different height of structures, which is five and ten.
4. To carry out the study on static analysis for different models of specified cases.
5. To plot the graphs between Storey Displacement vs. Storey height, storey Drift vs. Storey height, Base shear compare results for variations

Modelling Approach

The modelling approach includes the development of model, using ETABs 2016; static as well as dynamic analysis has been carried out.

3.3 Analysis Procedure

3.3.1 Equivalent Static Analysis

The effect of earthquake ground motion is defined in equivalent static analysis methods by series of forces acting on a structure. On the basis of mass and stiffness the computed base shear is distrusted along the floors of building. Depending upon the floor diaphragm action the obtained lateral force at each floor are being disturbed to lateral load resisting elements.

3.3.2 Response-spectrum analysis (RSA)

In any elastic structure to indicate maximum seismic response for the contribution of each natural mode of vibration linear dynamic statistical analysis method is adopt..

For any given time history and level by measuring pseudo-spectral acceleration, velocity or displacement, intuition of dynamic behaviour can be done by response spectrum analysis. For the selection of structural design on the basis of its response to dynamic performance response spectrum analysis is quiet useful. Structures with higher time period experience more displacement while the one with shorter time period experience more acceleration.

3.1 LRB Design

3.1.1 Lateral Load for Response Spectrum Analysis (according to UBC 1997)

Table 3.3.1 Input Data for LRB design

1	Seismic zone factor, Z	0.3	(UBC 97, Vol-2, Table 16-I & Zone Map)
2	Seismic Source Type	B	
3	Near source factor, N_a	1	(UBC 97, Vol-2, Table 16-S)
4	Near source factor, N_V	1	(UBC 97, Vol-2, Table 16-T)
5	ZN_v	0.3	
6	Maximum capable earthquake response coefficient, M_m	1.5	(UBC 97, Vol-2, Table A-16-D)
7	Soil Profile Type	S_D	(UBC 97, Vol-2, Table 16-J)
8	Seismic coefficient, $C_V = C_{VD}$	0.54	(UBC 97, Vol-2, Table 16-R)
9	Seismic coefficient, C_a	0.36	(UBC 97, Vol-2, Table 16-Q)
10	Choose Response Reduction Factor, R for SMRF	8.5	(UBC 97, Vol-2, Table 16-N)
11	For SMRF/IMRF/OMRF, Structural System Above the Isolation Interface, R_I	2	(UBC 97, Vol-2, Table A-16-E)
12	Effective Damping (β_d or β_m)	0.20	20% Damping []
13	Damping coefficient, B_d or B_m	1	Interpolate (UBC 97, Vol-2, Table A-16-C)

DESIGN OF BASE ISOLATOR

1 Maximum Vertical Load Column Support, W is Taken as vertical load of Column

1 Time Period = 2.5 [10]
2 Shear Modulus G = 0.7

3 Design Displacement D_D

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

4 Bearing Effective Stiffness , K_{eff}

$$K_{eff} = \frac{w}{g} * (\frac{2\pi}{T_D})^2$$

5 Force at design displacement or characteristic strength (Q)

$$Q = \frac{W_D}{4D_D}$$

6 Energy dissipated per cycle, W_D

$$W_D = 2\pi K_{eff} {D_D}^2 \beta_{eff}$$

7 Stiffness Of Rubber K_2

$$K_2 = K_{eff} - \frac{Q}{D_D}$$

Where, $\frac{Q}{D_D}$ = Stiffness of lead Core

8 Yield Displacement D_y (Distance From J End)

$$D_y = \frac{Q}{K_1 - K_2}$$

We Know that $K_1 = 10K_2$

9 Recalculation Of Q to Q_R

$$Q_R = \frac{W_D}{4 * (D_D - D_Y)}$$

10 Calculation Of Area and Diameter Of lead plug

Yield Strength of Lead Varies Between 10 – 18 Mpa

So, we will Take it as F_{pb} = 10Mpa

Area of Lead Plug

$$A_{pb} = \frac{Q_R}{F_{pb} * 10^3}$$

Diameter of Lead Plug

$$D_{pb} = \sqrt{A_{pb}\frac{4}{\pi}}$$

11 Recalculation of Rubber stiffness K_{eff} to $K_{eff(R)}$

$$K_{eff(R)} = K_{eff} - \frac{Q_R}{D_D}$$

12 Total Thickness of rubber Layer, t_r

$$t_r = \frac{D_D}{\Upsilon}$$

Where, Υ = 100% (maximum shear strain of rubber)

13 Calculation Of Area And Diameter Of Bearing

Area of Bearing

$$A_{LRB} = \frac{K_{eff(R)} * t_r}{G}$$

Diameter of Bearing

$$D_{LRB} = \sqrt{A_{LRB} * \frac{4}{\pi}}$$

14 So, Shape Factor, S

$$S = \frac{1}{2.4} * \frac{f_v}{f_h}$$

Where,

f_v = Vertical Frequency

f_h = Horizontal Frequency

$f_h = \frac{1}{2} = 0.5$ Hz

Consider, $f_v = 10$ Hz

Also,

$$S = \frac{D_{LRB}}{4t}$$

Where, t = Single layer Thickness

$$t = \frac{D_{LRB}}{4S}$$

So number of Rubber Layers, N

$$N = \frac{t_r}{t}$$

15 Dimensions of LRB

Let us Assume thickness of shim plates be,

t_s3.1mm

Number of shim plates = N-1

End Plate Thickness is between 19mm to 38 mm,

Assume, 30mm

So Total Height of LRB, h

h = (N*t_r) + ((N-1)*t_s) + 30 mm

Let us Assume Cover be, 30 mm

So, Bonded Diameter

$$B = D_{LRB} - 2(30) \text{ mm}$$

16 Compression Modulus, E_c

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

Where, K = Bulk Modulus (2000 Mpa)

17 Horizontal Stiffness K_H

$$K_H = \frac{GA_{LRB}}{t_r}$$

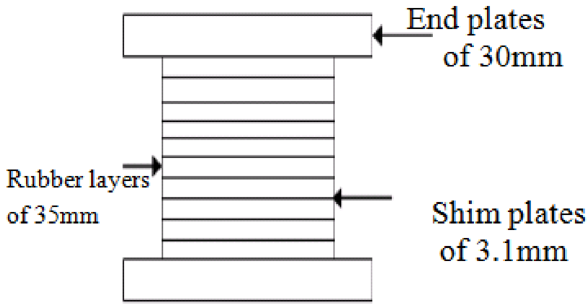
18 Vertical Stiffness, K_V

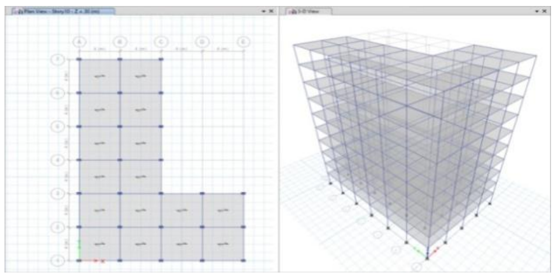
$$K_V = \frac{E_C A_{LRB}}{t_r}$$

19 Moment Of Inertia, I Since Circular LBR $I = \frac{\pi}{64} B^4$

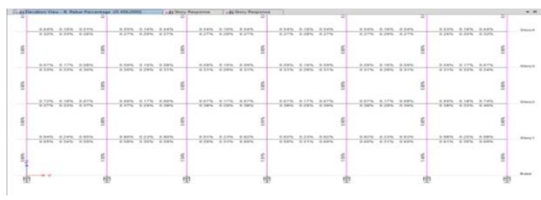
20 Yield Strength, F_y

$$F_y = Q + K_2 * D_y$$





Bare frame model



Percentage of Steel in Isolated Structure

Details of 5-storey building

Rotational Inertia	0.0002595	KN/m
For U1 Eff. Stiff.	503037.9433	KN/m
For U2 & U3 Eff. Stiff.	503.035	KN-m
For U2 & U3 Eff. Damping	0.20	
For U2 & U3 Distance from End-J	0.00490	M
For U2 & U3 Stiffness	3845.12421	KN/m
For U2 & U3 Yield Strength	18.84955567	KN

Members	**Size of Member (in mm)**
Column (M 25)	350X350
Beam (M25)	300X350

Details of 10-storey building

The configuration of building is G+9. Storey height provided is 3m. Thickness of slab is 150mm. Live load is 4KN/m^2.Grade of reinforcement used was Fe415.

Members	**Size of Member (in mm)**
Column (M 25)	400X400
Beam (M25)	300X350

Rotational Inertia	0.00186346	KN/m
For U1 Eff. Stiff.	1207291.08	KN/m
For U2 & U3 Eff. Stiff.	1207.288	KN-m
For U2 & U3 Eff. Damping	0.20	
For U2 & U3 Distance from End-J	0.00490	M
For U2 & U3 Stiffness	9228.297	KN/m
For U2 & U3 Yield Strength	45.2389318	KN

4.0 RESULTS AND DISCUSSION

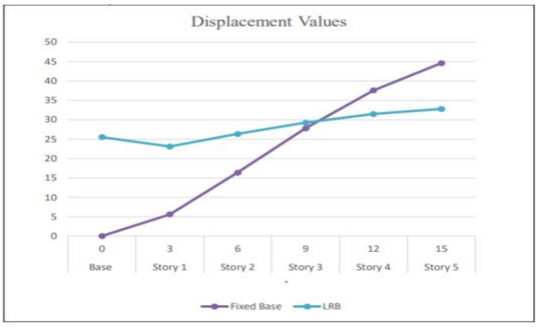
The results were inferred according to the values obtained by the static analysis carried out on 5 and 10 storey. The graphs of the parameters are shown in this chapter along with the discussion.

Following are the cases on which study has been carried out:

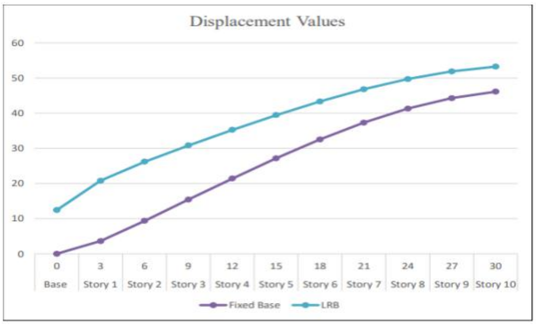
Case 1: Frame with Fixed Base

Case 2: Frame with LRB Base.

Plots: Displacement v/s Storey Height

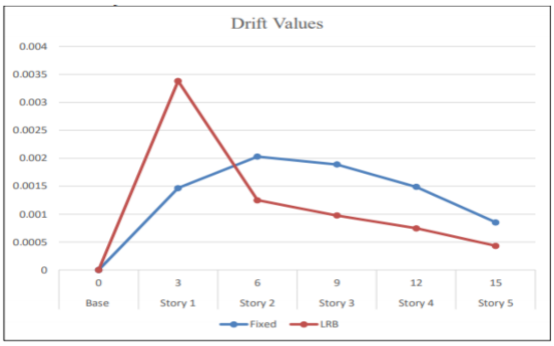


5 STOREY: STATIC ANALYSIS

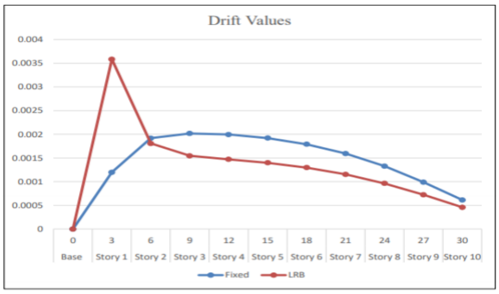


10 STOREY : STATIC ANALYSIS

Plots: Drift v/s Storey Height



5 STOREY: STATIC ANALYSIS



10 STOREY: STATIC ANALYSIS

DISCUSSION

Within the scope of present work, following conclusions are drawn form results:

1. The average maximum displacement for static analysis of 5 storey building in X-direction the cumulative displacement of LRBis 22.68% of fixed base building. Whereas in 10 storey structure up to 5 storey the displacement of fixed base building is approximately similar to cumulative displacement of LRB base and with the storey height displacement changes such as at the top cumulative displacement of LRB is 86.7% of fixed base building.

2. The above points conclude that use of LRB isolation system in low storey structure is more suitable than high rise structure.

3. The maximum drift reduction with LRB system in 5 storey structure for top stories (60% of stories) are 50.89%, 49.8% and 50.4% in static analysis.

4. The maximum drift reduction with LRB system in 10 storey structure for top stories (40% of stories) are 72.41%, 72.52%, 73.24% and 74.91% in static .

5. Average percentage reduction in storey shear of LRB building w.r.t. fixed base building is 48.765% and 70.37% in 5 and 10 storey building respectively.

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