

A Comparative Study on RC Frame Structure Considering Lead Rubber Bearing and Triple Friction Pendulum Bearing

Dr. H.M.Somasekharaiah¹, Er. Dharmesh. N², Mohammed Ghouse³

Professor, Department of Civil Engineering, R.Y.M. Engineering College, Ballari, Karnataka, India¹

Assistant Professor, Department of Civil Engineering, EPCET, Bengaluru, Karnataka, India²

P.G. Student, Department of structural Engineering, R.Y.M. Engineering College, Ballari, Karnataka, India³

ABSTRACT: Base isolation is one of the most widely accepted seismic protection system used in building in Earthquake prone areas. The base isolation system separates the structures from its foundation and primarily moves it relative to that of the super structure.

The purpose of this paper is to offer a relative understanding of the seismic performance enhancement that, a typical G+10, and G+ 20 storey's plan symmetrical RC building are considered 5 bays by 4 bays of dimension 30mx25m, has been taken for seismic analysis. Dynamic linear response spectrum analysis and Dynamic linear time history analysis are performed on both of fixed base and base isolator's buildings. Further a comparative study of performance of base isolated structure has been carried out by response spectrum analysis as per IS 1893 (Part 1):2002 of (zone-5) and soils condition II (medium soil). Also time history analysis has been carried out as per BHUJ earthquake data. Finally base shear, displacement, are compared from response spectrum and time history analysis between fixed base and base isolated condition, using ETABS.

KEYWORDS: Fixed base, lead rubber bearing, triple friction pendulum, response spectrum, time history, base shear, storey displacement, E TABS.

I. INTRODUCTION

Introduction: The Origin of an earthquake taken place below the ground Surface there the Rocks are suddenly disturbed, a large energy is released and that energy travels in the form of vibrations spread out in all direction from the source of the disturbance. During this earthquake, the seismic waves radiate from earthquake source somewhere below in the ground this is because of opposite sides of a slipping of fault rebound direction. A seismic wave is a means transfer of seismic energy from source to the other spots within the earth. In India they are large number of earthquake, most of them being in the North-East region due to their adverse seism-tectonic setup. The major earthquake was the Bhuj earthquake with 7.7 magnitudes on Richter scale in 2001 occurred in the India. The seismic analysis and design of buildings has traditionally focused on reducing the risk factor of life in the largest expected earthquake. In order to resist the structural from earthquake are as follows. The adjacent building is often building right up to property lines in order to make maximums using of space. Buildings have been built as if the adjacent structures do not existing.

A lateral load resisting structural can ensure inelastic by having larger ductility and damping. The lateral strength and lateral stiffness are the major requirements of seismic resistance. It's very much essential that all the lateral load-resisting structural components need to be rigidly connected. Following are the lateral load resistance structural system in practice: (1) Masonry Infill (2) Shear wall (3) Braced frame (4) Base-isolation.

Objectives: 3D building models consisting of dynamic methods have been analysed. To find the time period, displacement, base shear, for the G+10 and G+ 20 storeys RC framed structure with fixed base, leads rubber bearing and triple friction pendulum bearing. Determine the structure in both cases Response spectrum and Time history

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

methods. Compare the performance study on fixed base element with LRB and TFPB element for zone V & medium soil condition for Response spectrum analysis and Bhuj Earthquake data for Time history analysis.

Methodology: Literatures of review existing by different researchers. The response spectrum and time history analysis are carried out to get displacement, and base shear.

II. METHOD OF ANALYSIS

Table 1. Material properties.

Element	Parameters	Characteristics
Grade of concrete	M25 For Slab, Beam And Column	$f_{ck} = 25 \text{ N/mm}^2$
Modulus of Elasticity of concrete	$5000\sqrt{f_{ck}}$	$25.00 \times 10^3 \text{ N/mm}^2$
Grade of Steel	Fe415	415 N/mm^2

Note: - Live load @ roof 1.5 kN/m^2 , @ reaming floors 3 kN/m^2 , and floor finish 1.5 kN/m^2 for all floor, dead load of a structural element taken by ETABS.

Section properties.

- Special moment-resisting frame (SMRF).
- Building has different spans in both x and y – directions as shown in Fig 1 for both G+10 & G+20.
- The height of each storey is typical - 3.1m.
- Typical slab thickness as 100mm.

Case (a) G+10

- Column size
 - Bottom 5 Story – 250x750mm
 - Remaining 6 Story – 230x500mm
- Beam size as 230 x 400mm.

Case (b) G+20

- Column size
 - Bottom 7 Story – 300x1000mm
 - From 8 to 14 Story – 250x800mm
 - Remaining 7 Story – 250x500mm
- Beam size
 - Bottom 11 Story - 230 x 400mm.
 - Remaining 10 Story- 300 x 500mm.

Note: - Section properties are taken based on design code (IS 456 & IS 800-2007)

Case (a) G+10

- Model-1: RC frame building with fixed base.
- Model-2: RC frame building with Lead Rubber Bearing (LRB).
- Model-3: RC frame building with Triple Friction Pendulum Bearing (TFPB).

Case (b) G+20

- Model-4: RC frame building with fixed base.
- Model-5: RC frame building with Lead Rubber Bearing (LRB).
- Model-6: RC frame building with Triple Friction Pendulum Bearing (TFPB).

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

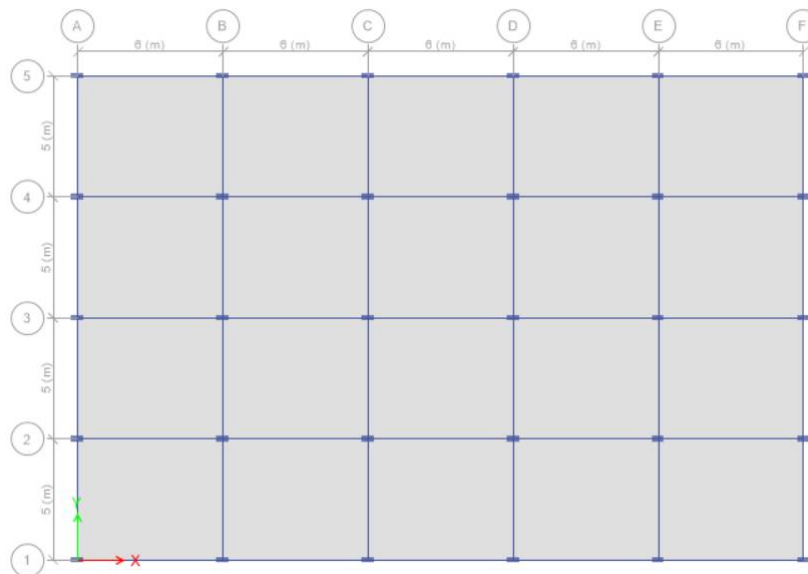


Figure 1: Typical G+10 & G+ 20 structures plan which is to be design for base shear by Etabs in fixed and isolation condition.

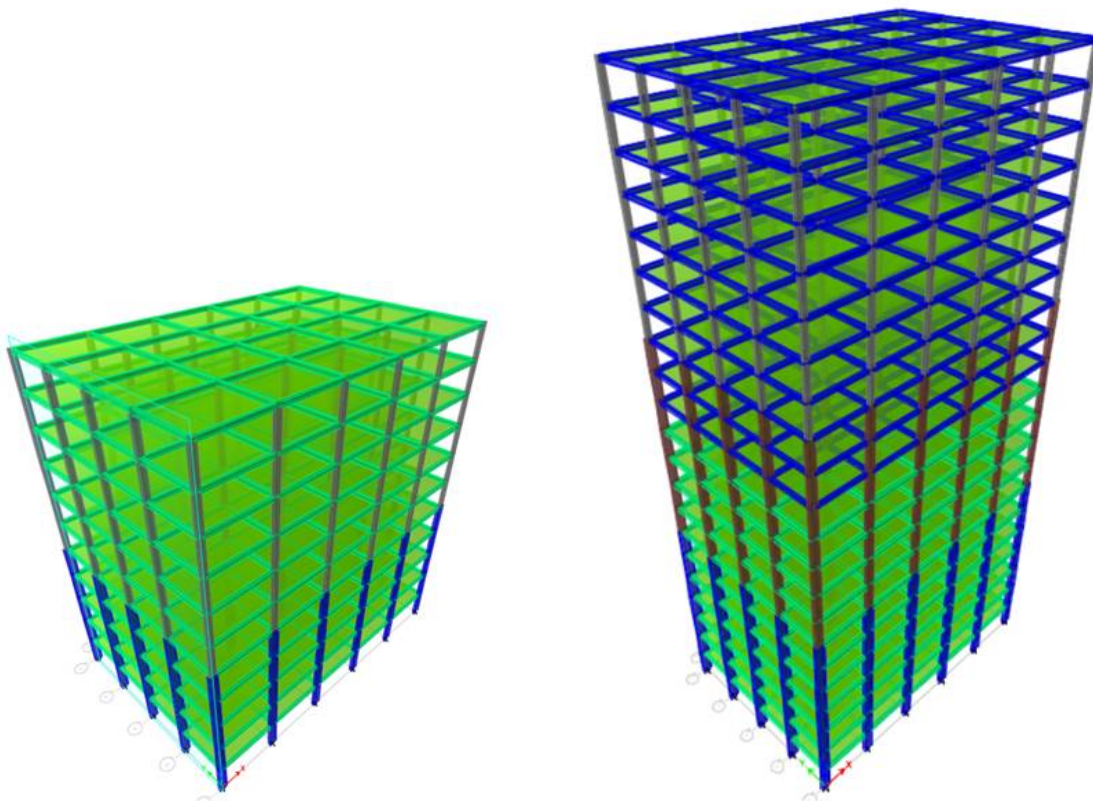


Figure 2: G+10 & G+ 20 3D RC frame structures which are to be design for base shear by Etabs in fixed and isolation condition.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

(A) Lead Rubber Bearing

$$\begin{aligned}
 \text{Axial Load } P_{DL+LL+EQ} &= W &= & 1300 \text{ kN.} \\
 \text{Time Period } (T_D) & &= & 2.5 \text{ sec.} \\
 \text{Design Shear Strain } (\gamma_{max}) &= 50\% &= & 0.5 \text{ kN/m}^2. \\
 \text{Effective Damping } (\xi_{eff}) &= 10\% &= & 0.1 \text{ For } U_1, U_2, U_3.
 \end{aligned}$$

**TABLE 1623.2.2.1
DAMPING COEFFICIENT, B_D or B_M**

EFFECTIVE DAMPING, β_D OR β_M (PERCENTAGE OF CRITICAL)	B_D OR B_M FACTOR
$\leq 2\%$	0.8
5%	1.0
10%	1.2
20%	1.5
30%	1.7
40%	1.9
$\geq 50\%$	2.0

From the Above Table 1623.2.2.1. of IBC32000, the Damping Coefficient B_D can be taken

$$\begin{aligned}
 \text{Damping Coefficient } (B_D) &= 1.2 && \text{Refer Table 1623.2.2.1, IBC 2000, Page No. 410} \\
 \text{Seismic Coefficient } (S_D) &= 0.4 && \text{Refer Table 1615.1.2(2), IBC 2000, Page No. 367}
 \end{aligned}$$

Hardness IRHD ± 2	Young's Modulus E (MPa)	Shear Modulus G (MPa)	Material Constant k	Elongation at Break Min, %
37	1.35	0.40	0.87	650
40	1.50	0.45	0.85	600
45	1.80	0.54	0.80	600
50	2.20	0.64	0.73	500
55	3.25	0.81	0.64	500
60	4.45	1.06	0.57	400

Table 5.4: Vulcanized Natural Rubber Compounds

Above Table Relation of rubber Hardness and Material constants, Selecting 60 to analysis in critical conditions
(Robinson Page No. 139)

$$\begin{aligned}
 \text{Young's Modulus (E)} &= 4.45 \text{ Mpa} &= & 4450 \text{ kN/m}^2. \\
 \text{Modification factor (k)} &= 0.57 \\
 \text{Shear modulu (G)} &= 1.06 \text{ Mpa} &= & 1060 \text{ kN/m}^2. \\
 \text{Elongation of rubber at break } (\epsilon_b) &= 4 &= & 400\% \\
 \text{Allowable normal stress} &= 7840 \text{ kN/m}^2. && \text{Refer the Hand Book Page No. 835} \\
 \text{Yield strength of core } (f_{py}) &= 8500 \text{ kN/m}^2. \\
 \text{Consult manufacture, usually 7 to 8.5 Mpa} &&& \text{Page No.132, Table 5.7} \\
 \text{Yield strength of steel plate } (f_y) &= 274400 \text{ kN/m}^2. \\
 \text{Shear Yield strength of steel (Fs)} &= 164640 \text{ kN/m}^2.
 \end{aligned}$$

A) Analysis

1) The effective Horizontal stiffness of the isolator K_{effH} is

$$K_{effH} = \frac{W}{g} \left(\frac{2\pi}{T_D} \right)^2 \quad K_{effH} = 837.055 \text{ kN/m} \quad U_2 \text{ \& } U_3 \text{ Linear effective stiffness}$$

2) Lateral displacement or Design displacement (D_D) 3) The Short term yield force or strength Q_d is

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

$$D_D = \left(\frac{g}{4\pi^2}\right) \times \frac{S_D T_D}{B_D} = \mathbf{0.20708 \text{ m}}$$

$$Q_d = \frac{W_D}{4 \times D_D} = \frac{\pi}{4} \times K_{effH} \times \xi_{eff} \times D_D = \mathbf{27.22714 \text{ kN}}$$

4) The Post-yield horizontal stiffness K_d is

K_U = Pre yield stiffness, K_d = Post yield stiffness,

Therefore $K_U = 10 K_d$

Note- The initial elastic stiffness has been estimated from experiments results in the range of 9 to 16 K_d So,

$$K_d = K_{effH} - \frac{Q_d}{D_D} = \mathbf{705.571 \text{ kN/m}}$$

5) Post yield stiffness ratio.

$$K_U = 10 K_d$$

$$\frac{K_d}{K_U} = \frac{705.57}{7055.708} = \mathbf{0.1} \text{ } U_2 \text{ \& } U_3 \text{ Post yield stiffness ratio.}$$

B) DESIGN

1) Lead Core Area A_p

$$A_p = \frac{Q_d}{f_{py}} = \mathbf{0.003203 \text{ m}^2}$$

2) Dia of lead core d_p

$$A_p = \frac{\pi d^2}{4} = d_p = \sqrt{\frac{4 A_p}{\pi}} = \mathbf{0.063863 \text{ m}}$$

3) Total height of rubber layer t_r

$$t_r = \frac{D_D}{\gamma_{max}} = \mathbf{0.41415 \text{ m}}$$

4) The Shape factor S

$$\frac{E(1+2kS^2)}{G} \geq 400, \mathbf{S = 90.0941}, \text{ For } S > 10, \quad 9-10 \text{ is qdequate(Naeim \& kelly 200)}$$

5) Compressive modulus of rubber & steel (E_c)

$$E_c = E(1+2kS^2) = \mathbf{511750 \text{ kN/m}^2}$$

6) Effective area of bearing A_o

$$A_o = W / \text{Allowable normal stress} = \mathbf{0.165816 \text{ m}^2}$$

7) Effective area from the shear strain A_1

$$\frac{6SW}{E_c \times A_1} \leq \frac{\epsilon_b}{3} = \mathbf{0.11431 \text{ m}^2}$$

8) Elastic Stiffness K_r of the bearing

$$K_d = K_r \times \frac{1+12 \times A_p}{A_o} = \mathbf{572.7907 \text{ kN/m}}$$

9) Effective area of individual rubber layer (A_{sf})

$$A_{sf} = \frac{\pi d^2}{4} = \mathbf{0.2237 \text{ m}^2}$$

10) Diameter of Rubber (d)

$$d = \sqrt{\frac{4 A_{sf}}{\pi}} = \mathbf{0.533801 \text{ m}}$$

11) Effective vertical stiffness (k_v)

$$K_v = \frac{E_c \times A_{sf}}{t_r} \quad \mathbf{K_v = 276533.6 \text{ kN/m}} \quad U_1 \text{ Vertical } K_v \text{ Linear effective stiffness.}$$

12) Damping reduction factor (β)

$$\beta = 2 \cos^{-1} \times \left(\frac{D_D}{d}\right) = \mathbf{2.34483}$$

13) Reduced area (A_2)

$$A_2 = \frac{d^2 \times (\beta - \sin \beta)}{4} = \mathbf{0.116096 \text{ m}^2}$$

14) Details of Lead Rubber Bearing

$$\mathbf{A = 0.16582 \text{ m}^2} \text{ (max Area of } A_o, A_1, \text{ \& } A_2), \quad \mathbf{d = 0.459482 \text{ m}} \text{ (dia for above area)}$$

$$\text{No. of layer (N)} = \frac{tr}{t} \quad \mathbf{N = 36.054} \quad \text{say } \mathbf{37.00}$$

Steel Plate thickness (ts)

$$ts = \frac{2 \times W \times 2t}{A \times Fs} \quad \mathbf{ts = 0.002188} \quad \geq \quad \mathbf{0.002 \text{ m}}$$

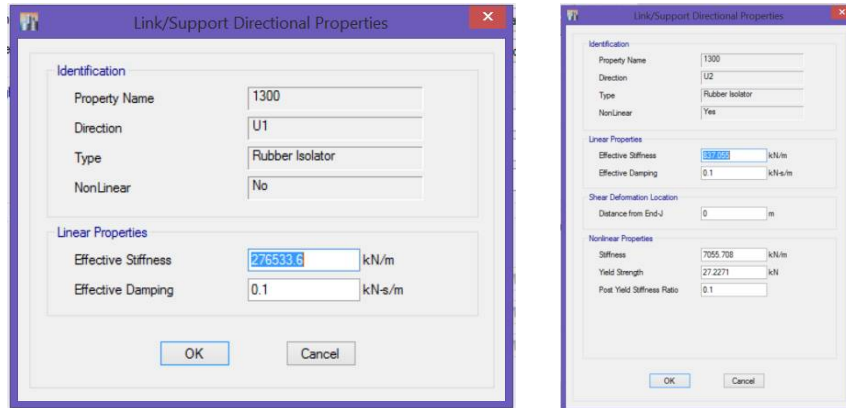
Total height of bearing (h)

$$h = tr + N \times (ts + 2 \times 0.0025) \quad \mathbf{h = 0.543036 \text{ m}}$$

Etabs Input Values

Nonlinear Link Type: Rubber isolator

Directional Properties ($U_1, U_2, \text{ \& } U_3$):



(B) Triple Friction Pendulum Bearing

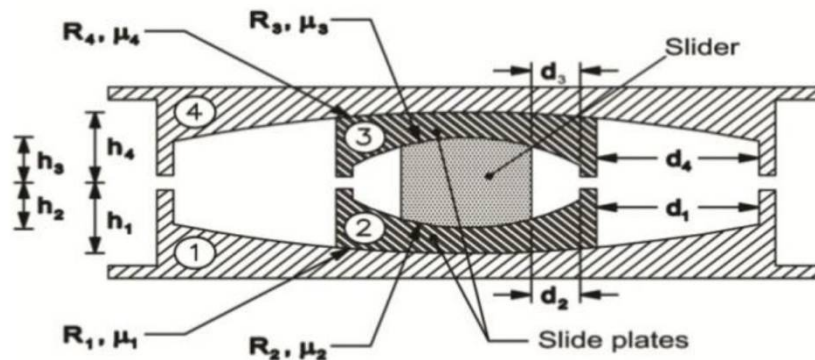


Figure 3: Triple Friction Pendulum Bearing Details.

A) Calculation of geometric, frictional and D_D

(a) Geometric Properties

R_1	=	R_4	=	1778 x 2 =	3556 mm	or	3.556 mtrs.
R_2	=	R_3	=	647 mm	0.647 mtrs.		
h_1	=	h_4	=	161 mm	0.161 mtrs		
h_2	=	h_3	=	121 mm	0.121 mtrs		
d_1	=	566.02 mm		d_2	=	81.05 mm	
$R_{1\text{ eff4}}$	=	$R_{4\text{ eff4}}$	=	R_1	-	h_1	= 3556 - 161 = 3395 mm.
$R_{2\text{ eff4}}$	=	$R_{3\text{ eff4}}$	=	R_2	-	h_2	= 647 - 121 = 526 mm.
$d_1^* = d_4^*$	=	$\frac{d_1 \times R_{1\text{ eff4}}}{R_1}$	=	540.39mm	≈	540.40mm.	
$d_2^* = d_3^*$	=	$\frac{d_2 \times R_{2\text{ eff4}}}{R_2}$	=	65.89mm	≈	65.90 mm.	

(b) Calculating frictional properties of the bearing

Bearing pressure at surfaces 1 and 4

$P = \frac{\text{Load}}{\text{Area}}$ Here V_k Load = 400 ton or 4000 kN,
 $A = \pi \times r^2$ $r = h_1 + h_4 = 161 + 161$ $P = 7.675E-04 \text{ ton/mm}^2$, $r = 322 \text{ mm}$
 $P = 0.0007 \times 1450 = 1.11 \text{ ksi}$. 1 ksi = Kilo square inch = 1450 ton/mm².

3- Cycle friction, $\mu = 0.122 - 0.01 P$, $\mu = 0.111$

Adjust for high velocity = -0.033 = 0.110 - 0.033 = 0.078 (Lower bound friction)

I - cycle friction $\mu = 0.12 \times 0.077 = 0.09344$ Say 0.093

Lower bound $\mu_1 = \mu_4 = 0.078$

Upper bound $\mu_1 = \mu_4 = 0.093$

Bearing pressure at surfaces 2 and 3

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

$P = \text{Load} / \text{Area}$ Here $V_k \text{ Load} = 400 \text{ ton or } 4000 \text{ kN}$,
 $\text{Area } A = \pi \times r^2$ $r = h_2 + h_3 = 121+121$, $P = 1.970 \text{ ksi.}$ $1 \text{ ksi} = 1450 \text{ ton/mm}^2$.
 3- Cycle friction, $\mu = 0.122 - 0.01 P$ $\mu = 0.102$
 Adjust for high velocity $= -0.036 = 0.102 - 0.036 = 0.066$ (Lower bound friction)
 I - cycle friction $\mu = 0.12 \times 0.066 = 0.0796$ Say 0.080
 Lower bound $\mu_1 = \mu_4 = 0.066$
 Upper bound $\mu_1 = \mu_4 = 0.080$
 $\mu = \text{force at zero displacement divided by the normal load}$

For Lower bound,

$$\mu = \mu_1 - (\mu_1 - \mu_2) \times \frac{R_{2eff}}{R_{1eff}} \quad \mu = 0.076$$

For Upper bound

$$\mu = \mu_1 - (\mu_1 - \mu_2) \times \frac{R_{2eff}}{R_{1eff}} \quad \mu = 0.091$$

(c) Calculating D_D (Upper bound Analysis)

$S_d = 0.5074$	$\mu = 0.091$
$\mu_1 = 0.093$	$D_y = 0.00731$
$F_d = 0.277243$	$W = 400 \text{ kN}$

No. of Bearing = 12

$\Sigma F_d = F_d \times W \times \text{Total Bearing} = 0.277243 \times 400 \times 12$	$\Sigma F_d = 1330.766$
$\Sigma W = V_k \text{ Load} \times \text{No. of bearing}$	$\Sigma W = 4800 \text{ tons}$

1. Let the displacement be $D_D = 0.07202 \text{ mtrs.}$

2. Effective stiffness, $Q_d = \mu * \Sigma W = 0.0912 \times 4800$ $Q_d = 438.21 \text{ ton}$

$k_D = \Sigma F_d / D_D = 1330.7664 / 0.0702$	$k_D = 18956.7863 \text{ ton/m.}$
---	-----------------------------------

$K_{eff} = k_D + Q_d / D_D = 18956.78 + 438.20 / 0.0702$	$K_{eff} = 25199.0873 \text{ ton/m.}$
--	---------------------------------------

3. Effective period, - refer Eq. 17.5-2, ASCE 7-10

$T_{eff} = 2\pi \sqrt{(\Sigma W) / (K_{eff} \times g)}$	$T_{eff} = 0.87554 \text{ sec.}$
---	----------------------------------

4. Effective damping, - refer Eq. 17.8-7, ASCE 7-10

$\beta_D = \frac{E}{2\pi K_{eff} \times D_D^2} = \frac{4\pi \Sigma W (D_D - D_y)}{2\pi K_{eff} \times D_D^2}$	$\beta_{eff} = \beta_D = 0.1413 \text{ or } 14.13\%$
---	--

5. Damping reduction factor,

$\beta = \left(\frac{\beta_{eff}}{0.05}\right)^{0.3}$	$\beta = 1.366$
---	-----------------

6. D_D^1

$D_D^1 = \frac{S_{D1} \times T_{eff}^2}{4\pi^2 \times \beta} \times g$	$D_D^1 = 0.0708 \text{ mtrs.}$
--	--------------------------------

B) Calculating SAP2000 or Etabs links / support property data(upper bound)

2.1 Main Properties

2.1.1 Determine of Bearing (Rotational Inertia)

It had been considered that the isolator is a cylinder with diameter $\varnothing = 0.305 \text{ m}$ with height $h = 0.32 \text{ m}$ (Total height of the bearing)

$\varnothing = 0.484 \text{ m,}$	$h = 0.5 \text{ m.}$
----------------------------------	----------------------

Then C/s Area $A = \frac{\pi \times \varnothing^2}{4} = \frac{\pi \times 0.484^2}{4}$	$A = 0.1840 \text{ m}^2$.
---	----------------------------

$K_{eff} = \frac{W}{R_{1eff}} + \frac{\mu W}{D_D}$	$K_{eff} = 638.012 \text{ ton/m.}$
--	------------------------------------

$I_1 = \frac{K_{eff} \times h^3}{12 E} = \frac{638.012 \times 0.5^3}{12}$	$I_1 = 6.65E-07 \text{ m}^4$.
---	--------------------------------

Note:- Young's modulus 'E' was assumed $1 \times 10^7 \text{ N/mm}^2$ equal to half of actual steel modulus as the bearing is not a solid piece of metal.

$E = 1.00E+07$	N/mm^2 .
----------------	-------------------

2.1.2 Determine of Bearing mass

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

$$\begin{aligned}
 D_{m-max} &= 0.0702 \text{ mtrs.} \\
 D_{TM} &= 1.15 \times 0.0702 && \text{refer (Eq. 17.5.3.5 – ASCE 7-10)} \\
 \mathbf{D_{TM}} &= \mathbf{0.0807 \text{ mtrs.}} \\
 D = 2 D_{TM} &= 2 \times 0.0807 && \mathbf{D} = \mathbf{0.16146 \text{ mtrs.}} \\
 w &= 0.241 D^2 - 0.0564 D && \mathbf{w} = \mathbf{0.0053721 \text{ ton.}} \\
 M &= w / g = 0.005372 / 9.81 && \mathbf{M} = \mathbf{0.000548 \text{ ton sec}^2/\text{m.}}
 \end{aligned}$$

2.2 Directional properties (U₁)

$$\begin{aligned}
 \emptyset &= 0.484 \text{ m.} \\
 h \text{ or } L &= 0.5 \text{ m.} \\
 \text{Effective stiffness} &= AE / L && \mathbf{K_{eff}} = \mathbf{3679684.6 \text{ ton/m.}} \\
 \text{Effective damping from the DD calculation} &= 14.13\% \\
 &K_{eff} = 3679684.6 \text{ ton/m.} \\
 &\beta_{eff} = 0.1413 \text{ or } 14.13\%
 \end{aligned}$$

2.3 Directional properties (U₂ - U₃)

2.3.1 Determinatin of liner properties.

$$\begin{aligned}
 \text{Effective stiffness } K_{eff} &= 638.02 \text{ ton/m} && \text{(Refer 2.1.1)} \\
 \text{Effective damping } \beta_{eff} &= 0.1413 \text{ or } 14.13\% \\
 \text{Height for outer surface, } &= h_1 = h_4 = 161 \text{ mm} && \text{or } 0.161 \text{ mtrs.} \\
 \text{Height for outer surface, } &= h_2 = h_3 = 121 \text{ mm} && \text{or } 0.121 \text{ mtrs.}
 \end{aligned}$$

2.3.2 Determinatin of Non - liner properties.

$$\begin{aligned}
 \text{Stiffness} &= \frac{\mu_1 w}{D_y} = \frac{0.0934 \times 400}{0.00731}, && R_{2\text{eff}} = 526 \text{ mmor } 0.526 \text{ mtrs.} \\
 Dy &= (\mu_1 - \mu_2) R_{2\text{eff}} = (0.093 - 0.079) \times 0.526 && \mathbf{Dy} = \mathbf{0.00731 \text{ mtrs.}} \\
 \text{Stiffness of outer surface} &= \frac{\mu_1 w}{D_y} = \frac{0.0934 \times 400}{0.00731} && = \mathbf{5116.426 \text{ ton/m.}} \\
 \text{Stiffness of inner surface} &= \frac{\mu_2 w}{D_y} = \frac{0.0795 \times 400}{0.00731} && = \mathbf{4355.973 \text{ ton/m.}} \\
 \text{Friction slow} &= \mu_1 \text{ for outer surface} = 0.093 \\
 &= \mu_2 \text{ for outer surface} = 0.080 \\
 \text{Friction fast} &= 2 \times \mu_1 \text{ for outer surface} = 0.187 \\
 &= 2 \times \mu_2 \text{ for outer surface} = 0.159
 \end{aligned}$$

$$\text{Rate Parameter} = \frac{\text{Friction slow} / \text{Friction fast}}{0.093 / 0.187} = \mathbf{0.5}$$

* Radius of sliding surface

$$\begin{aligned}
 \text{For outer} &= R_{1\text{eff}} = 3.395 \text{ mtrs.} \\
 \text{For inner} &= R_{2\text{eff}} = 0.526 \text{ mtrs.}
 \end{aligned}$$

* Stop distance

$$\begin{aligned}
 \text{For outer surface } u_1^* &= 2 Dy + 2 d_1^* = \mathbf{1.09540 \text{ mtrs.}} \\
 \text{For outer surface } u_2^* &= 2 Dy = \mathbf{0.01461 \text{ mtrs.}}
 \end{aligned}$$

Etabs Input Values

Nonlinear Link Type: Triple friction pendulum.

Directional Properties (U₁, U₂, &U₃):

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

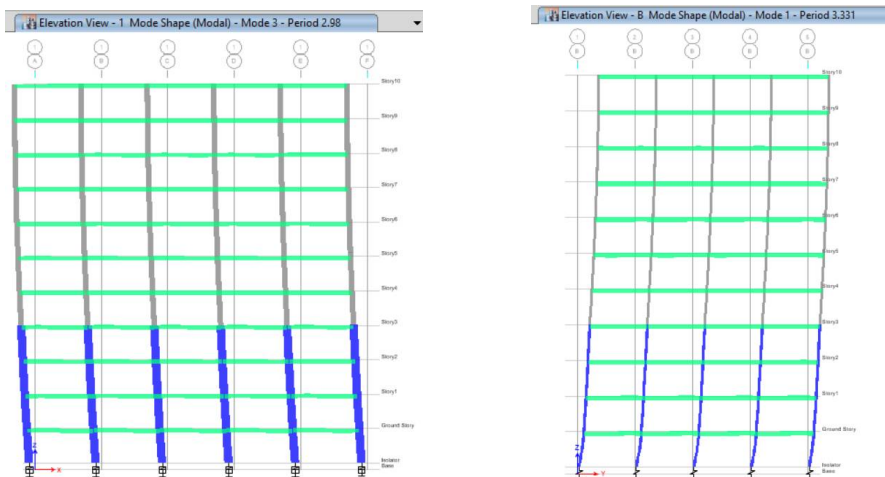
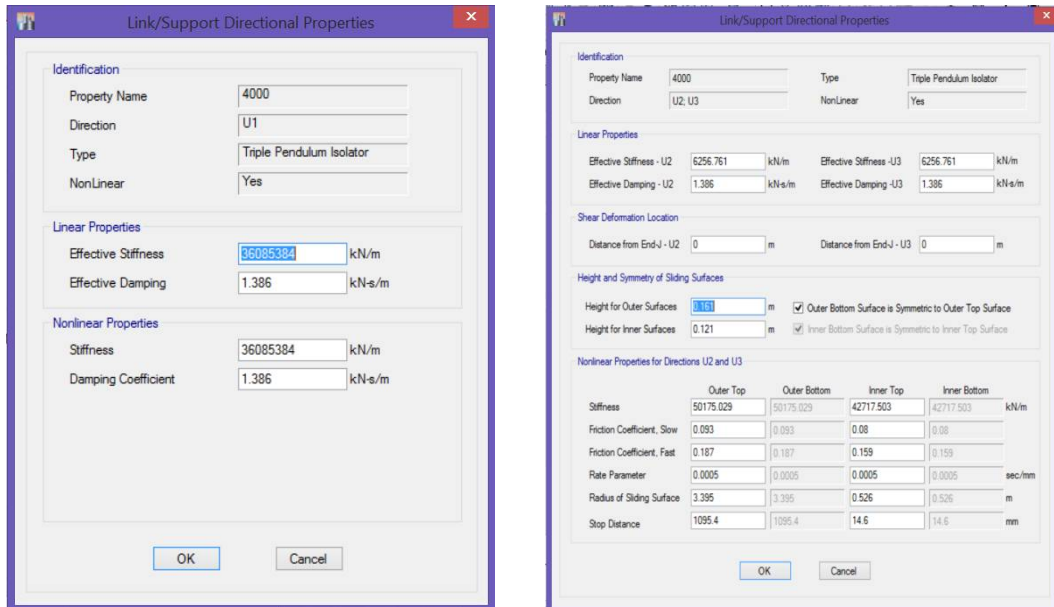


Figure 4: Bare frame with lead rubber & triple friction pendulum isolator (Y-direction).

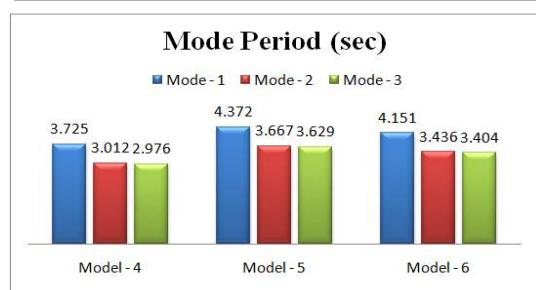
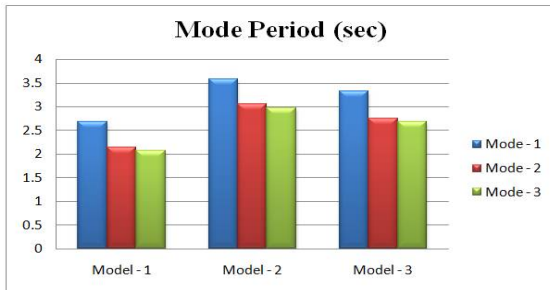
III. EXPERIMENTAL RESULTS

A) Mode period

Table 2. Comparison of mode period for G+10 & G+20 different Models.

Models	Mode Period (sec)		
	Mode - 1	Mode - 2	Mode - 3
Model - 1	2.688	2.136	2.081
Model - 2	3.590	3.059	2.980
Model - 3	3.331	2.758	2.685

Models	Mode Period (sec)		
	Mode - 1	Mode - 2	Mode - 3
Model - 4	3.725	3.012	2.976
Model - 5	4.372	3.667	3.629
Model - 6	4.151	3.436	3.404

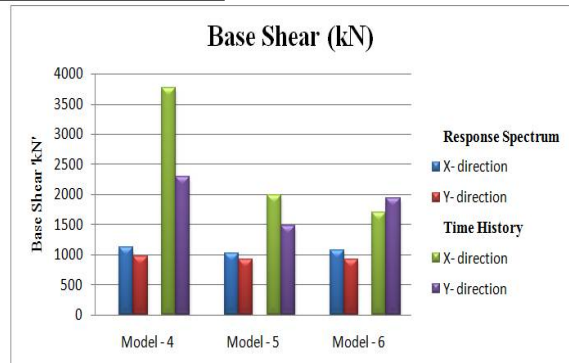
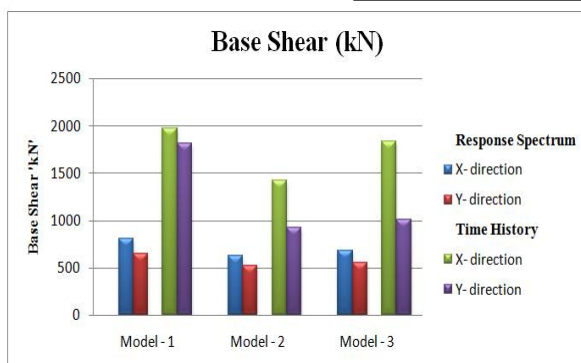


The Values clearly shows that the mode period for FB with LRB and TFPB are 25% and 19% higher value than with fixed base (FB) for G+10 same as FB with LRB and TFPB are 15% and 10% higher value than with fixed base (FB) for G+20 due to Flexible in the isolators. Hence isolation by the LRB and TFPB are same.

B) Base shear

Table 3. Comparison of base shear for different types of base isolators with response spectrum and time history analysis.

Models	Response Spectrum		Time History	
	X- direction	Y- direction	X- direction	Y- direction
G+10 storey				
Model - 1	809.193	654.538	1971.017	1813.270
Model - 2	626.157	518.893	1427.306	926.788
Model - 3	685.124	553.421	1841.516	1007.318
G+20 storey				
Model - 4	1132.029	968.987	3774.411	2296.443
Model - 5	1026.361	927.165	1990.04	1475.126
Model - 6	1079.431	921.666	1697.388	1943.690



For G+ 10 RC frame building the result show that the ratios of base shear for fixed base with LRB and TFPB are decrease by 27.5% and 18.9%. And for G+ 20 base shears for fixed base with LRB and TFPB are decrease by 55% and 38.5%, so hence LRB is more suitable for G+10, TFPB is more suitable for G+20 multi-storey building.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

C) Displacement

No. of Storey	Storey Displacement (mm) - Model - 1		Storey Displacement (mm) - Model - 2		Storey Displacement (mm) - Model - 3	
	Response Spectrum	Time History	Response Spectrum	Time History	Response Spectrum	Time History
	X- direction	X- direction	X- direction	X- direction	X- direction	X- direction
Storey - 10	33.9	88	45.1	109.8	45.1	109.8
Storey - 09	32.9	84.6	44.4	106.9	44.4	106.9
Storey - 08	31.2	78.6	43.3	101.7	43.3	101.7
Storey - 07	28.8	70.3	41.6	94.3	41.6	94.3
Storey - 06	25.7	60.1	39.4	85.2	39.4	85.2
Storey - 05	22	48.4	36.7	75.3	36.7	75.3
Storey - 04	17.8	38.4	33.5	66.8	33.5	66.8
Storey - 03	13.7	30.1	29.8	60.3	29.8	60.3
Storey - 02	9.5	21.1	26.2	53.5	26.2	53.5
Storey - 01	5.3	11.9	22.1	46.5	22.1	46.5
Ground - S	1.7	3.9	17.5	37.5	17.5	37.5
Base	0	0	12.3	27.2	12.3	27.2

No. of Storey	Storey Displacement (mm) - Model - 4		Storey Displacement (mm) - Model - 5		Storey Displacement (mm) - Model - 6	
	Response Spectrum	Time History	Response Spectrum	Time History	Response Spectrum	Time History
	X- direction	X- direction	X- direction	X- direction	X- direction	X- direction
Storey - 20	54	130.2	64.3	131.9	61	107.8
Storey - 19	53	126.6	63.5	128.7	60.2	105.8
Storey - 18	51.5	120.3	62.2	123.7	58.8	102.6
Storey - 17	49.3	111.2	60.4	117.8	56.8	98.4
Storey - 16	46.5	99.7	58	113.4	54.4	93.7
Storey - 15	43.3	86.8	55.2	109.8	51.4	88.4
Storey - 14	39.6	76.2	52	104.9	48.1	82.8
Storey - 13	35.6	69.4	48.4	97.8	44.3	76.5
Storey - 12	32.1	66.5	45	90	40.8	70.5
Storey - 11	28.7	63.1	41.6	81.6	37.3	64.1
Storey - 10	25.9	59.5	38.3	73.5	34	57.7
Storey - 09	23.5	55.5	35.6	67.3	31.2	52.1
Storey - 08	21.2	50.9	33.3	62.8	28.9	47.3
Storey - 07	18.8	45.6	31	58.7	26.6	42.6
Storey - 06	16.2	39.5	28.7	54.3	24.2	38.4
Storey - 05	13.6	33.4	26.4	50	21.9	34.9
Storey - 04	10.9	26.9	24.1	45.5	19.5	31.2
Storey - 03	8.2	20.2	21.6	40.7	16.9	27.3
Storey - 02	5.5	13.6	18.9	35.7	14.2	23.9
Storey - 01	3	7.4	16.1	30.5	11.2	19.7
Ground - S	0.9	2.3	12.9	25.2	7.9	14.4
Base	0	0	9.3	19	4.2	8.2

For G+ 10 storey building with RC frame having ratios of displacement for fixed base with LRB and TFPB are increase by 21.7% and 15.6%. And for G+ 20 storey for fixed base with LRB and TFPB are increase by 11% and 17%, so hence LRB is more suitable for G+10, TFPB is more suitable for G+20 multi-storey building.

IV. CONCLUSION

In the present study the response of multi storey RC frame building is due to earthquake excitations has been carried out using finite element analysis on all six types of structures i.e., G+10 & G+20 RC bare frame with fixed base, bare frame with lead rubber isolator, bare frame with triple friction pendulum isolator. It is concluded that Lead Rubber Bearing is more suitable for G+10, Triple Friction Pendulum Bearing is more suitable for G+20 multi-storey building.

REFERENCES

- Masoud Malekzadeh, Touraj taghikhany, "Multi-Stage Performance of Seismically Isolated Bridge Using Triple Pendulum Bearings", Advances in structural engineering, Vol. 15 No. 17, 2012.
- T. Okazaki, E, Sato K. Kajiwara, K. Ryan, S. Mahin, "Defense Base Isolation Tests: Performance of Triple-Pendulum Bearings", 15 WCEE, LISBOA2012, 2012.
- Nhan D. Dao, "Predicting the Displacement of Triple Pendulum Bearings in a Full Scale Shaking Experiment using a Three-Dimensional Element", Earthquake engineering & Structural Dynamics, Publication 7, 32 Citations, 2013.
- Luigi Petti, Fabrizio Polichetti, Alessio Lodato, Bruno Palazzo, "Modelling and analysis of base isolated structures with friction pendulum system considering near fault events, Open journal of civil engineering, Page no. 86-93, 2013.
- Pejman Namiranian, "Effects of Triple Pendulum Bearing on Seismic Response of Isolated Buildings under Near-Field Excitations", Earthquake engineering & Structural Dynamics, Publication 5, 0 Citations, 2014.
- Khloud El-Bayoumi, "Modelling Of Triple Friction Pendulum Bearing In Sap2000", International journal of advances in engineering & technology, Feb. 2015, ISSN:22311963, Vol. 8, Issue 1, PP.1964-1971, 2015.
- Anusha R Reddy, "Seismic Analysis of Base Isolated Building in RC Framed Structures", International journal of civil and structural engineering research, Sep. 2015, Vol.-3, Issue 1, Page No. 170-176, 2015.
- Mohammed Naguib, Fikry A, Salem, Khloud El-Bayoumi, "Dynamic Analysis of high rise seismically isolated building", American Journal of Civil Engineering, March 10, ISSN:2330-8737, Page No. 43-50, 2015.
- IS 1893 (part 1):2002, Criteria for earthquake resistant design of structures.
- IS 456:2000, Code of practice for plain and reinforced concrete.
- IBC 2000, International Building Code.
- UBC 1997, Uniform Building Code, Structural Design Requirements.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

BIOGRAPHY

1.



Dr. H.M.Somasekharaiah holds his PhD degree from JNTU, Ananthapura, India. He is a Professor in Department of Civil Engineering at RYMEC Ballari, Karnataka, India. He is having 30 years of academic teaching, consultancy and research experience. He is also carrying out third party quality auditing for government projects. His research interests are Composite fibers, supplementary cementations materials, and rheological characterization and durability studies of high performance concrete. He has published many international and national journals. He is supervising around eight PhD projects.

2.



Mr. Dharmesh. N received his BE in Civil Engineering, M.Tech in Earthquake Engineering and is currently pursuing his Ph.D (UVCE, bengaluru university) in Base isolation. He is an Assistant Professor in Department of Civil Engineering at East Point College of Engineering and Technology Bengaluru, Karnataka, India. He has around 04 years of academic teaching, consultancy and research works.

3.



Mr. Mohammed Ghouse as received his BE in Civil Engineering, pursuing his M.Tech in Structural Engineering at Rao Bahadur Y Mahabaleswarappa Engineering College Ballari, Karnataka, India. Email ID: muhammed2012@gmail.com.