# Seismic Performance of Base Isolated RCC Structure using Fibre Reinforced Elastomeric Isolator

1.Sai Rudrawar , 2. Abhijeet A. Galatage

1. P.G. Student, Department of structural Engineering Flora institute of technology khed ,pune
2. Assistant Professor, Department of Civil Engineering 2 Flora institute of technology khed ,pune

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**Abstract -** This Conventional seismic design attempts to make buildings that do not collapse under strong earthquake shaking, but may sustain damage to non-structural elements and to some structural members in the building. This may render the building non-functional after the earthquake, which may be problematic in some structures, like hospitals, which need to remain functional during the earthquake. Special techniques are required to design buildings such that they remain practically undamaged even in a severe earthquake. Base Isolation is passive vibration control system. The idea behind base isolation is to detach the building from the ground in such a way that earthquake motions are not transmitted up through the building, or at least get greatly reduced. It has become evident in recent times that base isolation can be very effective in the event of an earthquake. But the cost of installing base isolation system has been so great that it is generally only used for emergency centres, historical buildings, and buildings with very expensive and sensitive equipment and is limited to developed nations only. In a developing country like India, base isolation technique is as good as non-existent.

***Key Words*:** base isolation,earthquake

## 1.INTRODUCTION

The earthquakes in the recent past have provided enough evidence of performance of different type of structures, earthquake conditions and foundation conditions to be taken as a food for thought to the engineers and scientists. This has given birth to different type of techniques to save the structures from the earthquake effects. Conventional seismic design attempts to make buildings that do not collapse under strong earthquake shaking, but may sustain damage to non-structural elements and to some structural members in the building. Non-structural components may consist of furniture, equipment, partitions, curtain wall systems, piping, electrical equipment and many other items. There are mainly three main categories: architectural components, mechanical and electrical equipments, and building contents

## 2. Body of Paper

**Design of FREI:**

For the design Zone V is considered. As per IS 1893 : 2016, Z comes out to be 0.36, Site Profile Type is taken as Medium Soil which is Soil Type II.

i. Z = V (Zone)
 ∴ Z = 0.36

ii. Site Soil Profile Type: Medium or Stiff Soil
 Soil Type II: IS 1893
 $S_D$: UBC – 97

iii. Seismic Source Type
 Zone V Earthquake → $M \geq 7.0$
 … (Pg. 28 of IS 1893)
 ∴ Seismic Source Type – A

iv. Near Source Factor (Na & Nv):
 Distance of epicenter from source: 20 kms.
 For ≥ 10 kms → Na = 1.0
 Nv = 1.0

v. Design Basic Earthquake Shaking Intensity:
 Z.Nv → 0.36 × 1 = 0.36
 Z.Nv → Mm (Maximum Capable earthquake response coeff. Mm)
 0.3 → 1.5
 0.36 → ?
 0.4 → 1.25
 ∴ 0.36 → 1.35

vi. Seismic Coeff. ($C_{VD}$ & $C_{AD}$)
 … (Table 16R)

From 16R, $C_{VD}$: $S_D$→

| | | |
|---|---|---|
| Z = 0.3 | 0.36 | 0.4 |
| 0.54 | 0.6 | 0.6Nv = 0.64 |

From 16Q, $C_{AD}$: $S_D$→

| | | |
|---|---|---|
| Z = 0.3 | 0.36 | 0.4 |
| 0.54 | 0.41 | 0.44Na = 0.44 |

vii. Seismic Coeff. ($C_{VM}$ & $C_{AM}$)
 Mm.Z.Nv = 1.35 × 0.36 × 1
 = 0.49
 Mm.Z.Na = 1.35 × 0.36 × 1
 = 0.49
 $C_{VM}$ → Table A-16.G
 ∴ $S_D$ → 1.6 × 0.499 = 0.784
 $C_{AM}$ → Table A-16.F
 ∴ $S_D$ → 1.1 × 0.49 = 0.54

viii. Structural System Reduction Factor, $R_I$
 SMRF (Concrete) → 2.0

ix. Damping Coeff. $B_D$ & $B_M$ (Table A-16.C)
 Effective Damping (10%) → $B_D$ or $B_M$ factor
 → 1.2

x. Assuming Fundamental Period, $T_D$ = 2.5 secs
 $T_M$ = 3.0 secs

xi. Effective Stiffness of isolation system:

$$T_D = 2\pi \times \sqrt{\frac{W}{Kd.min.\times g}}$$

$Kd_{min}$ = Minimum Effective Stiffness at Design Displacement.
W = 1449.49 kN (from software)

$2.5 = 2\pi \times \sqrt{\frac{1449.49}{Kd.min.\times\ 9.81}}$

∴ $Kd_{min}$ = 933.31 kN/m

$T_M = 2\pi \times \sqrt{\frac{W}{Km.min.\times g}}$

$Km_{min}$ = Minimum Effective Stiffness at Maximum Displacement.

$3.0 = 2\pi \times \sqrt{\frac{1449.49}{Km.min.\ \times\ 9.81}}$

∴ $Km_{min}$ = 648.13 kN/m
10% variation:
$K_{Dmax}$ = Maximum Effective Stiffness at Design Displacement.
$K_{Mmax}$ = Maximum Effective Stiffness at Maximum Displacement.

$K_{Dmax} = 1.10\ \times \frac{933.31}{0.9} = 1140.71$ kN/m

$Km_{max} = 1.10\ \times \frac{648.13}{0.9} = 792.16$ kN/m

xii. Minimum design lateral displacement:
$D_D$ = Design Displacement
$D_M$= Maximum Displacement

$D_D = \frac{\left(\frac{g}{4\pi^2}\right).CVD.TD}{BD} = \frac{\left(\frac{9.81}{4\pi^2}\right)\times 0.6\times 2.5}{1.2} = 0.31$ m

$D_M = \frac{\left(\frac{g}{4\pi^2}\right).CVM.TM}{BM} = \frac{\left(\frac{9.81}{4\pi^2}\right)\times 0.784\times 3.0}{1.2} = 0.487$ m

xiii. Minimum Design Lateral Forces (Vb & Vs)
Vb: Minimum Design Lateral Forces for the isolation systems & structural system at or below the isolation interface
Vs: Above the isolation interface

$Vb = K_{Dmax} . D_D = 1140.71 \times 0.37 = 422.06$ kN

$Vs = \frac{KDmax.Dd}{RI} = 422.06 = 211.03$ kN

$K_H = \frac{GA}{tr}$ $K_H$ = Horizontal Stiffness G = 1.2MPa (assumed)

$r = \frac{Dd}{tr}$

G = Shear modulus of HDRB

r = 1.5

r = Shear strain

$1.5 = \left(\frac{0.37}{tr}\right)$

$t_r$ = Total thickness of Rubber

$t_r$ = 250 mm

A = Area of Device

$K_H = \frac{G.A}{tr} \rightarrow 933.31 = \frac{1.2\times 10^3\times A}{0.250}$

∴ A = 0.19 $m^2$
∴ Dimension = 450 × 450 mm

xiv. Actual Bearing Stiffness

$K_H = \frac{0.4\times 0.58\times 10^3}{0.250}$

∴ $K_H$ = 928 kN/m
Actual $T_D$:

$T_D = 2\pi\ \times \sqrt{\frac{1449.49}{928\times 9.81}}$

∴ $T_D$ = 2.51 secs

xv. Design of isolator
Fibre Reinforced Elastomeric Isolator (FREI):
Thickness of Rubber = 4 mm.
Thickness of Fibre = 0.5 mm.

Shape Factor $= \frac{B}{4t} = \frac{450}{4\times 4} = 28.125$
Top & Bottom Steel Plate = 28 mm.
Glass Fibre → 62 nos. of 0.5 mm – 480 gsm
Rubber → 63 nos. of

**Table -1:** Sample Table format

| Type of testing | Vertical Pressure (MPa) | Number of Cycles | Shear Strain Magnitude (%) | Cycle Magnitude | Vertical Stiffness (kN/m) | Horizontal Stiffness (kN/m) |
|---|---|---|---|---|---|---|
| Horizontal test | 6.90 | 3 | 25 | - | - | 690 |
| | 6.90 | 3 | 50 | - | - | 347 |
| | 6.90 | 3 | 75 | - | - | 236 |
| Vertical test | 6.90 | 3 | N/A | 1.73 MPa | 1408702.70 | - |

The testing was done in 2 parts. In the first part isolators were tested for horizontal stiffness and in the second part it was tested for vertical stiffness. The specimen was tested under vertical load control during the vertical test. The specimen was monotonically loaded up to 6.90 MPa vertical pressure, and three cycles with amplitude ± 1.73 MPa were performed. In the final stage the specimen was monotonically unloaded. The horizontal test was performed under horizontal displacement control. The specimen was tested in cyclic shear, with three cycles at three maximum strain levels of 25 %, 50 %, and 75 % (based on 339 mm thickness). For strain level of 25 %, the isolator is loaded to get the strain of 25 % i.e. the change of the dimension of the isolator is 85 mm (25 % of 339 mm), in the strain level of 50 %, the isolator is loaded to get the strain of 50 % i.e. the change in dimension of the isolator is 170 mm (50 % of 339 mm), and for strain level of 75 %, the isolator is loaded to get the strain of 75 % i.e. the change of the dimension is 250 mm (approximately 75 % of 339 mm).

**Fig -1**: Figure Photograph of Mould

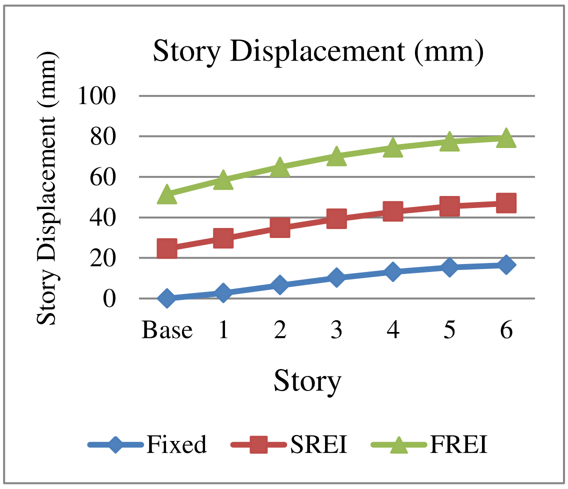


Chart 1-Displacement in Zone V

## 3. CONCLUSIONS

The overall conclusions drawn from the present study are:

01. From the manufacturing of FREI it can be concluded that the FREI is a light in weight replacement of SREI. From the testing it is seen that the vertical stiffness of FREI is at par with that of SREI and the horizontal stiffness of FREI is lower than that of SREI, thus giving a layer of lateral stiffness between ground and superstructure further less than that of SREI which will reduce the seismic loads transferred to the structure above.

02. From the study of seismic analysis it can be concluded that the seismic responses decrease when the building is base isolated. As we compare the performance of SREI and FREI we can see that the performance of FREI is comparatively better than that of SREI, thus making FREI an efficient replacement of SREI.

03. The FREI is found out to be efficient in all the zones considered. From section 5.4.5 we can see that the seismic response decreases as we go from higher zones to lower zone.

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