# Assessment of Seismic Response Analysis of Base Isolated RC Building frame

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Abstract: The main purpose of this study is to reduce the story accelerations and story drifts due to earthquake ground excitation, applied to the superstructure of the building by installing base isolation devices (base isolators) at the foundation level and then to compare the different performances between the fixed base condition and base-isolated condition by using SAP-2000 software. In this study, the 4-storey and 12- Storey R.C. building which is located in seismic zone V is used as test model. The R.C. shear wall is provided to the superstructure of the building to get stiffer frame. Lead rubber bearing (LRB) is used in this study. For the second portion, response spectrum analysis and time history analysis are used on both of fixed base and base isolated buildings. All of analyses used in this study are done by using SAP-2000 software. In fixed base condition, all of structures are considered in elastic stage and in base-isolated condition, the superstructure of the building is considered in this study, the static period of the building is 1.0 sec and it is lengthened to 2.0 sec, 2.5 sec and 3.0 sec at maximum earthquake level for comparative study. It is found that the more the period is lengthened, the lesser the story accelerations and story drifts of the superstructure above the base isolators and the displacement is increased with period of the building. The base shears in each direction are decreased significantly especially in 3.0 sec base-isolated building compared to the original building.

Keywords: Base Isolation, Multi-Storeyed Building, Response Spectrum Analysis, Time History Analysis

#### 1. Introduction

A large proportion of the world's population lives in regions of seismic hazards, at risk from earthquake of severity and varying frequency of occurrence. Earthquake cause significant loss of life and damage to property every year.

Various seismic construction designs and techniques have been over the years in attempts to mitigate the effects of earthquakes on Buildings. Buildings are lifeline structures. They play very important role in our life, and their failure during a seismic event will seriously hamper relief and rehabilitation work. The fundamental natural periods of normal single storey to 20 storey buildings are usually in the range 0.05-4.00 sec. In this range, the structural response is large because it is close to the predominant periods of earthquake-induced ground motions. The seismic forces on the buildings can be reduced if the fundamental period of the building is elongated or the energy dissipating capability is increased. Therefore, Base Isolation is a promising alternative for earthquake-resistant design of building. In a typical isolated building, different isolation devices are used which rest between the foundation and superstructure.

Nonlinear static analysis has recently emerged as a powerful means to study the overall behavior of structure from their elastic response through yielding and nonlinear response and all the way to global dynamic instability. In nonlinear static analysis intensity of the ground motion is chosen for the collapse investigation and it has increased until the global collapse capacity of the structure is reached. The analysis is repeated under different ground motions to obtain meaningful statistical results.



Figure 1: Base Isolation System, (a) Fixed Base, (b) Base-Isolated Building.

## 2. Principles of Seismic Isolation

The basic objective with seismic isolation is to introduce horizontally flexible but vertically stiff components (base isolators) at the base of a building to substantially uncouple the superstructure from high-frequency earthquake shaking. The basic concept of base isolation system is lengthening the natural period of the fixed base building. The benefits of adding a horizontally compliant system at the foundation level of a building can be seen in Figure 2a, using an acceleration response spectrum. Increasing the period of the structure reduces the spectral acceleration for typical earthquake shaking. Displacements in isolated structures are often large and efforts are made to add energy dissipation or damping in the isolation system to reduce displacements as shown in Figure 2b using a displacement response spectrum. The addition of damping to the isolation systems serves to reduce displacements in the seismic isolators, which can translate into smaller isolators.



Figure 2: Period Shift Effect on (a) Acceleration Curve, (b) Displacement Curve.

## **3.** Types of Base Isolators

The most common use types of base isolator in building are 1. Laminated Rubber (Elastomeric) Bearing.

- 2. High Damping Rubber (HDR) Bearing.
- 3. Lead Rubber Bearing (LRB).
- 4. Friction Pendulum (FPS) System Bearing.

Laminated Rubber (Elastomeric) Bearing: It is composed of alternating layers of rubber that provide flexibility and steel reinforcing plates that provide vertical load-carrying capacity. At the top and bottom of these layers are steel laminated plates that distribute the vertical loads and transfer the shear force to the internal rubber layer. On the top and bottom of the steel laminated plate is a rubber cover that provides protection for the steel laminated plates, shown in Figure 3a.

High Damping Rubber (HDR) Bearing: It is similar to elastomeric bearings where the elastomer used (either natural or synthetic rubber) provides a significant amount of damping, shown in Figure 3a.

Lead Rubber Bearing (LRB): It is formed of a lead plug force-fitted into a pre-formed hole in a low damping elastomeric bearing as shown in Figure 3b. The lead core provides rigidity under service loads and energy dissipation under high lateral loads.

Friction Pendulum Sliding (FPS) bearing: Although a number of curved shapes are possible, the only curved sliding which has been extensive used in which the sliding surface is spherical in shape, termed the Friction Pendulum System (FPS) as shown in Figure 3c. The FPS bearing allows the supported structure to return to its original position, rather than a flat sliding surface, thereby conquering the problem of recentering.



**Figure 3:** Various Types of Base Isolator, (a) Elastomeric/HDR Bearing, (b) LRB, (c) FPS.

## 4. Analysis Properties of LRB for SAP-2000 at Maximum Level of Earthquake

The base isolators are can be modelled as link elements in SAP-2000 software. To model the isolators in SAP-2000, the required links element properties for the isolators are calculated and input them in SAP-2000. The force displacement curve can be idealized as a bilinear curve, shown in Figure 4. From this curve, the required data for link properties are input. The isolators used in this building are divided into four groups according to the columns loads. Firstly, the design shear strain  $\gamma_{max}$  and effective damping ratio  $\xi_{eff}$  for the bearing, the target design period  $T_D$  and allowable displacement,  $D_D$ , for the isolated structure must be selected. The material properties for base isolator must also be selected according to the test report.



Figure 4: Bilinear Curve of Lead Rubber Bearing

#### **Analysis of Isolation Systems**

The isolation system can use the following four methods of analysis, by increasing level of complexity.

- 1. Linear Static Analysis.
- 2. Response Spectrum Analysis.
- 3. Linear Time History Analysis.

Linear Static Analysis: The linear static method of analysis is limited to small, regular buildings.

Linear Response-Spectrum Analysis: Linear Response spectrum analysis is the most common type of analysis used.

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This is sufficient for almost all isolation systems base on LRB and/ or HDR bearings.

Linear Time History Analysis: Linear Time History Analysis provides little more information than the response spectrum analysis for a much greater degree of effort and so is rarely used.

## **5. Building Modal Formulation**

In multi-storied buildings to reduce the Deflection, Story Shear, Acceleration and Storey Drift base isolator provided at base. Here, the main objective is to find that by providing base isolator at base how much amount of Deflection, Acceleration, and storey drift can be reduced.

For applying the above concept three case studies has been taken, Zone V are considered for these three case studies. Every case study has same plans but different height.

In order to investigate the seismic behavior of building with Base Isolator following building are considered.

S.N.	PARTICULAR	DISCRIPTION
1	Type of structure	Multi-story Ordinary RC moment-resisting frame(OMRF)
2	Area	19 X 19 (m2)
3	Seismic zone	V as per IS 1893 (Part 1):2002
4	Number of stories	4 and 12 stories
5	Building Height	14m, 42m
6	Story Height	3.5 m
7	Infill wall	150 mm thick including plaster
8	Imposed Load	1.5 KN/m2 for roof and 4.5 KN/m2 for floor
9	Materials	Concrete (M30) and Reinforcement Fe500
10	Size of column 4 stories	750 x 750, 600 x 600 (mm)
11	Size of beams 4 stories	450 x 900, 350 x 700 (mm)
12	Size of column 12 stories	1000 x 1000, 750 x 750, 600 x 600, 450 x 450 (mm)
13	Size of beams 12 stories	600 x 1200, 400 x 800, 450 x 900, 300 x 600 (mm)
14	Depth of slab	150 mm thick
15	Specific weight of RCC	25 KN/m3
16	Specific weight of RCC	20 KN/m3
17	Type of soil	Rock
18	Response spectra	As per IS 1893 (Part 1): 2002
19	Time History	Bhuj, Elcentro and Uttarkashi

## 6. Analytical Modelling and Results

In order to evaluate the Seismic gap between buildings with rigid floor diaphragms using dynamic and time history procedures two sample building was adopted the details of the building.

The finite element analysis software SAP-2000 Nonlinear is utilized to create 3D model and run all analyses. The software is able to predict the geometric nonlinear behavior of space frames under static or dynamic loadings, taking into account both geometric nonlinearity and material inelasticity. The software accepts static loads (either forces or displacements) as well as dynamic (accelerations) actions and has the ability to perform Eigen-values and nonlinear dynamic analyses. Details of the Models: The buildings are isolated R.C. building, located in upgraded seismic Zone V. The shape of building is rectangular shape and the frame system is ordinary moment resisting frame.

The models which have been adopted for study are asymmetric four storey (G+3) and twelve storey (G+11) buildings. The floor slabs are taken as 150mm thick. The foundation height is 1.5m and the height of the all stories is 3.5m. The modulus of elasticity and shear modulus of concrete have been taken as  $E = 2.55 \times 107 \text{ kN/m}^2$  and  $G = 1.06 \times 107 \text{ kN/m}^2$ .

Three models have been considered for the purpose of the study.

- 1) Four storey (G+3) adjacent buildings with equal floor levels.
- Twelve storey (G+11) adjacent buildings with equal floor levels.



Figure 5: Typical floor plan of RC framed building: Column location

**Building Geometry:** The required material properties like mass, weight density, modulus of elasticity, shear modulus and design values of the material used can be modified as per requirements or default values can be accepted.

Beams and column members have been defined as 'frame elements' with the appropriate dimensions and



Figure 6: Typical floor plan of RC framed building: Location of Base Isolator

reinforcement. Soil structure interaction has not been considered and the columns have been restrained in all six degrees of freedom at the base.

Slabs are defined as area elements having the properties of shell elements with the required thickness. Slabs have been modelled as rigid diaphragms.



Figure 7: '3-D view' of the four storey (G+3) building model created in SAP-2000

# Response spectrum analysis in SAP-2000

- The step by step procedure is as follows
- Defining quake loads under the load type 'quake' and naming it appropriately.
- Figure 8: '3-D view' of the twelve storey (G+11) building modal created in SAP-2000
- Defining response spectrum function as per IS 1893 (Part 1) 2002. The values of Sa/g Vs. T shown in Fig 9. can be linked in the program in the form of a data Curve.
- Modifying the quake analysis case with the appropriate analysis case type, applied loads and scale factors.

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• Running the analysis. 4 3.5 3 Spectral Acceleration 2.5 2 1.5 1 0.5 0 0 0.5 1 1.5 2 2.5 3 3.5 Time Period

Figure 9: Response Spectrum for Hard Soil IS 1893 (Part 1) 2002

Time history analysis in SAP-2000

The step by step procedure is as follows:

- Defining a time history function by adding a function from file. In our case, the Elcentro earthquake record of 1940 has been linked to the program.
- Defining a separate analysis case under the load type 'quake' with the appropriate analysis case type i.e. linear direct integration time history.
- Applying earthquake acceleration values from the defined time history function.
- Specifying the damping coefficients by calculating the mass and stiffness proportional coefficients as per the equations mentioned above or inputting the frequency or

time periods of two consecutive modes of the structure in the same direction whereby the program itself calculates the required damping coefficients.

- Specifying a direct integration method in the program. In our case, we have adopted Newmark's direct integration method.
- Running the analysis.

#### 7. Results



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Compression of Base Shear of Fixed base, Isolated 2.0 sec, Isolated 2.50 sec, Isolated 3.0 sec Figure 16: Twelve Storey Base Shear in Y- Direction



Comparission of Base Shear of Fixed base, Isolated 2.0 sec, Isolated 2.50 sec, Isolated 3.0 sec Figure 17: Twelve Storey Base Shear in X- Direction

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#### 8. Conclusion

Based on present work it is concluded that: -

From the comparative study, it is found that the sizes of the base isolators can be varied by adjusting the rubber hardness. The story accelerations are reduced significantly in the base-isolated building compared to the original building.

- 1) The story drifts of the building in this study are not in pattern of rigid body motion due to the flexibility of the superstructure the more the period is lengthened, the lesser the story accelerations and story drifts of the superstructure above the base isolators. The displacements are increased with period in the base isolated building for all cases. The base shears in each direction are decreased, especially in the base-isolated building with 3.0 sec period compared to the original building.
- 2) By providing base isolator in reinforced concrete building, it is observed that about 37.64 % to 81.52% base shear is reduced in comparison to the building without providing base isolator.
- 3) It is observed that, the storey drift of building is reduced up to 67.17 % to 82.53 % reduced by providing base isolator in building.
- 4) It is observed that the maximum displacement is reduced up to 57.10 % to 74.60 % in comparison to building without using isolator.
- 5) The percentage base shear taken by base isolator is about 40 % to 85 % in both direction of building plane.
- 6) It is observed that the percentage reduction in base shear in 12 story isolated building is 22% more than 4 story isolated building.

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