Impact of the Lead Rubber Base Isolators on Reinforced Concrete Building

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Abstract. Civil engineering infrastructures are prone to natural disasters like earthquakes, floods, and hurricanes. Dissipation energy plays the main role in design of structures under earthquake loads and controls the behavior of buildings when it bears the lateral loads and transfers them to the foundation. To resist the vibrations in the structure, it is important to use a high technology like Base isolation which reduces base frequency of building vibration and reaching it to a lower value. In other words, seismic isolation has the main objective to protect structure during earthquake events. Base isolation is a flexible layer between foundation and superstructure thus decoupling the structure from damaging effect of ground motion. This edits the dynamic characteristics of the structural system. A comparative study is conducted of seismic performance on three types of thickness (100mm, 200mm, 300mm) in which M1T1, M2T1, M3T1, M1T2, M2T2, M3T2, M1T3, M2T3, M3T3, M1T4, M2T4, and M3T4 has been analyzed of isolators namely Lead Rubber Base Isolators (LRBI). For this evaluation, an 8-story structure has been analyzed by using (ETABS) finite element program where Models have ordinary RC moment-resisting frames with square column cross-sections. Parameters like drift, displacement, story acceleration, frequency, and story velocity have been analyzed and it has been found that due to the presence of Lead Rubber Isolators the story drift, story accelerations, base shear, lateral shear forces, and velocity are greatly reduced and story displacement is increased in both X and Y directions compared for various thickness of lead rubber base isolation systems under near and far-field earthquakes. Most importantly it has been established that the transmission of the high energy seismic waves to the superstructure is greatly reduced by introducing base isolators in between the top of the footing and the bottom of the superstructure. The base isolator with thickness 100mm for the concrete grade M20, M30, M40 performed more efficiently than other thicknesses. In conclusion, the deformation and transmissibility ratio must be minimized to introduce as a solution for absorbing the vibrations where the engineer should consider this effect for adequate design.

1. Introduction

Strong earthquakes in the past have resulted in significant property damage and loss of lives. Earthquake damage is mainly associated with damage to seismically deficient buildings, often designed prior to the enactment of modern building codes. Therefore, researchers have focused their
efforts on developing new and effective seismic risk mitigation strategies for such buildings. Conventional seismic protection methods, such as enlarging structural elements or adding new stiffening and stiffening elements focus on improving the capacity of buildings to meet likely demands. However, stiffening buildings results in shorter vibration periods and higher floor accelerations, resulting in higher structural damage. Therefore, a preferred approach for seismic retrofitting buildings may be to decrease demands rather than to increase capacities. This can be achieved by introducing flexible devices to buildings at their ground levels to isolate them from the transfer of seismic energy. Research aims to improve the seismic performance of strategically important buildings such as commercial buildings, industrial structures, elevated water tanks, residential houses, etc. in addition to places where sensitive equipment are intended to protect from the hazardous effects during earthquake, base isolation is recognized as a mature and efficient technology that can be adopted to reduce the momentum of the seismic waves. The lead rubber base isolator dissipates a larger quantity of seismic energy as the lead plugs experience large hysteresis deformation. In addition, the lead rubber base isolators have a much higher lateral stiffness. This means that the incorporation of lead rubber base isolators can contribute towards lateral resistance to non-seismic loads, thereby controlling base displacements during strong earthquakes. The use of the isolation system depends on the extent of control to achieve the better for seismic response and thereupon its design is done to suit the requirement for structure. To design the base-isolated structures, the superstructure is decoupled from earthquake ground motion by introducing a flexible interface between the foundation and the base of the structure. Therefore the fundamental time-period of the structure is shifted to a large value for absorbing the energy in damping, limiting the amount of force that can be transferred to the superstructure such that inter-story drift and floor accelerations are decreased drastically. It also consequently avoided the matching of fundamental frequencies of base-isolated structures and the predominant frequency contents of earthquakes, leading to a flexible structural system with ductility and more suitable from earthquake resistance viewpoint. To present the lead rubber base isolator as shown in figure 1 and figure 2.

![Figure 1. LRB seismic isolator](https://doshinrubber.com/lead-rubber-bearing/)

![Figure 2. LRB seismic isolator](http://welllink.com.tw/en/lead-rubber-bearing)

2. Literature survey
Different sources of damping that are considered depending on the nature of the building. Furthermore, many types of isolators are studied, in which lead rubber base isolators were deeply enlightened with its importance.

2.1. Ras, I. Nait Zerrad (2016)
A 3D analytical study was done by taking the seismic behaviour of a 12-storey steel building retrofitted with a FPS. Fast nonlinear time history analysis (FNA) of Boumerdes earthquake (Algeria, May 2003) was conducted for analysis and carried out using SAP2000 finite element program. To
compare the structural performance with and without this tool of dissipation energy, the results of models were discussed and concluded to show the interesting potential of the FPS isolator out using SAP2000 finite element program. To compare the structural performance with and without this tool of dissipation energy, the results of models were discussed and concluded to show the interesting potential of the FPS isolator. [3]

2.2. Mital N. Desai (2015)
It was studied the comparative study of performance by using three types of base isolators namely Lead Rubber Bearing (LDRB), Low Damping Rubber Bearing (LDRB) and High Damping Rubber bearing (HDRB). Eight-storey building was analysed using the Response Spectrum Method. Dynamic analysis was done using STAAD-Pro software. Parameters like Base shear, Building displacement and frequency and spectral acceleration were compared for the building with base isolator and building with fixed base. [20]

2.3. Minal Ashok Somwanshi (2015)
It has developed a new base isolation system for a multi-storey RC building. This study occurred to analyze the 13-storey rigid jointed plane frame for two cases. The first case was fixed base and the second case was base isolated. Analytical study was done using ETABS software with Bhuj earthquake ground motion records. Maximum vertical reaction was included from analysis in ETABS software. Lead rubber bearings were designed manually using this vertical reaction and total mass of building. In order to evaluate floor response, Time-history analysis was conducted to have acceleration and displacement values under seismic loads. This intends to demonstrate how an isolation system can be efficient, evaluating its effectiveness for the building in terms of maximum shear force, maximum bending moment, base shear, storey drift and storey displacement reductions. [19]

2.4. Kilaret V
4-storey reinforced concrete building was analysed according to Eurocode 8 for seismic analysis and dynamic performance investigation. Different groups of base isolation devices were studied for evaluation. The first case was simple rubber bearing and the second one was lead rubber bearing as a base isolation system. For the evaluation of each system a soft, normal and hard rubber stiffness with different damping values were used. It performed Non-linear pushover analysis with the SAP 2000 software. It was concluded that the stiffer isolators with higher damping give smaller target base displacements as compared to softer one with lower damping. It also presents that the relative displacement of the superstructure was smaller since the softer isolators were used. It can be expected that the smallest relative displacement with the use of softer isolators. If the used isolators were too stiff it cannot protect the superstructure. [17]

3. Research Statement
In order the RCC building needs to be designed by the insufficient balance, strength, and ductility that have occurred. When the dynamic analysis under seismic load happened, it is important to introduce supplementary damping for building, the isolation systems considered include Lead rubber isolator of thickness 100mm, 200mm, 300mm. It is taken Base isolation as an opposite approach, i.e. to reduce the seismic demand instead of increasing the capacity. Controlling ground motion is impossible, but we can modify the demand on structure by preventing/reducing the motions being transferred to the structure from foundations. Moreover, the use of RCC frames is very common these days. Therefore, the problem of analyzing the RCC frames by introducing base isolators has been taken for the studies of the dynamic response of such frames. The concrete grade selected for such analysis is M20, M30, and M40. The details of material other in outs etc. are discussed in subsequent paragraphs. To know the dynamic response of the base-isolated buildings for a given soil bearing
capacity, four types of building frames have been generated by using software ETABS, Version (16.2.1). The detail of such models generated is given below as shown in tables (1, 2, and 3)

| Table 1. Models M20 (M1) |
|--------------------------|
| Type | T1 | T2 | T3 | T4 |
| Base | Fixed | 100 mm | 200 mm | 300 mm |

| Table 2. Models M30 (M2) |
|--------------------------|
| Type | T1 | T2 | T3 | T4 |
| Base | Fixed | 100 mm | 200 mm | 300 mm |

| Table 3. Models M40 (M3) |
|--------------------------|
| Type | T1 | T2 | T3 | T4 |
| Base | Fixed | 100 mm | 200 mm | 300 mm |

4. Objective of the Study
The objective of the current investigation is to assess the performance of different types of base isolation systems for seismic protection of reinforced concrete frame buildings, through dynamic analysis time history analysis and static analysis of a selected prototype building.

5. Modeling and Material Properties

5.1. Modeling
The seismic behavior of the model has been studied with ordinary RC moment-resisting frames by noting the impact of changes on seismic characteristics where lead rubber base isolators occurred. According to modeling, 8-story structure storey RC building occurred. The analysis (Standard) was done by considering the connection between columns and beams is completely fixed [8].

5.2. Design Parameters
- Regarding the study, Loads acting on the structure are shown as in table (4).

| Table 4. Loads. |
|-----------------|
| Dead load (DL)  | 1 As per IS 875(PART 1) (1987) and IS 875(PART 2) |
| and Live load (LL) | As per IS 1893(PART 1) (2000) |
| Seismic loads (SL) | Zone IV |
| Rock/soil type | Medium |
| Rock and soil factor | 1 |
| Damping ratio | 5% |

- The Preliminary data used, as shown in table (5)

| Table 5. Preliminary data. |
|---------------------------|
| Utility of building | Residential building |
| Number of stores | 8 |
| Shape of building | Rectangular with RCC Frame Structure |
Grade of concrete and steel

Ductility design

M20, M30, M40, and Fe415

IS:13920-1993

- Models Characteristics the following dimensions of column and beams have been considered in all the models as shown in table (6)

| Dimension of beam  | 380 x 420 mm |
|-------------------|--------------|
| Dimension of column | 500 x 500 mm |
| Support condition | Fixed |

Table 6. Column and beams.

- Height of models is shown in table (7)

| Models and Types  | M1T1 | M1T2 | M1T3 | M1T4 |
|-------------------|------|------|------|------|
| Base              | 2    | 0.1  | 0.2  | 0.3  |

| Models and Types  | M2T1 | M2T2 | M2T3 | M2T4 |
|-------------------|------|------|------|------|
| Base              | 2    | 4    | 3.9  | 3.8  |
|                   | 1    | 4    | 3.9  | 3.7  |
|                   | 2    | 4    | 4    | 4    |
|                   | 3    | 4    | 4    | 4    |
|                   | 4    | 4    | 4    | 4    |
|                   | 5    | 4    | 4    | 4    |
|                   | 6    | 4    | 4    | 4    |
|                   | 7    | 4    | 4    | 4    |
|                   | 8    | 4    | 4    | 4    |

Table 7. Floor to Floor height for Models (m)

- Characteristics of model cases are shown in table (8)

| Name of Models | Properties for Models |
|----------------|-----------------------|
| M1T2, M2T2, M3T2 | M1T2, M2T2, M3T2 |
| M1T3, M2T3, M3T3 | M1T3, M2T3, M3T3 |
| M1T4, M2T4, M3T4 | M1T4, M2T4, M3T4 |
| Dimension of beam | 380*420 mm |
| Dimension of column | 500*500mm |
| No. of column | 240 |
| No. of beam | 392 |
### Table 1: Parameters for Uttarkashi Earthquake

| Parameter                                      | Value       |
|-----------------------------------------------|-------------|
| U1 linear effective stiffness for model 2     | 229137.19 kN/m |
| U1 linear effective stiffness for model 3     | 114568.59 kN/m |
| U1 linear effective stiffness for model 4     | 57284.29 kN/m  |
| U1, U2, U3 linear effective damping          | 0.1 kN-s/m   |
| U2, U3 linear effective stiffness             | 800 kN/m     |
| U2, U3 non-linear stiffness                   | 2500 kN/m    |
| U2, U3 non-linear yield strength              | 80 Kn        |
| U2, U3 non-linear post-yield strength ratio   | 0.1          |

For time history, Uttarkashi earthquake is used with Record as shown in figure 3.

**Figure 3.** Uttarkashi earthquake of October 20, 1991

Direction values (Uttarkashi earthquake):
- Longitudinal (N 15 W) = 0.242 (237 cm/s/s)
- Transverse (N 75 E) = 0.310 (304 cm/s/s)
- Vertical = 0.196 (193 cm/s/s)
The procedure is generated by using ETABS with introducing Isolator to building, the procedure will not be changed for analysis methods.

6. Results and discussion
The results are carried out by ETABS, Version (16.2.1), as below to present the comparison of the dynamic performance of the structure. The response of the eight-story structure is investigated under three different thickness based on their effective damping. Parameters like drift, displacement, story acceleration, frequency, and story velocity have been analyzed and it has been found that due to the presence of Lead Rubber Isolators the story drift, story accelerations, base shear, lateral shear forces, and velocity are greatly reduced and story displacement is increased in both X and Y directions are compared for isolated building with responses of non-isolated building under near and far-field earthquake excitations.

6.1. Storey Drift
It has been observed that on the dynamic behavior of the seismic response the Story drift response decreases from ground floor to the upper floor in a building structure in both X and Y direction as shown in figure 4 and figure 5.

![Figure 4](image1.png) **Figure 4.** Comparison of story drifts in the X direction for fixed base and 100mm, 200mm, 300mm.

In figure 4, it has been observed that when the concrete grade increases the story drift decrease. The drift response for all the models in X-direction has been obtained at various story levels. The story drifts for concrete grade M20 has been decreased by 31.68%, 15.59% and 11.94% for M1T2, M1T3, and M1T4, respectively on the 8th story when compare to M1T1.

- For concrete grade M30 the value of story drift t has been decreased by 53.70%, 40.68% and 16.63% for M2T2, M2T3, and M2T4, respectively at 8th story when compare to M2T1.
- The story drifts for concrete grade M40 have been decreased by 63.22%, 51.99% and 30.43% for M3T2, M3T3, and M3T4, respectively on the 8th story when compare to M3T1.

![Figure 5](image2.png) **Figure 5.** Comparison of story drift in the Y direction.
grade M40 the value of story drift has been decreased by 67.87%, 61.17% and 47.97% for M3T2, M3T3, and M3T4, respectively at 7th story when compare to M3T1. 

- The story drifts for concrete grade M20 has been decreased by 34.43%, 26.23% and 11.48% for M1T2, M1T3, and M1T4, respectively at 6th story when compare to M1T1. For concrete grade M30 the value of story drift has been decreased by 60.11%, 54.08% and 42.77% for M2T2, M2T3, and M2T4, respectively at 6th story when compare to M2T1. For concrete grade M40 the value of story drift has been decreased by 69.20%, 64.17% and 54.34% for M3T2, M3T3, and M3T4, respectively at 6th story when compare to M3T1. 

- The story drifts for concrete grade M20 has been decreased by 34.70%, 28.18% and 16.32% for M1T2, M1T3, and M1T4, respectively at the 5th story when compare to M1T1. For concrete grade M30 the value of story drift has been decreased by 60.08%, 55.14% and 46% for M2T2, M2T3, and M2T4, respectively at 5th story when compare to M2T1. For concrete grade M40 the value of story drift has been decreased by 68.81%, 64.64% and 56.53% for M3T2, M3T3, and M3T4, respectively at 5th story when compare to M3T1. 

- The story drifts for concrete grade M20 has been decreased by 29.89%, 24.30% and 13.34% for M1T2, M1T3, and M1T4, respectively at 4th story when compare to M1T1. For concrete grade M30 the value of story drift has been decreased by 58.20%, 53.96% and 46.20% for M2T2, M2T3, and M2T4, respectively at 4th story when compare to M2T1. For concrete grade M40 the value of story drift has been decreased by 67.07%, 63.36% and 56.25% for M3T2, M3T3, and M3T4, respectively at 4th story when compare to M3T1. 

- The story drifts for concrete grade M20 has been decreased by 25.18%, 19.72% and 9.97% for M1T2, M1T3, and M1T4, respectively at 3rd story when compare to M1T1. For concrete grade M30 the value of story drift has been decreased by 53.84%, 49.84% and 42.80% for M2T2, M2T3, and M2T4, respectively at 3rd story when compare to M2T1. For concrete grade M40 the value of story drift has been decreased by 64.52%, 61.04% and 54.71% for M3T2, M3T3, and M3T4, respectively at 3rd story when compare to M3T1. 

- The story drifts for concrete grade M20 has been increased by 255.81%, 260.20% and 272.56% for M1T2, M1T3, and M1T4, respectively at 1st story when compare to M1T1. For concrete grade M30 the value of story drift has been increased by 104.74%, 111.78% and 118.72% for M2T2, M2T3, and M2T4, respectively at 1st story when compare to M2T1. For concrete grade M40 the value of story drift has been increased by 52.53%, 58.19% and 64.73% for M3T2, M3T3, and M3T4, respectively at 1st story when compare to M3T1. 

In figure 5, it has been observed that when the concrete grade increases the story drift decrease. The drift response for all the models in X-direction has been obtained at various story levels. The story drifts for concrete grade M20 has been decreased by 41.91%, 23.93% and 19.68% for M1T2, M1T3, and M1T4, respectively at 8th story when compare to M1T1. 

- For concrete grade M30 the value of story drift t has been decreased by 38.66%, 24.58% and 13.84% for M2T2, M2T3, and M2T4, respectively at 8th story when compare to M2T1. For concrete grade M40 the value of story drift has been decreased by 54.32%, 42.45% and 19.91% for M3T2, M3T3, and M3T4, respectively at 8th story when compare to M3T1. 

- The story drifts for concrete grade M20 has been decreased by 50.66%, 41.65% and 31.84% for M1T2, M1T3, and M1T4, respectively on the 7th story when compare to M1T1. For concrete grade M30 the value of story drift has been decreased by 45.56%,
37.10% and 21.32% for M2T2, M2T3, and M2T4, respectively at 7th story when compare to M2T1. For concrete grade M40 the value of story drift has been decreased by 58.54%, 51.25% and 37.39% for M3T2, M3T3, and M3T4, respectively at 7th story when compare to M3T1.

- The story drifts for concrete grade M20 has been decreased by 33.58%, 25.61% and 27.56% for M1T2, M1T3, and M1T4, respectively at 6th story when compare to M1T1.
- For concrete grade M30 the value of story drift has been decreased by 42.39%, 35.52% and 22.91% for M2T2, M2T3, and M2T4, respectively at 6th story when compare to M2T1. For concrete grade M40 the value of story drift has been decreased by 58.88%, 53.16% and 42.58% for M3T2, M3T3, and M3T4, respectively at 6th story when compare to M3T1.
- The story drifts for concrete grade M20 has been decreased by 22.59%, 15.45% and 22.87% for M1T2, M1T3, and M1T4, respectively at the 5th story when compare to M1T1. For concrete grade M30 the value of story drift has been decreased by 39.44%, 33.65% and 22.92% for M2T2, M2T3, and M2T4, respectively at 5th story when compare to M2T1. For concrete grade M40 the value of story drift t has been decreased by 59.24%, 54.70 and 46.24% for M3T2, M3T3, and M3T4, respectively at 5th story when compare to M3T1.
- The story drifts for concrete grade M20 has been decreased by 21.52%, 16.19% and 21.90% for M1T2, M1T3, and M1T4, respectively on the 4th story when compare to M1T1. For concrete grade M30 the value of story drift has been decreased by 37.03%, 32.19% and 22.87% for M2T2, M2T3, and M2T4, respectively at 4th story when compare to M2T1. For concrete grade M40 the value of story drift has been decreased by 57.01%, 53.125% and 45.87% for M3T2, M3T3, and M3T4, respectively at 4th story when compare to M3T1.
- The story drift t for concrete grade M20 has been increased by 292.63%, 300% and 304.61% for M1T2, M1T3 and M1T4, respectively at 1st story when compare to M1T1.
- For concrete grade M30 the value of story drift has been increased by 216.667%, 225% and 232.16% for M2T2, M2T3, and M2T4, respectively at 1st story when compare to M2T1. For concrete grade M40 the value of story drift has been increased by 112.67%, 119.284% and 126.26% for M3T2, M3T3, and M3T4, respectively at 1st story when compare to M3T1.
6.2. **Storey Displacement**

It has been observed that on the dynamic behaviour of the seismic response the displacement response increases from the ground floor to the upper floor in a building structure as shown in figure 6 and figure 7.

![Figure 6. Comparison Story Displacement in the X direction.](image1)

![Figure 7. Comparison Story Displacement in Y direction.](image2)

In figure 6 it has been observed that when the concrete grade increases the story displacement also increases. The displacement response for all the models in X-direction has been obtained at various story levels. The story displacement for concrete grade M20 has been increased by 134.20%, 142.66% and 155.03% for M1T2, M1T3 and M1T4, respectively at the 8th story when compare to M1T1.

- For concrete grade M30 the value of story displacement has been increased by 54.32%, 60.66% and 70.37% for M2T2, M2T3, and M2T4, respectively at the 8th story when compare to M2T1.
- For concrete grade M40 the value of story displacement has been increased by 28.59%, 33.9% and 42.89% for M3T2, M3T3, and M3T4, respectively at 8th story when compare to M3T1.

- The story displacement for concrete grade M20 has been increased by 143.02%, 151.02% and 162.08% for M1T2, M1T3 and M1T4, respectively at the 7th story when compare to M1T1.
- For concrete grade M30 the value of story displacement has been increased by 59.52%, 65.66% and 74.51% for M2T2, M2T3, and M2T4, respectively at 7th story when compare to M2T1.
- For concrete grade M40 the value of story displacement has been increased by 32.89%, 37.9% and 46.29% for M3T2, M3T3, and M3T4, respectively at 7th story when compare to M3T1.
- The story displacement for concrete grade M20 has been increased by 162.23%, 170.02% and 180.50% for M1T2, M1T3 and M1T4, respectively at 6th story when...
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compare to M1T1. For concrete grade M30 the value of story displacement has been increased by 70.19%, 76.05% and 84.55% for M2T2, M2T3, and M2T4, respectively at 6th story when compare to M2T1. For concrete grade M40 the value of story displacement has been increased by 41.89%, 46.77% and 54.68% for M3T2, M3T3, and M3T4, respectively at 6th story when compare to M3T1.

- The story displacement for concrete grade M20 has been increased by 193.02%, 200.76% and 210.59% for M1T2, M1T3 and M1T4, respectively at 5th story when compare to M1T1. For concrete grade M30 the value of story displacement has been increased by 89.41%, 95.23% and 103.17% for M2T2, M2T3, and M2T4, respectively at 5th story when compare to M2T1. For concrete grade M40 the value of story displacement has been increased by 58.25%, 63.10% and 70.72% for M3T2, M3T3, and M3T4, respectively at 5th story when compare to M3T1.

- The story displacement for concrete grade M20 has been increased by 242.08%, 249.965% and 259.11% for M1T2, M1T3 and M1T4, respectively at 4th story when compare to M1T1. For concrete grade M30 the value of story displacement has been increased by 86.18%, 91.15% and 98.63% for M2T2, M2T3, and M2T4, respectively at 4th story when compare to M2T1. For concrete grade M40 the value of story displacement has been increased by 58.25%, 63.10% and 70.72% for M3T2, M3T3, and M3T4, respectively at 4th story when compare to M3T1.

- The story displacement for concrete grade M20 has been increased by 335.05%, 343.54% and 351.92% for M1T2, M1T3 and M1T4, respectively at 3rd story when compare to M1T1. For concrete grade M30 the value of story displacement has been increased by 186.35%, 192.94% and 200.03% for M2T2, M2T3, and M2T4, respectively at 3rd story when compare to M2T1. For concrete grade M40 the value of story displacement has been increased by 138.30%, 143.69% and 151.28% for M3T2, M3T3, and M3T4, respectively at 3rd story when compare to M3T1.

- The story displacement for concrete grade M20 has been increased by 565.79%, 576.18% and 583.57% for M1T2, M1T3 and M1T4, respectively at 2nd story when compare to M1T1. For concrete grade M30 the value of story displacement has been increased by 332.45%, 340.67% and 348.44% for M2T2, M2T3, and M2T4, respectively at 2nd story when compare to M2T1. For concrete grade M40 the value of story displacement has been increased by 258.83%, 265.37% and 273.78% for M3T2, M3T3, and M3T4, respectively at 2nd story when compare to M3T1.

- The story displacement for concrete grade M20 has been increased by 1403.1%, 1419.83% and 1423.57% for M1T2, M1T3 and M1T4, respectively at 1st story when compare to M1T1. For concrete grade M30 the value of story displacement has been increased by 903.19%, 917.70% and 926.78% for M2T2, M2T3, and M2T4, respectively at 1st story when compare to M2T1. For concrete grade M40 the value of story displacement has been increased by 732.29%, 743.68% and 755.67% for M3T2, M3T3, and M3T4, respectively at 1st story when compare to M3T1.

In figure 7 it has been observed that when the concrete grade increases the story displacement also increases. The displacement response for all the models in Y-direction has been obtained at various story levels. The story displacement for concrete grade M20 has been increased by 160.75%, 168.52% and 180.25% for M1T2, M1T3 and M1T4, respectively at 8th story when compare to M1T1.

- For concrete grade M30 the value of story displacement has been increased by 109.84%, 117.03% and 127.74% for M2T2, M2T3, and M2T4, respectively at 8th story when compare to M2T1. For concrete grade M40 the value of story displacement has been increased by 60.20%, 66.23% and 75.48% for M3T2, M3T3, and M3T4, respectively on the 8th story when compare to M3T1.

- j) The story displacement for concrete grade M20 has been increased by 170.09%, 177.36% and 187.88% for M1T2, M1T3 and M1T4, respectively at 7th story when
The story displacement for concrete grade M20 has been increased by 117.64%, 124.40% and 134.24% for M2T2, M2T3, and M2T4, respectively at 7th story when compared to M2T1. For concrete grade M40 the value of story displacement has been increased by 66.13%, 71.87% and 80.43% for M3T2, M3T3, and M3T4, respectively at 7th story when compared to M3T1.

k) The story displacement for concrete grade M20 has been increased by 186.41%, 193.32% and 202.92% for M1T2, M1T3 and M1T4, respectively at 6th story when compared to M1T1. For concrete grade M30 the value of story displacement has been increased by 134.37%, 140.99% and 150.92% for M2T2, M2T3, and M2T4, respectively at 6th story when compared to M2T1. For concrete grade M40 the value of story displacement has been increased by 77.51%, 83.07% and 91.07% for M3T2, M3T3, and M3T4, respectively at 6th story when compared to M3T1.

l) The story displacement for concrete grade M20 has been increased by 215.61%, 222.35% and 231.36% for M1T2, M1T3, and M1T4, respectively on the 5th story when compared to M1T1. For concrete grade M30 the value of story displacement has been increased by 161.82%, 168.39% and 176.98% for M2T2, M2T3, and M2T4, respectively at 5th story when compared to M2T1. For concrete grade M40 the value of story displacement has been increased by 97.96%, 103.50% and 111.10% for M3T2, M3T3, and M3T4, respectively at 5th story when compared to M3T1.

m) The story displacement for concrete grade M20 has been increased by 266.61%, 273.40% and 280.78% for M1T2, M1T3 and M1T4, respectively at the 4th story when compared to M1T1. For concrete grade M30 the value of story displacement has been increased by 206.64%, 213.36% and 221.44% for M2T2, M2T3, and M2T4, respectively at 4th story when compared to M2T1. For concrete grade M40 the value of story displacement has been increased by 134.77%, 140.52% and 147.88% for M3T2, M3T3, and M3T4, respectively at 4th story when compared to M3T1.

n) The story displacement for concrete grade M20 has been increased by 365.11%, 372.24% and 379.79% for M1T2, M1T3 and M1T4, respectively at 3rd story when compared to M1T1. For concrete grade M30 the value of story displacement has been increased by 292.04%, 299.34% and 306.94% for M2T2, M2T3, and M2T4, respectively at 3rd story when compared to M2T1. For concrete grade M40 the value of story displacement has been increased by 201.46%, 207.77% and 215.11% for M3T2, M3T3, and M3T4, respectively at 3rd story when compared to M3T1.

o) The story displacement for concrete grade M20 has been increased by 585.3%, 593.49% and 600% for M1T2, M1T3 and M1T4, respectively at 2nd story when compared to M1T1. For concrete grade M30 the value of story displacement has been increased by 499.58%, 508.54% and 515.63% for M2T2, M2T3, and M2T4, respectively at 2nd story when compared to M2T1. For concrete grade M40 the value of story displacement has been increased by 358.28%, 366.18% and 373.65% for M3T2, M3T3, and M3T4, respectively at 2nd story when compared to M3T1. For concrete grade M40 the value of story displacement has been increased by 981.93%, 996.14% and 1005.03% for M3T2, M3T3, and M3T4, respectively at 1st story when compared to M3T1.

6.3. Spectral Acceleration.

It has been observed that on the dynamic behavior of the seismic response the spectral acceleration response increases as the grade of concrete increases as shown in figure 8.
- The spectral acceleration has been found to be maximum i.e. 0.756816g at response time 1.25 sec in the case of M40. Similarly the same has been found to be maximum i.e. 0.756816g at time 1.25 sec. The spectral acceleration in the case of M30 found to be 0.685512g at response time 1.265 sec. The spectral acceleration in the case of M20 found to be 0.393634g at response time 1.265sec. So, it can be inferred that as the grade of concrete increase the spectral acceleration also increases.

6.4. Spectral Displacement
It has been observed that on the seismic response, the spectral displacement response increases as the time response increases, it has been also observed that higher the concrete grade the higher will be the spectral displacement. Such spectral displacement response has been deployed in the forthcoming section as shown in figure 9.
- The value of spectral displacement has been increased for all the models (M1T1, M1T2 M1T3, and M1T4) of concrete grade M20. The spectral displacement has been found to be maximum i.e. 474.663mm at response time 5sec in the case of modal M1T4 for concrete M20. The spectral displacement has been found to be maximum i.e. 461.925mm at response time 5sec in the case of modal M1T3 for concrete M20. The spectral displacement has been found to be maximum i.e. 453.861mm at response time 5sec in the case of modal M1T3 for concrete M20. The spectral displacement has been found to be maximum i.e. 319.817mm at response time 5sec in the case of modal M1T1 for concrete M20.

6.5. Spectral Velocity
It has been observed that the dynamic behavior of the seismic response of the spectral velocity response increases as the grade of concrete increases. Such a spectral velocity response has been deployed in the forthcoming section as shown in figure 10.
- The spectral velocity has been found to be maximum i.e. 1391.4 mm/sec at response time 1.39 sec in the case of M40. Similarly the same has been found to be maximum i.e. 1391.4 mm/sec at response time 1.39 sec. The spectral velocity in the case of M30 found to be 1325.7 mm/sec at response time 1.265 sec. The spectral velocity in the case of M20 found to be 769.8mm/sec at response time 1.265sec. So, it can be inferred that as the grade of concrete increase the spectral velocity also increases.

6.6. Base Shear
Base shear is an estimate of the maximum expected lateral force that will occur at the base of a structure due to seismic ground motion. Infect base shear is a similar cumulative story shear from top to bottom story of the building structure as shown in figure 11.
The base shear response for all the models in X-direction has been obtained. The base shear for concrete grade M20 has been decreased by 150.10%, 149.61%, and 149.003% for M1T2, M1T3, and M1T4, respectively when compared to M1T1. For concrete grade M30 the value of base shear has been decreased by 147.14%, 147.14%, and 146.038% for M2T2, M2T3, and M2T4, respectively when compared to M2T1. For concrete grade M40 the value of base shear has been decreased by 145.024%, 144.56%, and 143.89% for M3T2, M3T3, and M3T4, respectively when compared to M3T1.

6.7. Lateral Shear

It has been observed that the dynamic behaviour of the seismic response of the lateral shear forces response increases from the ground floor to the upper floor in a building structure. Such lateral shear forces response has been deployed in the fourth coming section as shown in figure 12.
The lateral story force for all the models in X-direction has been obtained at various story levels. The lateral story force for concrete grade M20 has decreased by 49.89%, 50.38% and 50.98% for M1T2, M1T3, and M1T4, respectively at 8th story when compare to M1T1.

For concrete grade M30 the value of lateral story force has decreased by 52.85%, 53.32% and 53.95% for M2T2, M2T3, and M2T4, respectively at the 8th story when compare to M2T1. For concrete grade M40 the value of lateral story force has decreased by 54.97%, 55.43% and 56.06% for M3T2, M3T3, and M3T4, respectively on the 8th story when compare to M3T1.

The lateral story force for concrete grade M20 has decreased by 49.89%, 50.38% and 50.98% for M1T2, M1T3, and M1T4, respectively at 7th story when compare to M1T1. For concrete grade M30 the value of lateral story force has been decreased by 52.85%, 53.32% and 53.95% for M2T2, M2T3, and M2T4, respectively at 7th story when compare to M2T1. For concrete grade M40 the value of lateral story force has been decreased by 54.97%, 55.43% and 56.06% for M3T2, M3T3, and M3T4, respectively at 7th story when compare to M3T1.

The lateral story force for concrete grade M20 has been decreased by 49.89%, 50.38% and 50.98% for M1T2, M1T3, and M1T4, respectively at 6th story when compare to M1T1. For concrete grade M30 the value of lateral story force has been decreased by 52.85%, 53.32% and 53.95% for M2T2, M2T3, and M2T4, respectively at 6th story when compare to M2T1. For concrete grade M40 the value of lateral story force has been decreased by 54.97%,

Figure 11. Comparison Base shear in X direction.

Figure 12. Comparison Lateral story force in the X-direction.
55.43% and 56.06% for M3T2, M3T3, and M3T4, respectively at 6th story when compare to M3T1.

- The lateral story force for concrete grade M20 has been decreased by 49.89%, 50.38% and 50.98% for M1T2, M1T3, and M1T4, respectively at 5th story when compare to M1T1. For concrete grade M30 the value of lateral story force has been decreased by 52.85%, 53.32% and 53.95% for M2T2, M2T3, and M2T4, respectively at 5th story when compare to M2T1. For concrete grade M40 the value of lateral story force has been decreased by 54.97%, 55.43% and 56.06% for M3T2, M3T3, and M3T4, respectively at 5th story when compare to M3T1.

- The lateral story force for concrete grade M20 has been decreased by 49.89%, 50.38% and 50.98% for M1T2, M1T3, and M1T4, respectively at 4th story when compare to M1T1. For concrete grade M30 the value of lateral story force has been decreased by 52.85%, 53.32% and 53.95% for M2T2, M2T3, and M2T4, respectively at 4th story when compare to M2T1. For concrete grade M40 the value of lateral story force has been decreased by 54.97%, 55.43% and 56.06% for M3T2, M3T3, and M3T4, respectively at 4th story when compare to M3T1.

- The lateral story force for concrete grade M20 has been decreased by 49.89%, 50.38% and 50.98% for M1T2, M1T3, and M1T4, respectively at 3rd story when compare to M1T1. For concrete grade M30 the value of lateral story force has been decreased by 52.85%, 53.32% and 53.95% for M2T2, M2T3, and M2T4, respectively at 3rd story when compare to M2T1. For concrete grade M40 the value of lateral story force has been decreased by 54.97%, 55.43% and 56.06% for M3T2, M3T3, and M3T4, respectively at 3rd story when compare to M3T1.

- The lateral story force for concrete grade M20 has been decreased by 49.89%, 50.38% and 50.98% for M1T2, M1T3, and M1T4, respectively at 2nd story when compare to M1T1. For concrete grade M30 the value of lateral story force has been decreased by 52.85%, 53.32% and 53.95% for M2T2, M2T3, and M2T4, respectively at 2nd story when compare to M2T1. For concrete grade M40 the value of lateral story force has been decreased by 54.97%, 55.43% and 56.06% for M3T2, M3T3, and M3T4, respectively at 2nd story when compare to M3T1.

- The lateral story force for concrete grade M20 has been decreased by 50.02%, 50.63% and 51.35% for M1T2, M1T3, and M1T4, respectively at 1st story when compare to M1T1. For concrete grade M30 the value of lateral story force has been decreased by 52.97%, 53.56% and 54.30% for M2T2, M2T3, and M2T4, respectively at 1st story when compare to M2T1. For concrete grade M40 the value of lateral story force has been decreased by 55.08%, 55.65% and 56.40% for M3T2, M3T3, and M3T4, respectively at 1st story when compare to M3T1.

6.8. Frequency

It has been observed that the dynamic behavior of the seismic response of the frequency increases as modes increases in a building structure. Such a frequency response has been deployed in the forthcoming section as shown in figure 13.

- The frequency has been found to be maximum i.e. 13.333Hz/sec at response mode 20 in the case grade of concrete increase, the frequency of the modal system also increases. It has been found that the 13.333Hz/sec in the case of M40 and the same for M30, M20 respectively. The frequency in the case of M30 found to be 11.23596Hz/sec at response mode 20. The frequency in the case of M20 found to be 12.596Hz/sec at response mode 20. So, it can be inferred that as the grade of concrete increase the spectral frequency also increases.
The seismic analysis of fixed base and base-isolated RCC frames has been carried out. 12 types M1T1, M2T1, M3T1, M1T2, M2T2, M3T2, M1T3, M2T3, M3T3, M1T4, M2T4, and M3T4 have been used under seismic zone IV conditions. The following are the conclusion of the study.

- The flexibility at the base of the building increases with the use of rubber bearing isolators.
- The use of base isolation decreases the story drift, increases displacement and gives better seismic protection during earthquakes...
- In 100mm, 200mm, and 300mm thickness of lead rubber isolated building models for concrete grade M20, story drift is reduced by 31.68%, 15.59% and 11.94% in the X direction and 41.91%, 23.93% and 19.68% in Y direction compared to the fixed base model.
- In 100mm, 200mm, and 300mm thickness of lead rubber isolated building models for concrete grade M30, story drift is reduced by 53.70%, 40.68% and 16.63% in the X direction and 38.66%, 24.58% and 13.84% in Y direction compared to the fixed base model.
- In 100mm, 200mm, and 300mm thickness of lead rubber isolated building models for concrete grade M40, story drift is reduced by 63.22%, 51.99% and 30.43% in the X direction and 54.32%, 42.45% and 19.91% in Y direction compared to the fixed base model.
- In 100mm, 200mm, and 300mm thickness of lead rubber isolated building models for concrete grade M20, story displacement is increased by 134.20%, 142.66% and 155.03% in...
the X direction and 160.75%, 168.52% and 180.25% in Y direction compared to the fixed base model.

- In 100mm, 200mm, and 300mm thickness of lead rubber isolated building models for concrete grade M30, story displacement is increased by 54.32%, 60.66% and 70.37% in the X direction and 109.84%, 117.03% and 127.74% in Y direction compared to the fixed base model.
- In 100mm, 200mm, and 300mm thickness of lead rubber isolated building models for concrete grade M40, story displacement is increased by 28.59%, 33.9% and 42.89% in X direction and 60.20%, 66.23% and 75.48% in Y direction compared to the fixed base model.
- In spectral acceleration as the grade of concrete increases, the acceleration peak also increases as been found to be in the case of M40, M30, with respect to M20.
- In spectral displacement it has been found that the value of spectral displacement has been increased for all the models with lead rubber base isolator (M1T2, M1T3, and M1T4) of concrete grade M20. And in spectral displacement as the grade of concrete increases, the displacement peak decreases. And it has been found to be in case of M40, M30, with respect to M20 in case of lead rubber isolated base of the story.
- In spectral velocity as the grade of concrete increased the velocity peak also increased. And it has been found to be in case of M40, M30, with respect to M20 in case of fixed and isolated base of the story.
- Base shear was decreased when the lead rubber base isolator being operational. The percentage of reduction has been found i.e. 150.10%, 149.61% and 149.003% in X direction to be in case of M20 with thickness of base isolator.100mm, 200mm, and 300mm.
- Base shear was decreased when the lead rubber base isolator being operational. The percentage of reduction has been found i.e. 147.14%, 147.14% and 146.038% in X direction to be in case of M30 with thickness of base isolator.100mm, 200mm, and 300mm.
- Base shear was decreased when the lead rubber base isolator being operational. The percentage of reduction has been found i.e. 145.024%, 144.56% and 143.89% in X direction to be in case of M40 with thickness of base isolator.100mm, 200mm, and 300mm.
- Lateral story forces decreased when the lead rubber base isolator being operational. The percentage reduction has been found i.e. 49.89%, 50.38% and 50.98% in X direction to be in case of M20 with thickness of base isolator.100mm, 200mm, and 300mm.
- Lateral story forces decreased when the lead rubber base isolator being operational. The percentage reduction has been found i.e. 52.85%, 53.32% and 53.95% in the X direction to be in case of M20 with a thickness of base isolator.100mm, 200mm, and 300mm.
- Lateral story forces decreased when the lead rubber base isolator being operational. The percentage reduction has been found i.e. 54.97%, 55.43% and 56.06% in the X direction to be in case of M20 with a thickness of base isolator.100mm, 200mm, and 300mm.
- The frequency increases as the strength of the concrete increases. However, the variation increases in the frequency is to the extent for concrete grade M20 found to be 11.596Hz/sec at response on mode 20. For concrete grade M30 found to be 12.23596Hz/sec at the response on mode 20. For concrete grade M40 found to be 13.3333Hz/sec at the response on mode 20.
- The effect of higher energy seismic waves mitigated by using the different thickness of lead rubber base isolators
- It is more important to isolate the structure from the source of seismic force through some medium of the material of stiffness lesser than the stiffness of the structure.

8. Recommendation
More study on base isolation needs to be done in view of the various base isolators available in the market.

More study can be done on 100mm 200mm 300mm lead rubber base isolators with more concrete grade.

More study can be done on the geometry of base isolators.

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