# Effectiveness of Specific Rubber Bearing Isolator for Multi-storeyed Residential Building in Dhaka

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## Abstract

Earthquake is one of the most dreadful, sudden and uncontrolled natural disasters. ‘Base Isolation’ is one of the popular seismic retrofitting techniques used through-out the world. The prime objective of this study is to identify the effectiveness of a specific rubber bearing isolator in reducing the overall drift of a structure caused by lateral forces like earthquake. An 8 storey RCC building assumed to be located in the moderate seismic zone of Bangladesh is taken as a reference for this work. The building is modelled with and without base ‘Isolator’ by using the finite element software ‘SAP 2000’ and designed by adopting the building design code ‘ACI 318’. It is evident from the research that, use of the rubber bearing isolator increases the fundamental period of vibration and the overall displacement of the structure to a greater extent. At the same time the relative storey drift decreases significantly. Though the whole work focuses on a specific example, but it paves the way for the design of rubber bearing isolators which can be used in the multi-storeyed residential buildings with confidence.

**Keywords:** Earthquake, Base Isolation, Relative Displacement

## Introduction

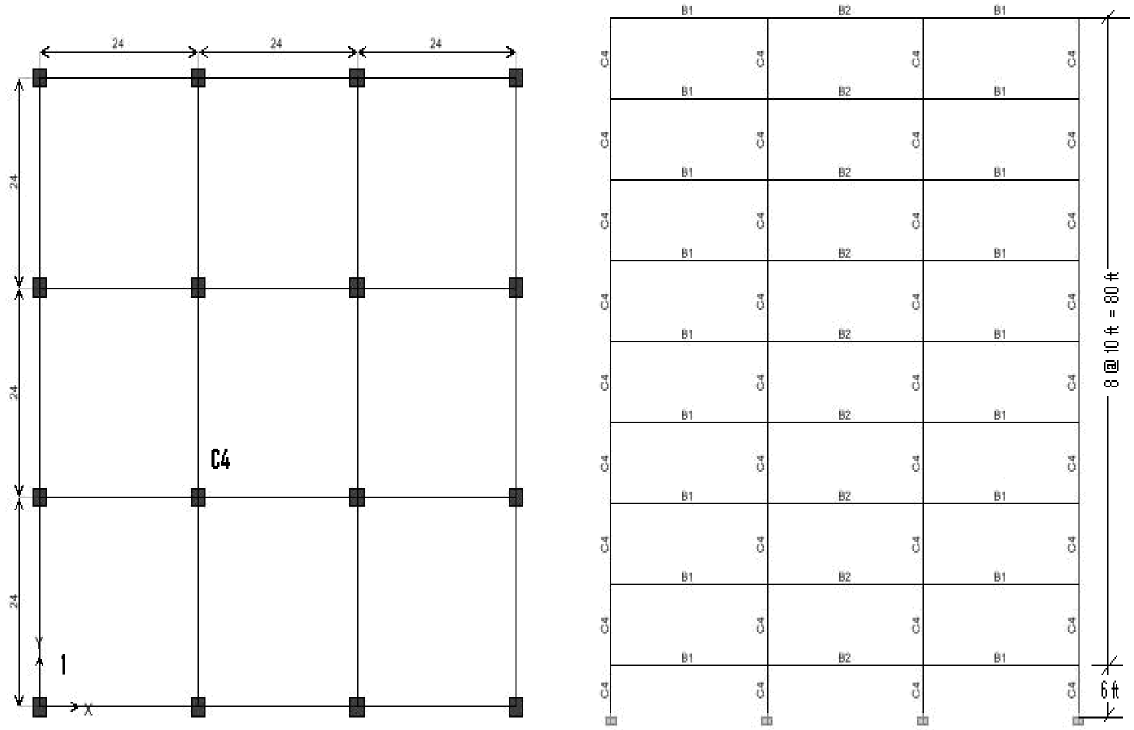
Earthquake can be called as one of the most dreadful, sudden and uncontrolled natural disasters especially for a country like Bangladesh which stands in the earthquake prone zone of the world. An examination of the historical background of Bangladesh and its surrounding region reveals that several earthquakes of large magnitude with epicentres within the region have occurred in the past. The Great Indian earthquake (1897) with a magnitude of 8.7 (Oldham, 1899) is one of the strongest earthquakes in this region as well as in the world. It had its epicentre only 230 km from Dhaka. Not only this, Dhaka has been pointed out as one of the most vulnerable towns due to its large population density to any type of natural calamities. Since 'Base Isolation' is one of the popular seismic retrofitting techniques used through-out the world, the prime objective of this study is to identify the effectiveness of a specific rubber bearing isolator in reducing the overall drift of a structure caused by lateral forces like earthquake. An 8 storey RCC building assumed to be located in Dhaka, the moderate seismic zone of Bangladesh, is taken as a reference for this work.

## Research Approach

The scope of this research work is to examine the effectiveness of a rubber bearing isolator while using it in an 8 storey residential building. Firsty, the structure is analysed by assuming it as a fixed base structure and then based on the site geology, displacement data, time period and weight of the structure, an isolator is chosen. Later on, the structure is re-analysed by incorporating that isolator at the ground level in between the foundation and column. Analyses have been done in three steps i.e. linear static analysis, response spectrum analysis based upon the site geology of Dhaka and time history analysis with suitable ground motion. Reinforced concrete is designed according to the American Concrete Institute's (ACI) regulations, base isolation designs conform to Uniform Building Code (UBC 1997) requirements, and seismic zonation is developed from Bangladesh National Building Code (BNBC-2006). Modelling and analysis of the structure is performed by using the finite element software SAP 2000.

## Assumptions for the Assignment

The eight storey residential building is assumed to be located in Dhaka, Bangladesh. Preliminary assumptions regarding the design of the structure are: Concrete compressive strength, $f'_c$= 4000 psi, Steel yield stress, $f_y$ = 60000 psi, dead load (excluding self-weight) = 120 psf, live load = 40 psf, slab thickness = 6 inches, columns are all 24 in. by 24 in. square whilst the ground level beams are 12 in. by 18 in. each. All other beams are of 12 in. by 24 in. sizes. The plan and elevation of the building is provided in Figure 1. In order to identify the variation of the outcomes, mark ***1*** at the top storey level has been chosen as benchmark. Rubber properties for isolator are G= 58 psi, $\beta$ = 0.08, Maximum shear strain, $\gamma$ = 1.5. Each isolator is 30 inches in diameter having a total depth of 11 inches. There are 16 layers of laminated rubbers each having a thickness of 0.5 inches. The top and bottom bearings are of 1.5 inch depth. The bearing of isolator is assumed to have 15% damping for which the damping coefficient ($B_D$) of the isolator will be ***1.35***.




a) Plan View b) Elevation

Figure 1 Plan & elevation of the hypothetical structure

In order to design the reinforced concrete structure, all the loadings have been considered as per BNBC-2006. The building is located in Dhaka, which is in Zone-2 and zone coefficient (Z) is ***0.15***. The importance coefficient (I) for this residential building is considered as ***1.0*** for standard occupancy category. The soil profile is assumed to be 'S3', which resembles to the $S_D$ soil profile of Uniform Building Code (UBC-1997). For '$S_3$' soil profile the site coefficient is ***1.5***. From the past historic data of earthquake occurrences, it is found that most of the severe earthquakes affecting Bangladesh are of large magnitudes. Hence, 'Seismic Source Type' can be considered as '***A***'. Also the distance of epicentre of major earthquakes affecting Bangladesh from Dhaka is found ***greater than 15 Km***. Since, closest distance to seismic source > 15 Km and seismic source type is 'A', both the values of $N_a$ and $N_v$ are found as ***1.0***. Hence, the value of $Z*N_V$ = 0.15*1.0 = 0.15. With this value of $Z*N_v$ in hand, the maximum capable earthquake coefficient $M_M$ is found as ***2.0***. The value of $M_M*Z*N_V$ is computed as 0.30, which is less than 0.40. With this value of $M_M*Z*N_V$ and soil profile $S_D$ the value of $C_{AM}$ and $C_{VM}$ is obtained as ***0.37*** and ***0.55*** according to UBC-1997. The value of $C_A$ and $C_v$ (from UBC-1997 for Z =0.15 and soil Profile Type '$S_3$') is found as ***0.22*** and ***0.32***. Using these values of $C_A$ and $C_V$, a response spectrum curve has been derived. Furthermore, for time history analysis, ALTADENA-1 & 2 have been selected to be assigned in x and y direction.

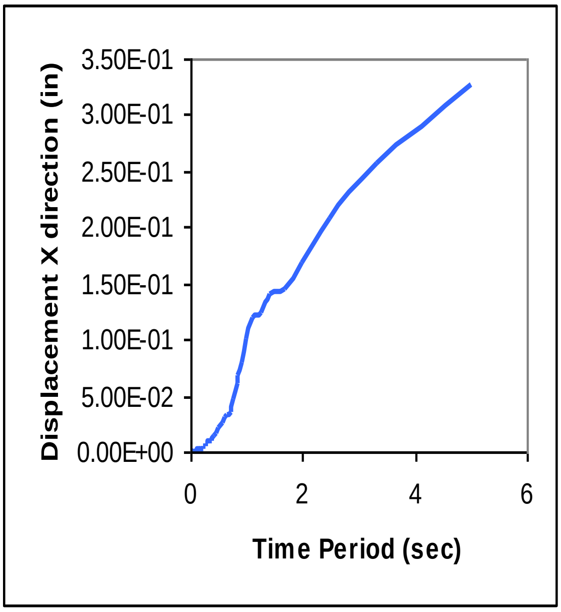
## Results and Interpretations

The 3D structural model prepared in SAP 2000 is analysed in fixed base and isolated base condition. The results are presented in table-1.

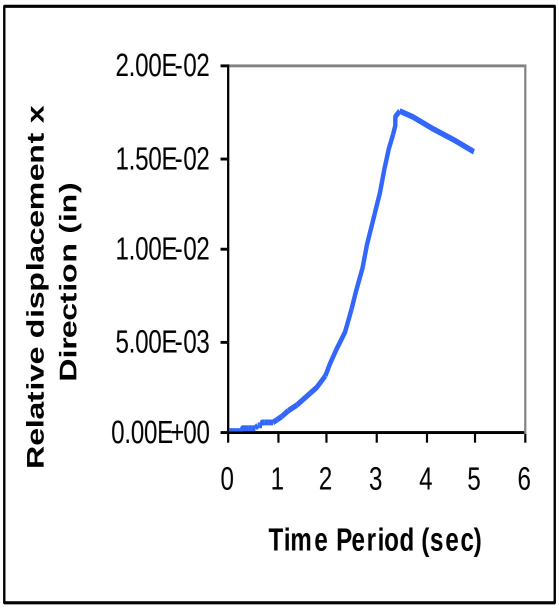
*Table 1: Structural outcomes in fixed base and isolated base condition*

| *Observed Items* | *Without using Isolator* | *Using Isolator* |
|---|---|---|
| *Fundamental Natural Period (sec)* | *0.613* | *3.748* |
| *Top story Displacement in x direction (inch) for earthquake load* | *0.630* | *0.437* |
| *Top story Displacement in y direction (inch) for earthquake load* | *-0.705* | *-0.548* |
| *Top story (Bottom Story) Displacement in x and y direction for response spectrum analysis (inch)* | *2.446 (0)* | *11.220 (11.1575)* |
| *Relative Displacement at top in x and y Direction for response spectrum analysis (inch)* | *2.446* | *0.0625* |
| *Total weight of building, W (kips)* | *9596.877* | |

It is evident from the above table that the fundamental natural period of the structure increases almost six folds after using isolators at the foundation level which is a significant improvement against the possibility of resonance due to the ground motion. For the fixed base structure in linear static case, the maximum top storey displacement is observed as 0.705 inches relative to the base due to the earthquake forces coming from y direction whilst this value decreases to 0.548 inches after using isolators. In case of response spectrum analysis, top storey displacement comes like 2.446 inches for the fixed base structure. Interestingly, this value decreases to 0.0625 inches while isolators are used. The result of the time history analysis ends up with the same interpretation and is provided in Figure 2.




a) Fixed Base Structure




b) Isolated Base Structure

Figure 2 Displacement of total structure in x direction due to time history loading

The maximum isolator deformation is observed as 0.08 inches, which is only 0.267% of the isolator's diameter (30 in.) and 0.73% of its depth. This indicates that the isolator will still be in the elastic limit without damaging its performances and behaviour. Figure 3 shows the isolator deformation in x and y direction for time history loading.

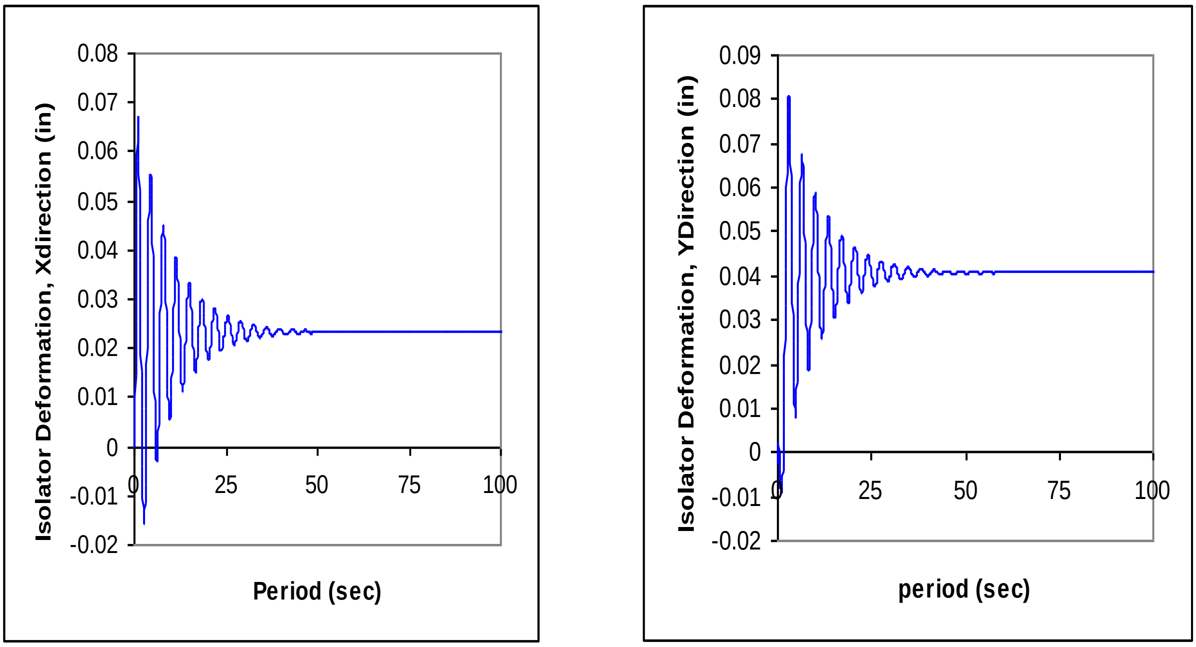



Figure 3 Isolator deformations in x and y direction due to time history loading

## Conclusion

The analysis of the isolated and non-isolated structure reveals that the use of specific rubber bearing isolator increases the fundamental period of the structure and thus reduces the possibility of increased base shear to the structure within a very short time. Moreover, isolators increase the overall displacement of the structure but reduce the relative displacement significantly, which enables the structural members (column, beam etc.) to withstand lesser torsional forces. Importantly, the rubber bearing undergoes very minor deformation which helps it remain elastic in nature and recoverable after the removal of lateral loading. Hence the devices are expected to be working under multiple events.

Base Isolation can turn out to be the best design in so far as structural safety against earthquake tremors is concerned. The parametric study explores the fact that, proper design of base isolation system by using rubber bearing isolators can work effectively under low to moderate seismic loading.

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