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Evaluation of Structural Implication of Incorporating Base Isolator as Earthquake Protection Device

Md.Arman Chowdhury[1], Rajib Kumar Biswas[2,] Md.Nazmul Haq[3,]
Syeed Md. Iskander[4]

[1](*Graduate student, Department of Civil Engineering, Ahsanullah University of Science and Technology)*
[2](*Undergraduate student, Department of Civil Engineering, Ahsanullah University of Science and Technology)*
[3](*Graduate student, Department of Civil Engineering, Bangladesh University of Engineering and Technology)*
[4](*Lecturer, Department of Civil Engineering, Ahsanullah University of Science and Technology)*

Abstract : *Introduction of the flexible element at the base of a structure and at the same time ensuring damping is probably the best option for the seismic isolation technique. The device that meets such criteria is known as isolator. In this study incorporation of such base isolator in buildings has been investigated. A study was done considering different building with different plan to justify the applicability of base isolation. The characteristics and performance effect of a building with and without base isolator system were compared. Study shows the applicability of base isolator to the range up to buildings of 30m-40m height. The installation of isolator in building considerably increases the time period of building, which means it reduces the possibility of resonance of the structure. Provision of isolator in building often increases the total cost, but reinforcement requirement and construction material cost is reduced due to isolator. So, isolator may be incorporated at the bottom of the building to exploit economic and structurally safe alternative.*
Keywords: *Equivalent Static Analysis, Time history method, Base Isolation, Reinforce concrete building.*

I. Introduction

Historical seismic catalogues reveal that Bangladesh has been affected by earthquake since ancient times. Earthquakes occurred in 1664, 1828, 1852 and 1885 are shown to have Dhaka as epicentral area.
Similarly cities like Rangpur, Sylhet, Mymensing, Chittagong, Saidpur, Sirajgong, Pabna etc. have been shown to be the epicentral area of some of the major earthquakes in the past. Although the ancient record do not specify the earthquake epicenter by giving coordinates in terms of latitude and longitude. It is difficult to figure out whether these cities were directly hit by earthquakes. However occurrence of earthquakes both inside and outside of the country and around major cities indicates that earthquake hazard exists for the country in general and the cities in particular. Consideration of earthquake forces in structural design, city planning and infrastructure development is therefore a prerequisite for future disaster mitigation.

Several earthquake of large magnitude (Richter magnitude 7.0 or higher) with epicenters within Bangladesh and India close to Indo-Bangladesh have occurred (AM and Chowdhury, 1994). **Table 1** and **Table 2** provide lists of the major earthquakes that have affected Bangladesh and its surroundings. Furthermore the country is divided into three zones determined from the earthquake magnitude for various return periods and the acceleration attenuation relationship (Ali and Chowdhury, 1994) namely zones 1,2,3 being most to least severe gradually (BNBC, 1993).

Table 1. Lists of Major Earthquakes Affecting Bangladesh

Date of occurrence	Name (Place)	Magnitude	Epicenter distance from Dhaka(Km)
10 Jan 1869	Cachar Earthquake	7.5	250
14 Jul 1885	Bengal earthquake(Bogra)	7.0	170
12 Jun 1897	Great Indian Earthquake	8.7	230
08 Jul 1918	Srimangal Earthquake (Srimangal)	7.6	150
02 Jul 1930	Dhubri Earthquake	7.1	250
15 Jan 1934	Bihar-Nepal Earthquake(Bihar)	8.3	510
15 Aug 1950	Asam Earthquake (Aasm)	8.5	780

Table 2. Recent Major earthquakes in Bangladesh (Ansary, 2005)

Date of Occurrence	Name(Place)	Magnitude	Epicentral distance from Dhaka (Km)
08 May 1997	Sylhet Earthquake (Sylhet)	6.0	210
21 Nov 1997	Chittagong Earthquake (Chittagong)	5.5	264
22 Jul 1999	Moheskhali Earthquake (Cox's Bazar)	5.2	300
27 Jul 2003	Chittagong-Rangamati Earthquake	5.9	290

The historical seismicity data of Bangladesh and adjoining areas indicate that Bangladesh is vulnerable to earthquake hazards. As Bangladesh is the world's most densely populated area, any future earthquake shall affect more people per unit area than any other seismically active regions of the world. Both of the above factors call for evaluation of seismic hazard of Bangladesh so that proper hazard mitigation measure may be undertaken before it is too late.

The basic objective of the research is to: 1) Conduct a through literature survey on the base isolation principle and its suitability for use in buildings. 2) Perform non linear dynamic analysis of buildings with isolated bearings and non-isolated one.

The investigation gives emphasis on the feasibility of incorporation of isolators and its structural implication on buildings is limited to the following extents: 1) Only buildings in Dhaka are considered in this work. 2) Two types of isolators namely high damping rubber bearing and lead rubber bearing is considered in this research.

II. MODAL ANALYSIS

A base isolated demonstration building has been considered in Dhaka, Bangladesh as part of an ongoing effort to promote the use of base isolation technology for common structures in earthquake-prone developing countries. The superstructure of the demonstration building I a ten-story reinforced concrete frame.

A specially developed isolation system for this project consisted of 25 lead rubber bearings which were connected to all the column and foundation using recessed-type connections at the ground level. Developed site-specific spectra were used for the design of the isolation system. The building is of 4 spacing @7.62m c/c in both directions. Chosen properties are: f'c=28MPa, f_y=414MPa, dead load(excluding self weight)=4.8 KPa, Live load=2.4KPa, slab thickness=150mm, Exterior corner column are all C1=750x750mm, Exterior middle column are all C2=950x950mm,Interior columns are all C3=1000x1000mm, Grade beams are GB=300x375mm, and beam B1=525x825mm each, beam B2=600x900mm each, beam B3=550x900mm each. SAP2000 version 15 was used for Analysis and Design.

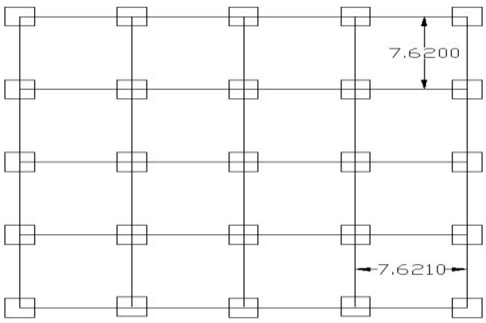

Figure 1: Plan of the Building

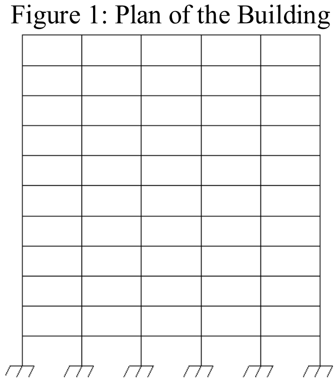

Figure 2: Elevation view of the building

III. DESIGN EARTHQUAKE FOR DYNAMIC ANALYSIS

There is a lack of suitable earthquake result in Bangladesh. In this study an earthquake record obtained at lacc_nor-1.th (Figure 3) and lacc_nor-2.th (Figure 4) is used for the analysis.

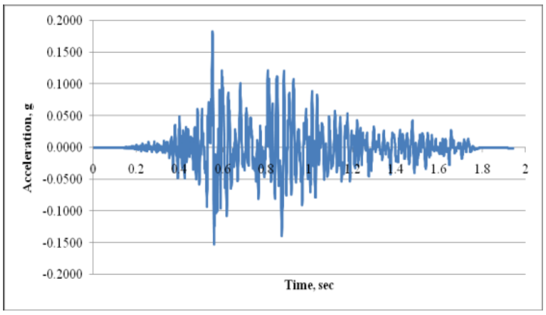

Figure 3: lacc_nor-1.th

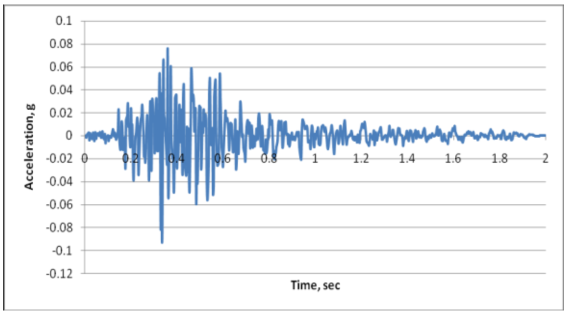

Figure 4: lacc_nor-2.th

IV. RESULT AND DISCUSSIONS

Linear static analysis

From **Table 3** we can see that design shear for earthquake loading is greater than that for wind loading and the structural time period is in within the reasonable value of 0.1-1.0 sec which is within maximum severity range. (Soleimanloo, 2012) Again here lateral load due to wind is less than 10% of the weight of the building which is another criteria for using the base isolation concept. So, we can incorporate isolator at the base of the structure to justify more about the feasibility of base isolation.

Table 3: Data obtained after static analysis without isolator

Structural Time period	0.913
Design Base Shear (EQ load)	4785KN
Design Base Shear (Wind Load)	2789KN
Top story displacement in U1 direction (EQ load)	13.70mm
Top story displacement in U2 direction (EQ load)	11.8mm
Top story displacement in U1 direction (Wind load)	7.0mm
Top story displacement in U2 direction (Wind load)	6.8mm
Total weight of the Building	128040KN
Governing axial load under column C3(Linear analysis)	7190KN
Governing axial load under column C2(Linear analysis)	4602KN
Governing axial load under column C1(Linear analysis)	2575KN

Time History Analysis

A Non linear time history analysis was performed by choosing appropriate time history i.e. ground motion that resembles the site condition of the structure. We have selected here lacc nor-1.TH in the X direction and lacc nor-2.TH in the Y direction. Here result for dynamic analysis is shown in **Table 4.**

Table 4: Data obtained after dynamic analysis without using isolator (Time history analysis)

Design Base Shear in X direction	19590KN
Design Base Shear in Y direction	14495KN
Design Base Moment in X direction	123690KN-m
Design Base Moment in Y direction	76770KN-m
Top story displacement in U1 direction	33mm
Top story displacement in U2 direction	30.8mm

Result of Analysis using Isolator

Assigning the value of the stiffness to the isolators and analyzing the structure with isolator by SAP2000 we get the following result (Table 5a and 5b). The seismic performance is evaluated for the maximum seismic events.

Table 5.a: Displacement after dynamic analysis using isolator

	Isolator displacement(mm)	Total structural drift (mm)
U1 Direction(static Analysis)	151.6	56.3
U2 Direction (Static Analysis)	145.8	53.1
U1 Direction (Time History Analysis)	119.1	30.1
U2 Direction (Time History Analysis)	73.8	28.6
Structural period for model	2.85sec	

Table 5.b: Base Shear and Base Moment after dynamic analysis using isolator

	Time history analysis
Design Base Shear in X direction	7803KN
Design Base Shear in Y direction	4837.3KN
Design Base Moment in X direction	43932.1KN-m
Design Base Moment in Y direction	26930.8KN-m

All Values of maximum displacements at Table 6 lie below the design displacement 292.61mm. So, the isolator properties are satisfactory.

Table 6: Comparison of Drift in isolated and non-isolated structure

		Base displacement (mm)	Top displacement (mm)	Total structure drift (mm)
Isolated Building	U1	119.1	149.2	30.1
	U2	73.8	102.4	28.6
Non Isolated Building	U1	12.59	133.35	120.76
	U2	3.23	37.57	40.8

V. CONCLUSION

Seismic response and characteristics of an isolated and non-isolated building is studied using the finite element method by SAP 2000. An elaborate investigation of the influence of various parameters involved in isolation is performed. For the detail analysis and design, static analysis along with time history analysis is executed. After an extensive and systemic study, the following conclusions may be drawn:

1) The period for the seismically isolated structures are much greater compared to that of the fixed based structure.
2) There is a fixed based soft storey in the first floor, but the addition of the base isolation system corrects this problem (rigid motion of the whole structure).
3) Design base shear due to the presence of isolator is reduced by about 2.5 to 3 times in Time History Analysis.
4) Design Base Moment is reduced by about 2.8 to 2.85 times in Time History Analysis after using Base Isolator.
5) Top displacement of isolated building decreases by about 2 to 4 times than non-isolated building.

So, installation of isolator provides the greater safety to the building.

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