EFFICIENT DESIGN IN BUILDING CONSTRUCTION WITH RUBBER BEARING IN MEDIUM RISK SEISMICITY: CASE STUDY AND ASSESSMENT

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Abstract. Earthquakes pose tremendous threats to life, property and a country's economy, not least due to their capability of destroying buildings and causing enormous structural damage. The hazard from ground excitations should be properly assessed to mitigate their action on building structures. This study is concerned with medium risk seismic regions. Specifically, the heavily populated capital city Dhaka in Bangladesh has been considered. Recent earthquakes that occurred inside and very close to the city have manifested the city's earthquake sources and vulnerability. Micro-seismicity data supports the existence of at least four earthquake source points in and around Dhaka. The effects of the earthquakes on buildings are studied for this region. Rubber base isolation is selected as an innovative option to lessen seismic loads on buildings. Case studies have been carried out for fixed and isolated based multi-storey buildings. Lead rubber bearing and high damping rubber bearing have been designed and incorporated in building bases. Structural response behaviours have been evaluated through static and dynamic analyses. For the probable severe earthquake, rubber bearing isolation can be a suitable alternative as it mitigates seismic effects, reduces structural responses and provides structural and economic benefits.

Keywords: medium risk seismicity, conventional structure, base isolation, multi-storey buildings, structural damage, rubber bearing.

Introduction

Over the past few decades, a rapid increase of building construction in medium risk seismic prone areas has been observed. Conventional building design approaches pose a huge economic demand in such regions. There is a need to prevent, reduce and remedy any potential seismic threat and damage inflicted on buildings. An alternate approach to incorporating rubber bearings at a building base is a remarkable technology that allows mitigating the seismic hazard in such zones. The earthquake disaster risk index places Dhaka in Bangladesh among 20 most vulnerable cities in the world. The recently measured plate motions at six different sites of Bangladesh clearly demonstrate that Dhaka is moving 30.6 mm/year in the northeast direction (Khan, Hossain 2005). Furthermore, the rate of strain accumulation is relatively high in and around Dhaka. It may precipitate in an earthquake of magnitude 6.8 in the event of the release of accumulated strain (Khan, Hossain 2005). Building structures experience time varying loads while subjected to such strong earthquake excitations. Earthquakes pose a serious threat to human life and economies as they can damage structures and infrastructure systems.

Designing building structures in Dhaka, Bangladesh to withstand seismic damage is usually based on the traditional design approach. Literature that describes major earthquakes shows the performances of the intended ductile structures to be unsatisfactory. Seismic isolation is one of the most promising alternatives. This type of structural system can be implemented for new structures and as the retrofit of existing building structures. The isolation system is a collection of structural elements which substantially decouples a superstructure from its substructure resting on a shaking ground. The superstructure is supported on base isolators whose dynamic characteristics are chosen to uncouple the ground motion.

For the preceding years, seismic isolation has been increasingly implemented internationally and has proven to be most promising for earthquake safety. The separation of the structure from the harmful motions of the ground occurs by providing flexibility and energy dissipation capability through the insertion of the isolators between the foundation and the building structure (Ismail

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et al. 2010; Kvedaras 2010). Invention of lead rubber bearing (LRB, 1970's) and high damping rubber (HDR, early 1980's) gives a new dimension to the design of base isolated structure. The use of these elastomeric bearings such as HDRB and LRB has shifted to popular applications in recent days (Islam *et al.* 2011a). Jangid (2007) and Providakis (2008) investigated seismic responses of multi-storey buildings for near fault motion isolated by LRB. Dall'Asta and Ragni (2008) have covered experimental tests, analytical model and nonlinear dynamic behaviour of HDRB.

Although it is a relatively recent technology, seismic isolation for structural application has been thoroughly evaluated and reviewed (Lin *et al.* 2011; Lu, Lin 2008; Rasiulis, Gurkšnys 2010; Spyrakos *et al.* 2009; Vaidogas, Šakėnaitė 2011). Chen *et al.* (2007) explored the stochastic seismic response analysis and assessed the reliability of base isolated structures. They combined the physical stochastic ground motion model and the probability density evolution method. Base isolator with hardening behaviour under increasing loading has been developed for medium-rise buildings and sites with moderate earthquake risk (Pocanschi, Phocas 2007). Resonant behaviour of base-isolated high-rise buildings under long-period ground motions was dealt with by Ariga *et al.* (2006) and for long period building responses by Olsen *et al.* (2008). Wilkinson and Hiley (2006) presented a non-linear response history model for the seismic analysis of high-rise framed buildings. Islam *et al.* (2011b) presented the optimal isolation systems and the dynamic characteristics of structural responses in multi-storey buildings. The vicinity of Dhaka, Bangladesh was considered in this study. Islam *et al.* (2011c) added the soft-storey consideration for multi-storey buildings in the same region to evaluate the structural behaviour.

Seismic intensity has been seen to have a significant influence on structural behaviour. Base isolation reduces the lateral forces on the structure and hence the structural excursions (Islam *et al.* 2012a, 2013) as well as cost (Islam *et al.* 2010). However in the city of Dhaka in Bangladesh, the concept of isolation of building structures is still young and has rarely been incorporated for multi-storey buildings (Islam *et al.* 2012b; Jameel *et al.* 2012a). In addition, there is a lack of proper research on the actual seismic threat in this region and there is an acute need to introduce competent alternatives for building design to confront the seismic threat on structures. Therefore, the objective of this study is to introduce the seismic base isolation through rubber bearing as a reliable alternative in the medium risk seismic prone zone. The seismic status in this medium risk earthquake disaster vicinity has been assessed. Lead Rubber Bearing and High Damping Rubber Bearing have been incorporated in a multi-storey building to provide flexibility and damping to a structure in the event of seismic attack. The implemented isolation systems were seen to be better alternatives to reduce seismic influences and promise significant structural and economic advantages in the study area.

1. Study area and its seismic status

Several earthquakes of large magnitude (Richter magnitude 7.0 or higher) with epicentres within Bangladesh and in India close to Indo-Bangladesh have occurred (Ali, Choudhury 1992). Tables 1 and 2 provide lists of the major earthquakes that have affected the surrounding vicinity and the internal region of Bangladesh, respectively (Ali, Choudhury 1994). Data of previous earthquakes inside and around the Bangladesh region are presented in Figure 1 according to magnitude. Furthermore, the country Bangladesh is divided into three zones determined from the earthquake magnitude for various return periods and the acceleration attenuation relationship (Ali, Choudhury 1994) namely zones I, II, III (Fig. 2) being most to least severe gradually (BNBC 1993). This essentially means that Zone I is the least severe and Zone III is the most severe in seismic hazard. It is an alluvial deltaic land with Himalayas on its north and Bay of Bengal on its south. It is located between 20.35° N to 26.75° N Latitude and 88.03° E to 92.75° E Longitude. It has an area of about 1,47,570 km^2 with population more than 140 million. Most of its area is relatively flat lying in the deltaic plain of the Ganges-Brahmaputra-Meghna river system.

Table 1. Prominent earthquake records affecting Bangladesh (Ali, Choudhury 1994)

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

Table 2. Recent major earthquakes around Dhaka, Bangladesh (Ali, Choudhury 1994)

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

In the generalized tectonic map of Bangladesh, the distribution of epicentres is found to be linear along the Dauki Fault system and random in other regions of Bang-

ladesh. A close look at the map reveals that the epicentres lie in the weak zones comprising surface or subsurface faults. Most of the events are of moderate rank (magnitude 4–6) and lie at a shallow depth, which suggests that the recent movements occurred in the sediments overlying the basement rocks. In the north-eastern region (Surma basin), major events are controlled by the Dauki Fault system. The events located in and around the Madhupur tract also indicate shallow displacement in the faults separating the block from the alluvium (Khan 2004). Also the tectonic provinces acting around Bangladesh (Ali, Choudhury 1992) show the severity of earthquakes in the region (Table 3).
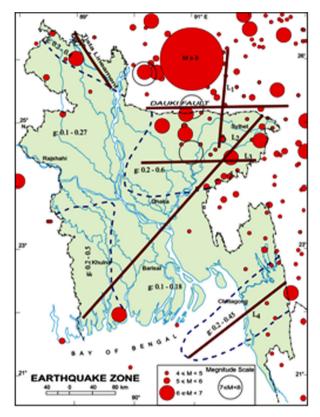

Fig. 2. Seismic zoning map of Bangladesh (Ali, Choudhury 1994)

Fig. 1. Earthquake occurrences around Bangladesh as per magnitude (Khan 2004)

Fig. 3. Earthquake risk in Dhaka, Bangladesh (Ahmed, S., Ahmed, A. 2010)

Table 3. Tectonic provinces and their earthquake potential (Ali, Choudhury 1992)

Location	Operative Basis Magnitude (Richter)	Maximum Credible Magnitude (Richter)	Depth of Focus (km)
Assam fault zone	8.0	8.7	0–70
Tripura fault zone	7.0	8.0	0–70
Sub-Dauki fault zone	7.3	7.5	0–70
Bogra fault zone	7.0	7.5	0–70

Dhaka, located in the central region of Bangladesh, could be affected by any of the four earthquake source zones, presented earlier. Another point of major concern is that there are active faults near the city also. This was realized during the 19 December 2001 magnitude 4+ Dhaka earthqua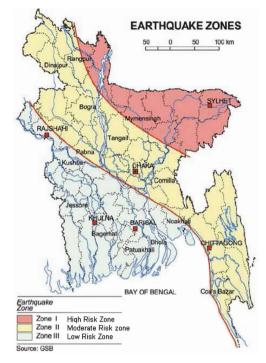ke that caused panic among many city residents. The epicentre was very close to Dhaka city. Frightened people in several high rise buildings rushed down the stairs, as they felt considerable shaking in the upper floors. The location of a probable earthquake source so near Dhaka with prediction of earthquake magnitude needs to be further investigated (Al-Hussaini 2004). Figure 3 represents the seismic hazard of Dhaka city among the important cities in Bangladesh.

The coincidence of the zones of high particle velocity with the location of faults suggests that the western part of Dhaka city from Mirpur-Kalyanpur to Pagla along Buriganga River and the eastern part of Dhaka city from Uttar Khan-Badda to Demra along Balu River has emerged as a high risk zone. The entire Dhaka megacity

has been considered from the perspective of an earthquake hazard. It has been divided into four zones of earthquake hazard vulnerability (Fig. 4) ranging between very high risk and low risk (Khan, Hossain 2005).
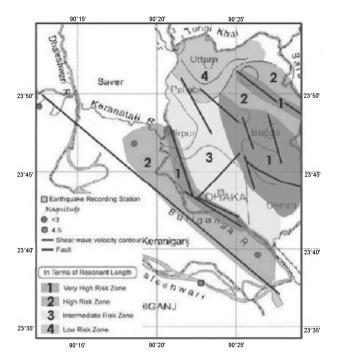

Fig. 4. Earthquake hazard zoning map of Dhaka mega city (Khan, Hossain 2005)

Earthquakes cannot be prevented, but the damage they cause can be greatly reduced with proper structural design, communication strategies, emergency preparedness planning, mass awareness through education and safer building standards. For this reason, the philosophy behind the earthquake resistant design of buildings is to:

− Provide safe and economic design of structures in earthquake hazardous zone;
− Allow only slight, repairable, non-structural damage due to design earthquakes;
− Prevent collapse of structure due to more severe earthquakes.

In order to realize these objectives, a thorough review is needed that extensively covers the past history of earthquake occurrences, number and magnitude of earthquakes occurring each year along with their strength and capability of causing damages and destruction, and major earthquakes throughout the world with a special focus on the Bangladesh scenario.

2. Earthquake induced damages to buildings

The enormous amount of energy released by an earthquake causes devastating damages. The energy released by an earthquake of small magnitude 4.3 (Richter) is equivalent to the energy released by the atomic bomb that destroyed Hiroshima, Japan, which is equivalent to about 20 kilotons of TNT. The largest recorded earthquake of magnitude 9.5 (Richter) released as much as 66,000,000 times that of the Hiroshima atom bombs. The Richter

scale ranks earthquakes based on how much the ground shakes 100 km (60 miles) from the earthquake's epicentre. Table 4 shows earthquakes classified according to their magnitudes.

Table 4. Distinguishing earthquake types by occurring magnitude

Earthquake Type	Magnitude (Richter)
Small	<5.0
Moderate	5.0
Large	6.0
Major	7.0
Great	>=8.0

Since the Richter scale is a logarithmic scale, an increase of 1 on the Richter scale represents a 10-fold increase in movement and 32 fold increase in energy release (e.g. an earthquake registering 7 on the scale is 10 times stronger and releases 32 times the energy of an earthquake registering 6, with the earth's movement being 10 times as distant). As a result, even a slight increase in magnitude corresponds to a high increase in damage. The Moheshkhali earthquake in Bangladesh (300 km epicentre distance to Dhaka) of magnitude 5.2 that occurred on July 22, 1999, caused major destruction (Ansary *et al.* 2001).

Collapsing buildings are the main reason for damage and casualties in an earthquake. To date, a few structural collapses have occurred in and around Dhaka city. During the last 450 years Dhaka was jolted multiple times by local and teleseismic earthquakes of magnitude 4 to 9 on the Richter scale. The intensity of these earthquakes at Dhaka ranged from III to VIII on the Modified Mercalli (MM) intensity scale. Some of these earthquakes, such as those in 1762, 1812, 1865, the 1885 Bengal Earthquake and the 1897 Great Indian Earthquake were tremendously damaging to lives and properties in Dhaka City.

In 1812 two earthquakes visited Dhaka – on 10 April and 11 May. The epicentres of these earthquakes are unknown, but might have been close to Dhaka. The earthquakes jolted Dhaka violently and damaged a number of houses and several buildings at Tejgoan (Rizvi 1969). The degree of ground shaking had a MM intensity of VIII. An earthquake that struck in December 2001 with a magnitude of 4.5 and focal depth of 10 km located very close to Dhaka caused a four-storey building to collapse and injured 100 prisoners in the Dhaka central jail (Ahmed, Ahmed 2010). Figure 5 shows the collapse of building structures due to earthquakes in and around Dhaka.

Earthquake waves induce the ground to move, buildings to shake and cause poorly designed inadequate strength of columns, foundations or weak structures to partially (Fig. 6) or totally (Fig. 7) collapse. Collapse of structures results in human deaths and injuries. Fire hazard (from short circuits and gas explosions) is another post-earthquake threat. In the devastating 1923 Tokyo earthquake, about 130,000 lives were lost due to fire-

storms fanned by high winds. Zhang *et al.* (2010) have shown the simultaneous identification of moving masses and structural damage in earthquake excitation.

Therefore, the damage to buildings due to seismic tremors may be classified into three major categories:

1. Damage due to inadequate strength of structural elements (e.g. columns, beams, foundation);
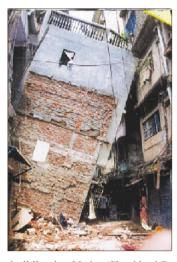

Fig. 5. 6 storey building in old city (Shankhari Bazar) collapsed on June 9, 2004

Fig. 6. Partial damage due to earthquake

Fig. 7. Total damage due to earthquake

2. Damage due to soil liquefaction;
3. Damage due to post-earthquake threats (e.g. Fire hazards, Tsunamis).

To enhance the structural design of buildings (low rise and high rise buildings) by improving the strength of the columns, beams, etc. in an economic and effective way, an alternative to fixed based structures is to use Base Isolators, depicted in Figure 8.

Fig. 8. Separating the superstructure by Base Isolator

3. Seismic base isolation against conventional design

Seismic base isolation decouples the building structure from the damaging components of the earthquake input motion, i.e. to prevent the superstructure of the building from absorbing the earthquake energy. The entire superstructure is supported on discrete isolators (Fig. 8) whose dynamic characteristics are chosen to uncouple the ground motion. Some isolators are also designed to add substantial damping. Displacement and yielding are concentrated at the level of the isolation devices, and the superstructure behaves very much like a rigid body. Therefore, the effect of ground motion is minimal. The building can remain serviceable throughout the construction. The base isolator does not involve major intrusion upon the existing super structure.

The isolation technique for structures has been around for some time. The first patent for such a system was filed in 1909 in England. Base isolation methods were implemented during the early 1900's at the Tokyo Imperial Hotel (Kuntz, Tanner 1999). But the entry of base isolation into the mainstream of structural engineering occurred during the 1970's. The isolation technique was used on bridge structures in the early 1970's and on buildings in the late 1970's (Buckle, Mayes 1990). Lead rubber bearing and high damping rubber bearing added the innovative advancement in design of base isolated structures. There are currently hundreds of buildings worldwide that are held up by rubber, i.e. they are not rigidly fixed to the foundations on which they rest. It may come as a surprise that these rubber foundation elements can actually help to minimize earthquake damage to buildings, considering the tremendous forces these buildings must endure in a major quake (Jameel *et al.* 2012b). Some of the most prominent structures, e.g. Pasadena City Hall, San Francisco City Hall, Salt Lake City, County Building or LA City Hall were mounted on base isolation systems. Here a few famous buildings are shown as an example of isolated structure. The use of isolation in

Japan continues to increase, especially in the aftermath of the Kobe earthquake. As a result of the superior performance of the West Japan Postal Computer Centre, there has been a rapid increase in the number of permits for base-isolated buildings, including many apartments and condominiums.

Interest in base isolation as an effective means of protecting structures from earthquakes has therefore been revived in recent years. In summary, the following are the five developments that have enabled base isolation to become a practical reality:

1. The design and manufacture of high quality isolation bearings that are used to support the weight of the structure and at the same time release it from earthquake induced forces;
2. The design and manufacture of mechanical energy dissipaters (absorbers) that are used to reduce the movement across the bearings to practical and acceptable levels 100–150 mm (4–6 inches) and to resist wind loads;
3. The development and acceptance of computer software for the analysis of base-isolated structure which includes nonlinear material properties and the time-varying nature of the earthquake loads;
4. The ability to perform shaking table tests using real recorded earthquake ground motions to evaluate the performance of structures and provide results to validate computer modelling techniques;
5. The development and acceptance procedures for estimating site-specific earthquake ground-motions for different return periods.

Conventional seismic design practice permits the reduction of forces for design below the elastic level on the premise that inelastic action in a suitably designed structure will provide it with significant energy dissipation potential and enable it to survive a severe earthquake without collapse. Inelastic behaviour in specially detailed critical regions, while able to dissipate substantial energy, also often results in significant damage to the structural member, and although the regions may be detailed, their hysteric behaviour will degrade with repeated inelastic cycling. On the contrary, base isolation devices experience large inelastic deformations during a severe earthquake and shift the structural fundamental natural frequency lower and away from the range of frequencies where the earthquake energy is strongest.

Also from the patterns of seismic damage and the types of failure, it is clear that merely increasing the design lateral forces for the design of structural elements (columns, beams, foundations) may not prevent certain types of failures. The more effective technique is to isolate the whole structure from the ground, which prevents most of the horizontal movements from being transmitted to the building during a seismic event. Base isolation has proved to be an effective way of reducing the impact of earthquakes on existing structures under many circumstances. The pattern of seismic effect of a fixed base building is shown in Figure 9a and of an isolated based building in Figure 9b.
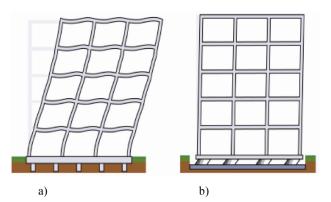

Fig. 9. Differential deflection pattern at: a) conventional fixed based structure; b) base isolated structure

The installation of isolator considerably increases the time period and damping characteristics of the building. Therefore, it reduces the possibility of resonance of the structure. The installation of isolator thus ensures greater safety of the building by considerably reducing the severity of damage to both the structure and to human lives. This is reaffirmed by a comparative study of performance of various isolation systems on structures (Shrimali, Jangid 2010).

There is a noteworthy diminishment in lateral loads due to the isolation system which allows members to be smaller and still meet the demands. The reduction in member size corresponds to a lessening in steel weight. Therefore, the cost of the building, taking into account only the steel framing, is brought far down. In addition, the isolating strategy contributes to the flexibility of base isolated building to reduce structural needs. The isolation system changes the deflection pattern of the building, thereby reducing the structural responses significantly. For Dhaka region, the seismic base isolation approach has obvious benefits and can be more extensively adopted for building structures.

4. Case study

A base-isolated demonstration building has been considered in the region of 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 is a six-storey reinforced concrete frame. Designed isolation system for this project consists of 25 Rubber-steel Bearings. The isolators were connected to the columns and foundation using recessed-type connections at the ground level. Site-specific earthquake time history (Islam *et al.* 2011d) and response spectra (Islam *et al.* 2011e) were used for the analysis of the multi-storey building with and without isolation.

The 6 storey building is of 4 spacing @ 7.62m c/c in both directions. The selected properties were: f'c = 28 MPa, fy = 414 MPa, dead load (excluding self-weight) = 4.8 KPa, live load = 2.4 KPa, slab thickness = 150 mm, exterior corner columns are all of 750×750 mm, Exterior middle columns are all 950×950 mm and all interior columns
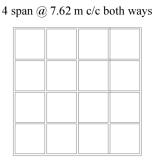
4 span @ 7.62 m c/c both ways

Fig. 10. Plan view of prototype multi-storey building

are 1000×1000 mm in cross sectional dimensions. The plan view of the demonstration multi-storey building is shown in Figure 10 and 3D modelling view of the building is shown in Figure 11. High damping rubber bearing (HDRB) has been incorporated in the base of interior columns. Furthermore, lead rubber bearings are inserted at exterior column base. The sophisticated finite element program SAP 2000 (2005) was used for analysis and design of structures.
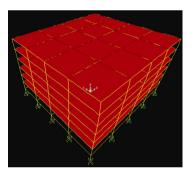
Fig. 11. 3D view of the modelled multi-storey building

Static analysis was carried out following the code BNBC (1993). The results obtained after equivalent static analysis are shown in Table 5 for the conventional fixed based building. From the results, it is seen that the design base shear for earthquake loading is greater than that for wind loading and the structural time period is in within the reasonable value for isolation. Again here, the lateral load due to wind is less than 10% of the weight of the building, as per the requirement (Kelly 2001; Kelly *et al.* 2006). Therefore, isolation device is suitable to be incorporated at the base of the structure.

Table 5. Response behaviour in static analysis without isolation

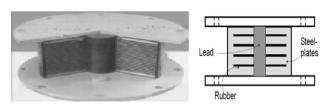| Structural Time Period	0.826 sec
Design Base Shear (EQ load)	3265 KN
Design Base Shear (Wind load)	1898 KN
Top story Displacement in UI Direction (EQ load)	13.63 mm
Top story Displacement in U2 Direction (EQ load)	11.5 mm
Top story Displacement in UI Direction (Wind load)	6.6 mm
Top story Displacement in U2 Direction (Wind load)	6.1 mm
Building Weight	39983 KN

Fig. 12. Geometry and sectional view of lead rubber bearing

Fig. 13. Geometry and sectional view of high damping rubber bearing

Designs of the base isolators viz. the bearing size, number and thickness of rubber layers, etc. were done for this building using the generated design spread sheet code DESBEA2010. Properties for designing isolator were obtained through the spread sheet. The models of LRB and HDRB were selected as shown in Figures 12 and 13 respectively. The design progression for both rubber bearings follows the flow diagram in Figure 14. It was accomplished following the base isolation design guidelines (Islam *et al.* 2011f).

Dynamic analyses for time histories (Fig. 15) and response spectrum (Fig. 16) of local suited earthquake have been performed for fixed base structure along with the static analysis. The outputs from these three types of analyses provide insights into the structural behaviour. Design base shear, design base moment and top storey displacement in two orthogonal directions have been illustrated in Table 6. The solution in time history analysis shows the lowest responses. It is obviously desirable as the time history represents the time varying actual behaviour of seismic loading. Whereas response spectrum uses the peak values and the static computation takes approximate over estimations.

The isolation systems have been linked to the bottom of the corresponding column base as per the properties of isolators by the isolation system design procedure. The static analysis is then carried out again for the base isolated structure through modelling in the finite element analysis tool. Both the dynamic approach viz. time history analysis and response spectrum analysis have also been followed for the dynamic evaluation in base isolated case.

Assigning the appropriate values of stiffness to the isolators and analysing the structure with isolator, the results for displacements have been obtained. The structural time period has been observed as 2.62 sec. Figure 17 shows the structural displacement pattern of the isolated base building structure in static, response spectrum and time history analysis. The values of displacement follow the descending order as static, response spectrum and time history solution. The seismic performance is evaluated for both the design level and the maximum seismic events. It is noted that for fixed based building, the displacement at
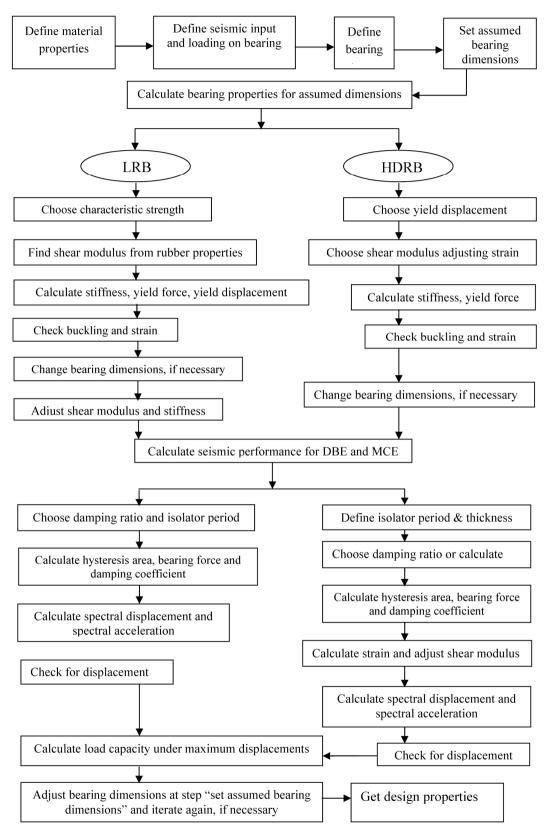
| Define material properties | → | Define seismic input and loading on bearing | → | Define bearing | → | Set assumed bearing dimensions |

Calculate bearing properties for assumed dimensions

LRB

Choose characteristic strength

Find shear modulus from rubber properties

Calculate stiffness, yield force, yield displacement

Check buckling and strain

Change bearing dimensions, if necessary

Adjust shear modulus and stiffness

HDRB

Choose yield displacement

Choose shear modulus adjusting strain

Calculate stiffness, yield force

Check buckling and strain

Change bearing dimensions, if necessary

Calculate seismic performance for DBE and MCE

Choose damping ratio and isolator period

Calculate hysteresis area, bearing force and damping coefficient

Calculate spectral displacement and spectral acceleration

Check for displacement

Define isolator period & thickness

Choose damping ratio or calculate

Calculate hysteresis area, bearing force and damping coefficient

Calculate strain and adjust shear modulus

Calculate spectral displacement and spectral acceleration

Check for displacement

Calculate load capacity under maximum displacements

Adjust bearing dimensions at step "set assumed bearing dimensions" and iterate again, if necessary

Get design properties

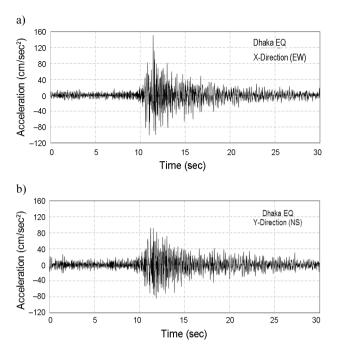Fig. 14. Flow diagram of isolation system design

a)

b)

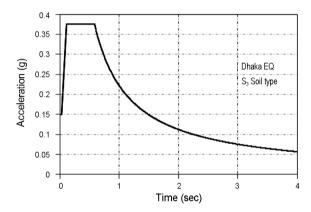Fig. 15. Time history for Dhaka EQ: a) X-direction; and
b) Y-direction

Fig. 16. Acceleration response spectrum for S3 soil for Dhaka

Table 6. Response behaviour in dynamic analysis without
isolation

	Response Spectrum analysis	Time history analysis
Design Base Shear (KN) in X direction	16221	14610
Design Base Shear (KN) in Y direction	12666	11528
Design Base Moment (KN-m) in X direction	93114	763726
Design Base Moment (KN-m) in Y direction	67047	56880
Top story Displacement in UI Direction (mm)	58.1	31.0
Top story Displacement in U2 Direction (mm)	38.1	28.7

base level is zero and shows maximum value at the top
storey level. The structure should be more strong and stiff
to tackle the responses. Apart from this, in base isolated
cases, the isolator itself shows movement. Though the top

storey displacement is higher, the total structural drift
shows trivial values. This peculiar characteristic of isola-
tion system on structural base makes the superstructure
flexible. The design base shear and moment accordingly
reduce. Outputs of the design base shear and design base
moment in both response spectrum and time history anal-
ysis have been illustrated in Table 7. Significant reduc-
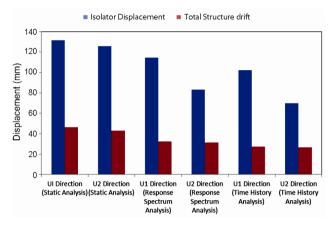tions of these values have been observed compared to the
fixed based case.

Fig. 17. Displacement for static and dynamic analysis of base
isolated structure

Table 7. Design base shear and moment in dynamic analysis
of base isolated structure

	Response Spectrum analysis	Time History analysis
Design Base Shear (KN) in X direction	7842.5	6703.2
Design Base Shear (KN) in Y direction	4926.9	3937.3
Design Base Moment (KN-m) in X direction	38923.7	33934.1
Design Base Moment (KN-m) in Y direction	27955.63	24930.6

The results clearly indicate that there is a drastic re-
duction of structural responses when the isolator bearings
are incorporated at the structural base. This reduction
serves to improve the structural safety as well as the eco-
nomic feasibility for the structural design in the study
area. Providing flexibility in structural design ensure
structural durability and longevity as well along with the
protection in ground excitation hazard at medium risk
earthquake region. The isolation system can therefore be
regarded as efficient alternatives against the traditional
approaches of building design.

Conclusions

There is a great possibility of earthquake occurrence and
the inevitable major damages that follow, especially to
building structures, at the medium risk seismic zone Dha-
ka, Bangladesh. A remedy to reduce the extent of damage
is presently an urgent need. Base isolation has been intro-
duced as a seismic protection device. Separation of super-
structure from the substructure by base isolator reduces the

seismic dissipated energy. The significant reduction of structural responses allows for greater structural safety and a more economic design, which decisively makes base isolation a better option for seismic design. Though it is a novel idea for Bangladesh, the seismic base isolation system may be adopted in the region especially for areas with extensive urban land use like Dhaka. The proposed system is an effective alternative against conventional fixed based building designs and promises considerable structural and economic benefits.

Acknowledgments

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