LESSONS LEARNED FROM NEPAL EARTHQUAKE (M 7.8): DAMAGE BEHAVIOUR OF BUILDINGS IN BANGLADESH

M.R. Awall[1], M.A. Rahman[*2], K.M.S. Uddin[3]

[1]Associate Professor, RUET, Rajshahi, 6204, Bangladesh, e-mail: robi95@gmail.com
[2]B.Sc. in Civil Engineer, RUET, Bangladesh, e-mail: shuvo10ruet@gmail.com
[3]B.Sc. in Civil Engineer, RUET, Bangladesh, e-mail: polashkhan107@gmail.com

ABSTRACT

In the last few years several devastating earthquakes has occurred in different part of the world. In the year 2015 a major earthquake has occurred in Nepal (M 7.8), caused a great loss of life and property. It also affected the neighboring country like Bangladesh and India. This review paper represents the effect of Nepal earthquake in buildings of Bangladesh. The buildings designed and constructed by taking proper earthquake resistant measures have helped to minimize the damage. Some measures for designing earthquake resistant buildings are also discussed in this paper. The significance of this work is to reduce the earthquake damage by introducing some resistive measures in the design of buildings.

Keywords: *Nepal earthquake, Damages, Earthquake resistant measures*

1. INTRODUCTION

In, recent past major earthquake has not happened in Bangladesh. But Bangladesh is one of the most tectonically active regions in the world. It is situated in the meeting point of the Indian tectonic plate, the Eurasian tectonic plate and the Burmese tectonic plate (American Museum of Natural History, 2013). The Indian plate is moving northwest gradually and it is slowly colliding with the Eurasian plate. As a result the Himalayas is rising. Along this border active faults are notiched. The northern part of Bangladesh is enclosed by Dauki fault of length 300 km. Shilling Plateau fault system is the main risk for Bangladesh because it is closest to Bangladesh. On the other hand in the east the Burmese plate pushes against the Indian plate to the west. The faults in the northern and western part of Bangladesh can generate huge earthquake. The devastating 2004 earthquake and tsunami in Sumatra occurred along the boundary between the Indian and Burmese plates (American Museum of Natural History, 2013).

In different time terrible earthquakes occurred in Bangladesh. The first recorded earthquake in Bangladesh was occurred in the year of 1548. Sylhet and Chittagong was affected by this earthquake. The next earthquake occurred in 1642. Sylhet district was damaged terribly. In 1963 a severe earthquake occurred in ASSAM. Another earthquake occurred in 2nd April, 1762. It caused a permanent submergence of 155.40 sq km area near Chittagong (Institute of Earthquake Engineering Research, CUET, 2012). This earthquake seriously affected Dhaka and along the eastern bank of the Meghna as far as Chittagong. In Dhaka about 500 persons lost their lives, the rivers and Jheels were agitated and raised high above their usual levels. Another earthquake was occurred in 1775 around April 10. In 1812 earthquake occurred in many places of Bangladesh. Sylhet was proved to be mostly affected. Cachar earthquake was occurred in 1869. Another earthquake of magnitude 7.5 occurred on 10 January, 1889 in Jaintia Hills.The great Indian earthquake of magnitude 8.7 was occurred in 1897. In 18 July, 1918 Srimangal earthquake was occurred. Its magnitude was 7.6 and epicenter was at Srimangal. Dhubri earthquake of magnitude 7.1 was occurred at Dhubri, Assam in 1930 (Institute of Earthquake Engineering Research, CUET, 2012)**.** Eastern part of Rangpur district was affected by this earthquake. Another earthquake of magnitude 8.4 was occurred at Assam, India. It took place on 15 August, 1950. In 1997 an earthquake of magnitude 6.0 was occurred in Chittagong. 1999 and 2003 an earthquake of magnitude 5.2 and 5.1 respectively were occurred in Maheskhali Island and Rangamati. Recently a terrible earthquake was occurred in Nepal. It occurred at 11:56 NST on 25 April 2015. This earthquake affected Nepal, India, Bangladesh and China (Wikipedia, the free encyclopedia, 2015). It causes a great damage to life and property of the people of this area. The prediction of scientists is that a major earthquake closer to Bangladesh is only a matter of time (American Museum of Natural History, 2013).

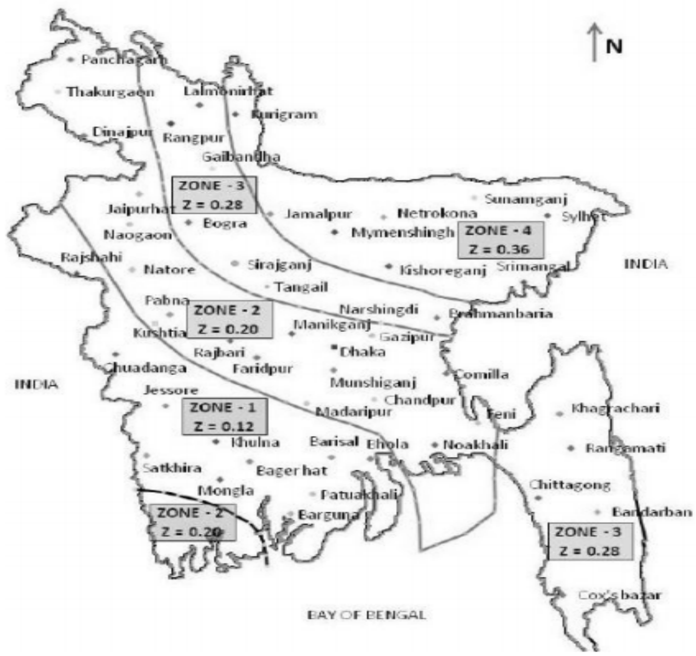

Figure 1: Earthquake zoning map of Bangladesh (Surraz *et.al*, 2015)

Based on seismic susceptibility Bangladesh has been divided into four zones like Zone-1, Zone-2, Zone-3 and Zone-4. The north-eastern region of Bangladesh is considered as Zone-4 with the value of basic seismic co-efficient z=0.36. This zone has high seismic risk. The district Rangpur, Tangail, Narshindi etc. are situated in Zone-3. The basic seismic co-efficient of this zone is z=0.28. The central part of Bangladesh is considered as Zone-2. The capital of Bangladesh, Dhaka is in this zone. The basic seismic co-efficient of this zone is z=0.20. The south western part of Bangladesh is considered as Zone-1. This zone is comparatively safe zone. The basic seismic co-efficient of this zone is z=0.12 (Surraz *et.al*, 2015). Figure 1 represents the earthquake zoning map of Bangladesh.

2. NEPAL EARTHQUAKE

Recently a terrible earthquake has occurred in Nepal on 25th April 2015 at 11:56 NST with a magnitude of 7.8 (USGS, 2015). The epicenter was in the east of the Lamjung district located at a distance of 80 km from the capital of Nepal and its hypocenter was located at a depth of approximately 8.2 km (5.1 mi) (Wikipedia, the free encyclopedia, 2015). Figure 2 shows the location of epicentre of the Nepal earthquake. After the 1934 Nepal–Bihar earthquake, it was the worst natural disaster in Nepal. About 8900 people was died in Nepal ("Massive Damage", 2015). Thousands of people have lost their home. Their villages were flattened. Centuries-old buildings were destroyed at UNESCO World Heritage sites in the Kathmandu Valley, including some at the Kathmandu Durbar Square, the Patan Durbar Squar, the Bhaktapur Durbar Square, the Changu Narayan Temple and the Swayambhunath Stupa (Wikipedia, the free encyclopedia, 2015). More than 100 aftershocks were recorded in Nepal. They have occurred within 15-20 minute interval. Among these shocks one shock reached the magnitude of 6.7 on April 26 at 12:54:08 NST (Wikipedia, the free encyclopedia, 2015). Landslides have also occurred in different part of the Nepal. This earthquake also affected India, Bangladesh and China. The epicentre of the earthquake was located at a distance 745 km from the capital of Bangladesh. Figure 3 show the relative position of Bangladesh and Nepal with respect to epicenter respectively.

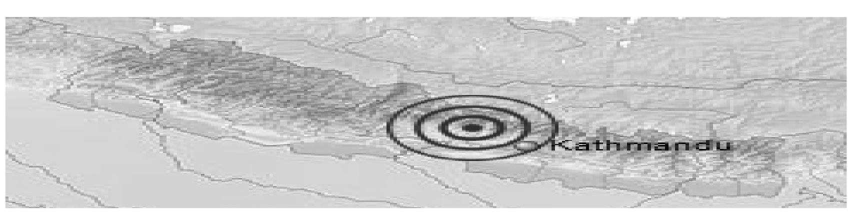

Figure 2: Location of epicentre of the Nepal earthquake (Wikipedia, the free encyclopedia, 2015)

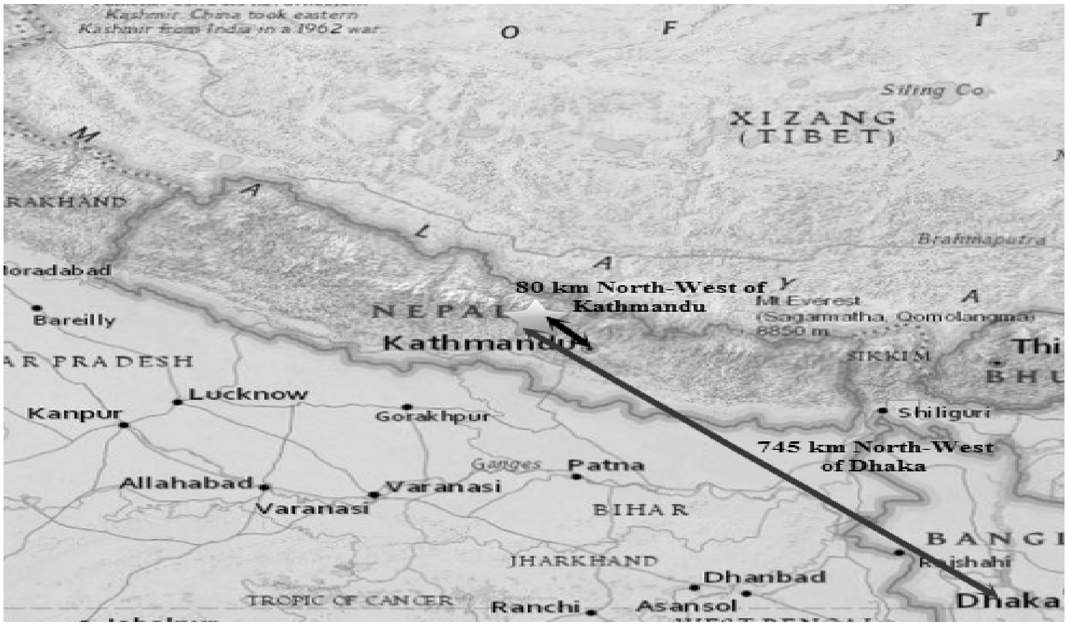

Figure 3: Relative position of Bangladesh and Nepal with respect to epicenter (USGS, 2015)

3. EFFECT OF NEPAL EARTHQUAKE IN BANGLADESH

Bangladesh was affected by the Nepal earthquake. Most of the district of Bangladesh felt the shake of the Nepal earthquake 2015. This earthquake created a great panic amongst the people of Bangladesh. In different places buildings were cracked. The Ponds and Jheels were agitated and raised high above their usual levels.

In Bongsal, Dhaka a six storied building was tilted due to this earthquake as shown in Fig. 4 ("Losses of Earthquake", 2015). Due to vibration of earthquake differential settlement occurred in the soil layer below the structure. As a result the building was tilted.

In Dhaka another building was affected by earthquake. Crack was formed in the wall of staircase of this Building. In Bogura wall of a primary school was cracked and boundary wall of a hospital was collapsed as shown in Fig. 5 ("Losses of Earthquake", 2015). The primary cause of these types of failure is the use of solid brick. Solid brick walls are vulnarable to earthquake. They can be supported only by sand and cement mortar. In solid brick wall there is no way to provide rebar in horizontal or vertical direction for stiffening it. So due to heavy shake of earthquake it cracks and collepses. Beside this due to use of solid bricks the total weight of building increases which adversely affect the earthquake resisting capacity of the building structure.

Figure 4: Tilted Building in Bongsal ("Losses of Earthquake", 2015)

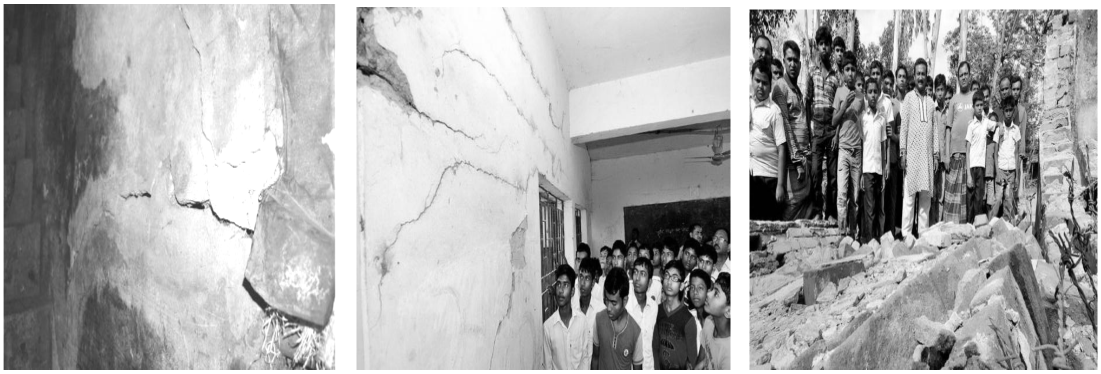

Figure 5: Cracked Staircase, Cracked wall of Primary school & Collasped boundary wall ("Losses of Earthquake", 2015)

In Khulna district, the Khulna City Corporation Women college Building was terribly damaged. Beams and columns of this building were cracked seriously. A part of this Building was tilted and crack was formed along the beams and columns of the inner face of the building. Cracked beam-column joint is shown in Fig. 6. It was cracked during earthquake due to presence of eccentric beam-column joint. From Fig. 6 it can be seen that the beam was not located centrally with the column. As a result eccentricity was developed at the joint and the joint cracks during earthquake. A cracked column with an uncracked beam is shown in Fig. 7. In this case the stiffness of the beam was more than the stiffness of the column. As a result cracking of column has occurred during earthquake due to formation of plastic hinge in the column. If the column of the building frame was made stronger than the beam then the energy of earthquake can be more uniformly distributed throughout the building. In this system plastic hinge generally form in the beam while the column remains elastic. As a result the structure become partially damaged which may be repairable. The tilted part of the Khulna City Corporation Women College building is shown in Fig. 8. This part was tilted due to differential settlement in the soil layer. Cracks were developed in different beams and columns of this tilted building.

Glass of a commercial building was broken in Shaheb Bazar, Rajshahi. The affected building is shown in Fig. 9. The building is face to the west. Vibration of earthquake was in north-south direction. Due to this vibration tension governs on one side of the structure and compression governs on the opposite side of the structure. But the less stiff glass used in this building cannot stand with this tension and compression phenomenon. As a result it broke. It is seen that annealed and heat strengthened laminated glass exhibited higher rasistance to glass fall out during earthquake (Behr, 2001). So for better performance during earthquake these types of glass should be used.

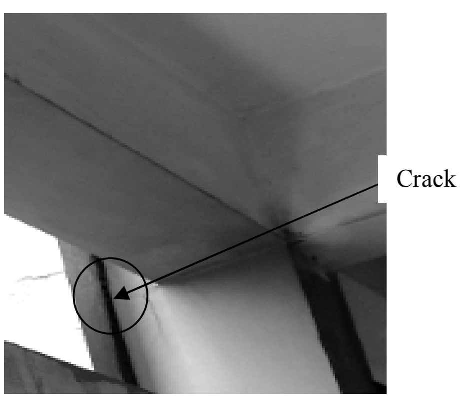

Figure 6: Cracked Beam-Column joint

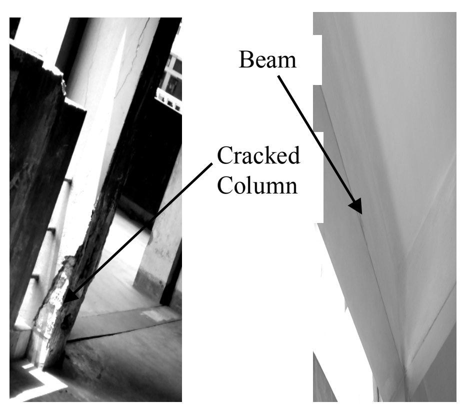

Figure 7: Cracked Column with uncracked beam

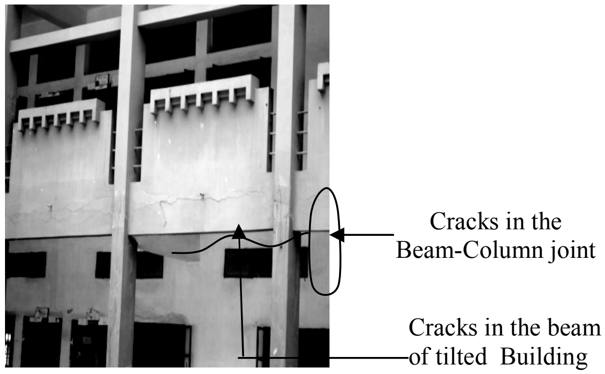

Figure 8: Cracks of tilted Building

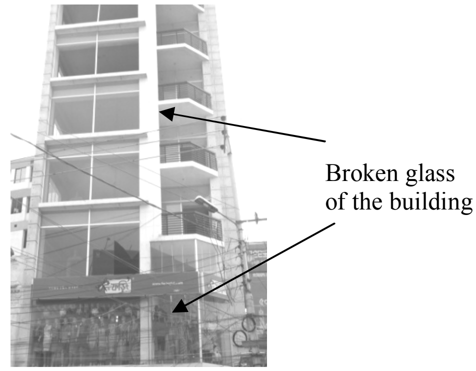

Figure 9: Broken glass of the Building

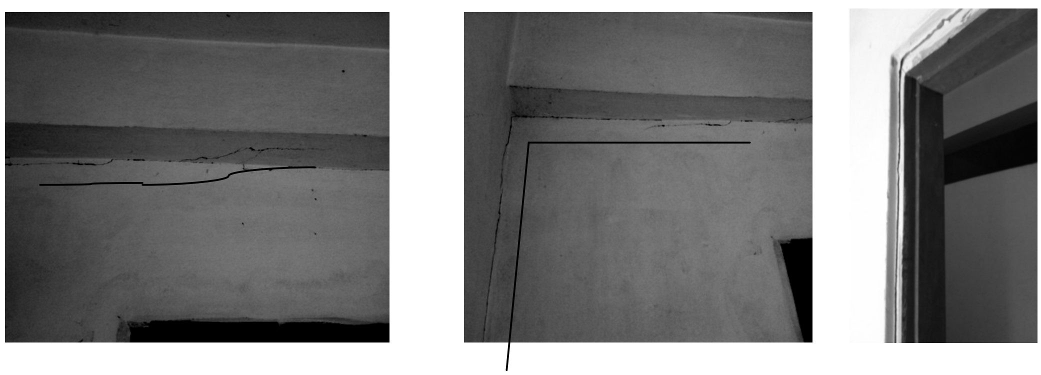

Figure 10: Cracked beam, wall joint and displaced door of the affected building

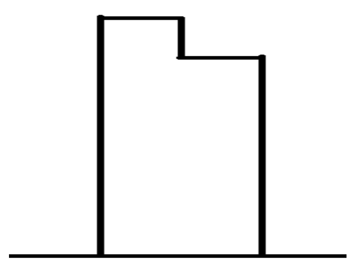

Figure 11: Elevation of the Building

In Rajshahi another 6 storied building was affected by the earthquake. Cracks were formed in different beams, walls and at the joint of wall with beam and columns. Cracked portion of the building is shown in Fig. 10. The frames of door and window of this building were displaced from their original position by an amount $1/2^{//}$. The elevation of the building is as shown in Fig. 11. From this figure, it can be seen that the building has vertical irregularity. The left side of the building is higher than the right side. So, the mass of left portion of the building is greater than the right portion. Again, the inertia force, generated during the earthquake is proportional to the mass. So, the inertia force generated due to tilting of building in the left direction is greater than due to tilting of building in the right direction. As a result displacement of building in the left direction is more. This uneven displacement of structure due to shake of earthquake was resulted in cracks in different components of the building.

The largest shopping center of Bangladesh "Jamuna Future Park" was also affected by the earthquake. Crack was formed at different Beam-Column joints of this building as shown in Fig. 12. From this figure it can be seen that the beam was not located centrally with column. As a result some eccentricity was induced in this joint. Due to this eccentricity cracking of beam-column joint occur during earthquake.

The example of the damages of Fig. 6 to Fig. 12 were collected from different locations in Bangladesh.

(a) (b) (c)

Figure 12: Cracked Beam-Column joints of Jamuna Future Park Shopping Center

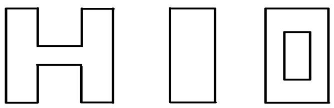

Figure 13: Regular plans

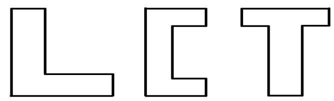

Figure 14: Irregular plans

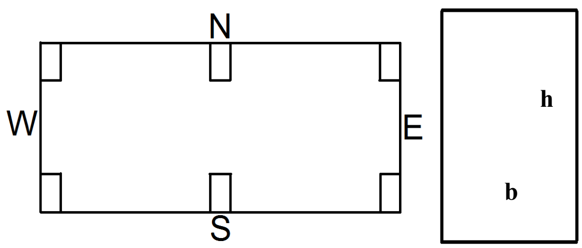

Figure 15: Orientation of column in plan

4. POSSIBLE WAY TO MITIGATE EARTHQUAKE DAMAGES

Earthquake damages a huge amount of our life and property. It is not possible to stop earthquake or to predict about the time of occurrence of earthquake. But it is possible to reduce the losses of earthquake by adopting some preventive measures in the design of different structures. Some important measures are-

4.1 Avoiding Irregular Plan of Building

The plan of building should be regular to make it better against earthquake. H, I, O shaped plans as shown in Fig. 13 are regarded as good plan. These plans are symetric with respect to any direction. On the other hand L, C, T shaped plans as shown in Fig. 14 are regarded as bad plan (Mollick, 2013). These plans are not symetric. Displacement of these type of plans is not same in both direction when subjected to earthquake shaking. As a result the structure become imbalanced. Buildings with irregular plan have been observed to be susceptible to significantly larger deformation and damages than building with regular plan when subjected to earthquake motion.

4.2 More Stiff Column and Less Stiff Beam

By using strong column and weak beam energy of earthquake can be more uniformly distributed throughout the building. In this system plastic hinge generally form in the beam while the column remains elastic. As a result the structure become partially damaged which may be repairable. On the other hand if strong beam and weak column is used then there is possibility of forming plastic hinge in the columns of a lower storey. Due to this total structure will collapse and causes a great loss of life and property (Smith, 1988).

4.3 Orientation of Column

Orientation of column in a plan of a building is very important. It will affect the stiffness of the building. Consider the plan as shown in Fig. 15. Moment of inertia of the building is greater in east-west direction. So the building is weaker in north-south direction and stronger in east-west direction. Assume the column section of width b and depth h. Here h>b. If column is oriented in north-south direction then the moment of inertia in this direction will be bh^3/12. On the other hand if column is oriented in east-west direction then the moment of inertia in north-south direction will be hb^3/12. Here bh^3/12>hb^3/12. For better stiffness in north-south direction column should be oriented in north-south direction (Mollick, 2013).

4.4 Avoiding Flat Plate Design

In recent time flat plate design method become popular over beam-column frame method. But in flat plate design method total weight of structure become high. During earthquake due to ground shake an internal force is generated within the building. This force is called the inertia force. This force causes most of the seismic damages (Lorant, 2012). This inertia force can be expressed by the equation given below-

F(inertia) = Mass(M) X Acceleration(A)

So, the inertia force increases with the increase of the mass (weight) of the building. In the flat plate design the weight of the building is more. The inertia force will be more which results in increasing damage during earthquake. Beside this weak beam-strong column philosophy cannot be applied in the flat plate design. As a result building frame collapses due to formation of plastic hinge in the columns.

4.5 Use of Hollow Brick Instead of Solid Brick

Solid brick is heavier than hollow brick. So if solid brick is used, the weight of structure will be more. On the other hand seismic force is proportional to the weight of the structure (Lorant, 2012). So, if we use solid brick then the seismic force generated on the structure will be high. Beside this in hollow brick there is provision to provide rebar in horizontal and vertical direction to increase the stiffness of brickwork. As a result the shear resistance capacity of the brick wall increases (Mollick, 2013).

4.6 Avoiding Eccentric Beam-Column Joint

Eccentric beam-column joint make a building vulnerable to earthquake. Building collapses due to eccentric beam-column joint during an earthquake. A research report founded that shear strength of eccentric beam-column joint is reduced by 40% due to seismic force. This results in the collapse of beam-column joint (Hirosawa *et al.,* 2000). So, eccentric beam column joint should be avoided. To avoid eccentricity in joint beam should be connected centrally with the column. Beam-Column joints with and without eccentricity are shown in Fig. 16.

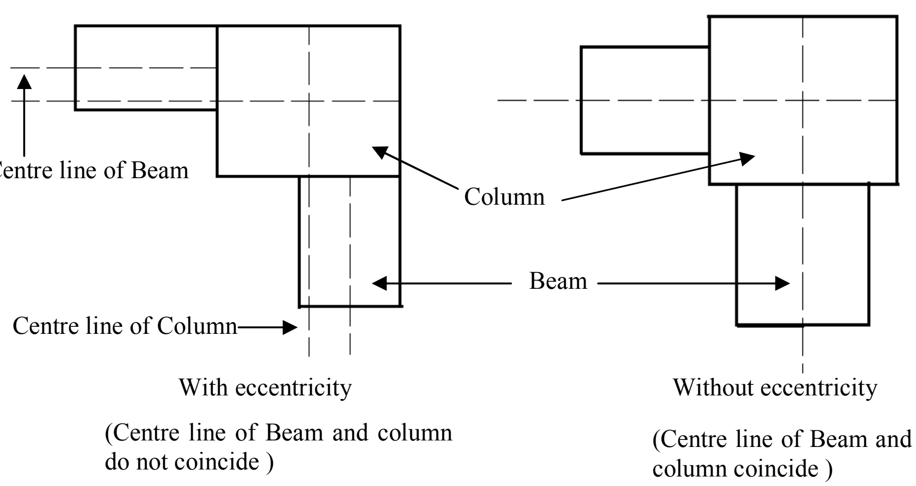

Figure 16: Beam-Column joint with and without eccentricity

Building with soft Storey

Collapse of building due to soft storey

Figure 17: Presence of soft storey in a building and its effect

4.7 Avoiding Presence Of Soft Storey

If any storey of a building has stiffness less than 70% of the stiffnes of the storey immediately above it or less than 80% of combined stiffness of three stories above, then it is called a soft storey. Presence of soft storey in the structure will make it vulnerable to earthquake. Due to presence of soft story excessive drift occur in that story. However, excessive drifts in the story coupled with p-delta effects on the yielded columns make buildings collapse (Hejazil *et al.,* 2011). Figure 17 shows the presence of soft storey in a building and its effect.

Besides, minimum clear space between two structures should be maintained. If not maintained, hammering will occur between the structures due to the shake of earthquake and cause damages.

5. CONCLUSION

Earthquake is an unpredictable and unavoidable natural disaster. No one can say when and where it will occur. The only way to be safe from earthquake is to take necessary precautions. In this review paper the effects of Nepal Earthquake-2015 on the building structures of Bangladesh are discussed. From the observation it can be concluded that in Bangladesh several number of buildings are damaged during the Nepal earthquake. Most of these buildings were built with improper planning and not considering the adequate safety measures in design which are required incase of earthquake. These damages during earthquake can be minimized by taking some preventive measures which are also discussed in this paper. An investigation shows that Bangladesh has got a natural destructive energy which is located 32-km below earth surface in the Indian area but only 250-km away from the capital city of Bangladesh. This energy may come out any time with a major shaking all over Bangladesh. So, sufficient measures should be taken to make the existing structures safe against earthquake. An active interaction between earthquake engineers, structural engineers, seismologist, architects and government authorities should take place which will greatly help in reducing the building seismic vulnerability. Beside this training of engineers about earthquake resistant design and construction practices should be imparted on a continued basis.

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