EFFECT OF HORIZONTAL IRREGULARITY ON THE BEHAVIOR OF MULTY-STOREY R/C BUILDINGS DUE TO HORIZONTAL LOADS (BNBC/2006)

Sagar Ghos*[1], Rafid-Al-Zahur Khandker [2] and Md. Rokonuzzaman[3]

[1] *Lecturer,* Khulna University of Engineering & Technology
, Bangladesh, e-mail: ghossagar@gmail.com
[2] *Undergraduate Student,* Khulna University of Engineering & Technology
, Bangladesh, e-mail: rafidalzahur@gmail.com
[3] *Professor,* Khulna University of Engineering & Technology
, Bangladesh, e-mail: rokoncekuet@yahoo.com

ABSTRACT

This paper represents a parametric study of structural behavior of multi- storey r/c buildings with horizontal irregularity. In this research, multistory horizontally irregular buildings, as described in BNBC-2006, were modeled using ETABS, a commercial finite element package, for the analysis of their stability. Irregular plan like L-shape, H-shape and U-shape are considered for study. Assessment is done on the basis of lateral length ratio for each shape. Buildings are analyzed for Dead loads, Live loads and Wind loads are set as described in BNBC-2006(5.6.3.4) as well as the Earthquake load is set as per BNBC-2006(5.6.1.2). Parameters like internal forces and roof displacement are used for the assessment. Results are plotted for internal forces of critical members and roof displacements versus lateral length ratios for different shapes.

Keywords: Horizontal Irregularity, Lateral Loads, Lateral Length Ratio.

1. INTRODUCTION

Structural configuration has implications for both safety and economy of the building. In building with plan irregularities load distribution to different vertical elements is complex. The direct action of lateral loads (earthquake and wind) causes heavy moments and forces at base of the building. With asymmetric plan, further complexity is introduced as torsional forces become predominant. Recent reports on post-earthquake surveys have shown that many buildings have collapsed due to torsional effects in buildings with irregular plan. BNBC 2006 (Bangladesh National Building Code) for earthquake resistant design of structures (part-1, general considerations and building) also defines different categories of irregularities in building plan and elevation. In case of horizontally asymmetric buildings, the asymmetry is measured by the presence of torsion in the building. Asymmetric horizontal buildings possess separate centre of mass and centre of stiffness of the storey. Eccentricity between the two centers causes the torsion in the building which in turn is responsible for successive damage. If building is symmetrical about the two axes the centre of lateral stiffness of the storey and centre of mass coincides on each other. The earthquake forces acts through the centre of mass of the floor diaphragm and is resisted by the building at the centre of rigidity by its stiffening members. According to *S.K. Jain et. al*(2000)., there are so many buildings that have soft first storey. Due to the functional requirement of the first storey like parking facility, economic functionality etc. buildings are designed with no considerations towards the stiffness of first storey's. There is soft storey due to the absence of brick infill walls which has been removed for the functional requirement. Absence of wall reduces stiffness of this first storey leading it to soft storey. They have suggested that use of central concrete core method or providing additional strength to the columns are the two ways that can eliminate the effect of this soft storey. *F. Gultan Gulay et. al.* have presented the work on torsional unbalanced irregular structures for the verification of code specific design requirement of irregular structures of Turkish Earthquake Code, TEC'97. Irregular structures face torsional forces in them due to the different stiffness distribution. In irregular building, there may be concentration of ductility demand in a few locations. Special care needed in detailing. Just dynamic analysis may not solve the problem. Dynamic analysis is not always sufficient for irregular buildings, and dynamic analysis is not always needed for irregularities. Due to the architectural requirement of the building it is inevitable to introduce irregularity in the building and designers need to design the building to resist these severe twisting forces. Different types of plan irregularities according to BNBC 2006 are discussed in the following table.

Table-1: Plan Structural Irregularities

Irregularity Type and Description	Reference Section (BNBC)	Seismic Design Category Application
Stiffness Irregularity – Soft Story	5.2.5.1	D, E, and F
Stiffness Irregularity--Extreme Soft Story	5.2.5.1 5.2.6.5.1	D, E, and F E and F
Weight (Mass) Irregularity	5.2.5.1	D, E, and F
Vertical Geometric Irregularity	5.2.5.1	D, E, and F
In-Plane Discontinuity in Vertical Lateral-Force Resisting Elements	5.2.5.1 5.2.6.2.10 5.2.6.4.2	D, E, and F B, C, D, E, and F D, E, and F
Discontinuity in Capacity – Weak Story	5.2.6.2.3 5.2.5.2 5.2.6.5.1	B,C, D, E, and F D, E, and F E, and F

The present study is an attempt to parametrically studying the effects of building plan irregularities on different internal forces and top storey displacements. Three different shapes of buildings were considered with different length ratios.

2. METHODOLOGY

2.1 Model Analysis

In general, the Structural system of a building is a 3-D complex assemblage of various combination of inters connected structural elements. The primary function of the structural system is to carry effectively and safely of the loads acting on the budding and to transmit them to the foundation. A structural system is therefore, expected to:

- Carry static and dynamic loads.
- Carry lateral loads due to wind and earthquake effects.
- Resist stress caused by temperature and shrinkage effects.
- Resist external or internal blast and impact loads.
- Resist and help damp vibrations and fatigue effects.

2.2 Analysis Procedure

Most building code suggests two ways of carrying analysis for buildings subjected to seismic loads i.e. the equivalent static force procedure and a dynamic analysis procedure based on “accepted principles of dynamics”. The equivalent static force procedure has been used for many years now and its use is quite straightforward. However, true dynamic analysis procedures, particularly response spectrum analysis and time history analysis have gained foothold in the design offices recently to find out the actual behavior of structures imposed on lateral loads.

2.3 Generation of the plans of the buildings:

In the present paper horizontally irregular buildings are considered for the study. Each building modeled in ETABS is twenty storey's high. Bays are of 4 meters length each whereas roof height is set as 3 meters high each. Material considered is of reinforced concrete. In Figure 1 typical floor plans are shown for different shapes of horizontal irregular buildings. For more elaboration take the example of L shape plans. In the figure, this particular floor plan is for lateral length ratio (L1/L2) 0.43. In the same way this ratio of lateral length is varying from zero to 4 for all L shape plans.

In the same way other horizontal irregular plans are modeled with varying lateral length ratio for finding the most stable structure among them. In ETABS, after providing the story heights and story no’s for the buildings, this 3D model was generated to carry out the analysis and design. The models were checked for the frame sections and material properties so that they were assigned as described.

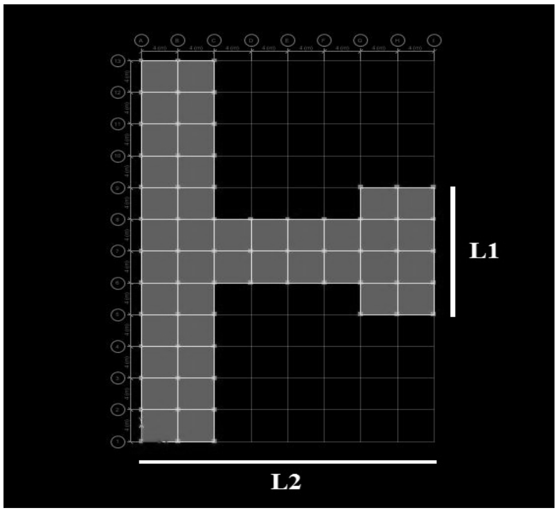


Figure 1: Plan view of H shaped building in ETABS

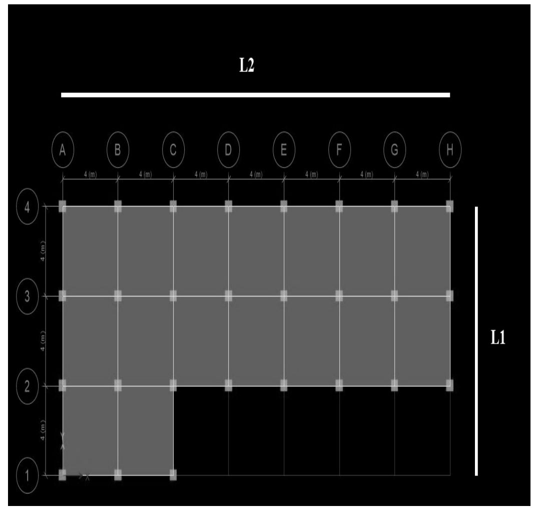


Figure 2: Plan view of L shaped building in ETABS.

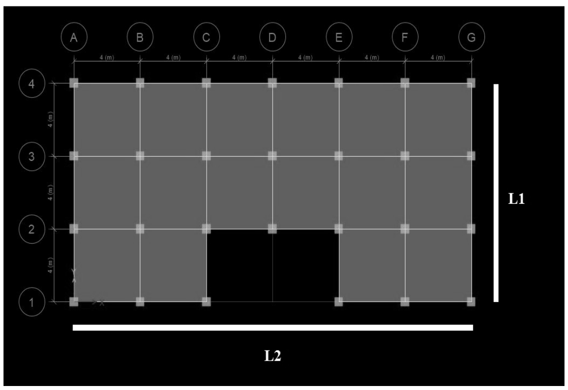
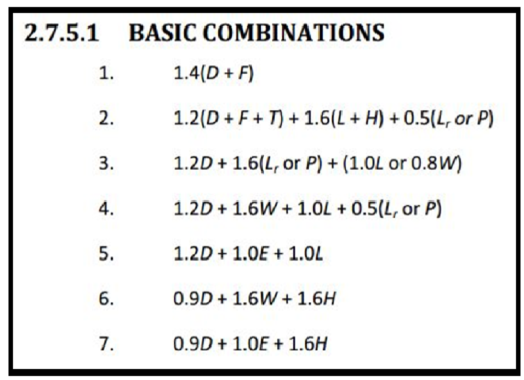


Figure 3: Plan view of U shaped building in ETABS.



2.7.5.1 BASIC COMBINATIONS

1. $1.4(D + F)$
2. $1.2(D + F + T) + 1.6(L + H) + 0.5(L_r \text{ or } P)$
3. $1.2D + 1.6(L_r \text{ or } P) + (1.0L \text{ or } 0.8W)$
4. $1.2D + 1.6W + 1.0L + 0.5(L_r \text{ or } P)$
5. $1.2D + 1.0E + 1.0L$
6. $0.9D + 1.6W + 1.6H$
7. $0.9D + 1.0E + 1.6H$

Figure 4: Load combinations according to BNBC 2006.

2.4 Assign Loads on Frames and Slabs:

On all three shaped the buildings, same loading values were applied for our comparison process. All the frames and slabs were assigned with Dead load, Live load, Stair live load, Wall load, Partition wall load with the following values listed in the table and the buildings were assigned with Wind and Earthquake loads as per BNBC code prohibition. Seismic zone co-efficient, exposure category, Response modification factor, wind speed, importance co-efficient were input to carry out the lateral load analysis.

Table 1: Loads on three buildings and design.

MATERIAL	LOADS	VALUE	DESIGN
RCC& COMPOSITE	LIVE	50 PSF	ACI 318-08 & AISC 360-10 CODE
	WALL	1KIP/FT.	
	FLOOR FINISH	25 PSF	
	STAIR CASE LIVE LOAD	80 PSF	
	PARTITION WALL	40 PSF	
	WIND AND EARTHQUAKE	AS PER BNBC	

Lateral loads are defined in static and dynamic load cases with Exposure and Pressure Coefficients, Wind Exposure Parameters, Exposure Height, and Wind Coefficients, Wind Speed, Terrain Category, Structure Class, Risk Coefficient Factor, Topography Factor Values of these are taken as mentioned in BNBC code. For Dynamic analysis, Normalized Response spectrum graph was plotted from BNBC code and that was assigned in the models to run the analysis. As code represents that above 90% mass should be considered while running Response spectrum, so mode no 20 were selected for getting above 90% of total mass source of the buildings to affect for the seismic load pattern.When strength design method is used, structural members and foundations were designed to have strength not less than that required to resist the most unfavorable effect of the combinations of factored loads listed in the following sections that are defined as design load combinations in ETABS. These load combinations as shown in figure 4 are the design combinations that were used for the building design in ETABS. Wind and Earthquake loads were assigned following the ETABS manual to get the accurate results and to find out the effects of lateral loads on the buildings.

3. RESULTS AND DISCUSSION

The aim of this study was to find the stable horizontal configuration of buildings. After running the analysis in ETABS graphs were plotted between parameters used against lateral length ratios for different types. Figure 5 and 6 shows the structural response of L- shaped buildings of different length ratios.

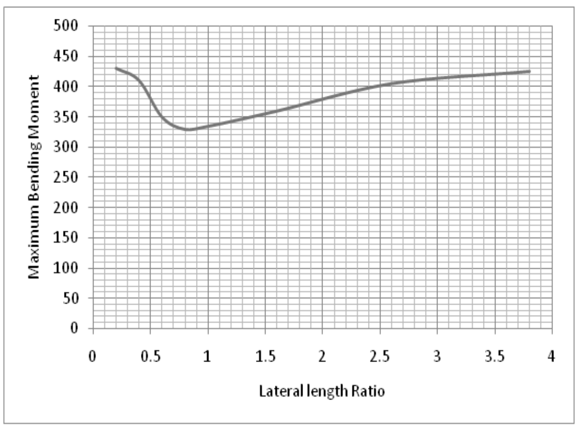


Figure 5: Variation of maximum bending moment with lateral length ratio (L-shape)

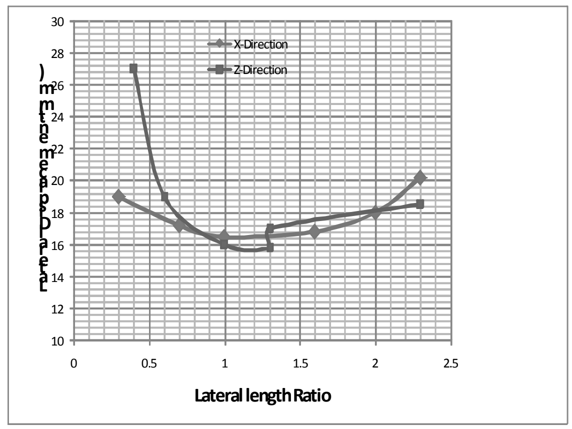


Figure-6: Variation of lateral displacement of top floor with lateral length ratio (L-shape)

Figure 5 shows the variation of maximum bending moment for a particular column among all columns of ground storey with lateral length ratio. From figure 5, it was observed that the minimum value of maximum bending moment was found at lateral length ratio of 0.80. Figure 6 shows the variation of lateral displacement of top floor with lateral length ratio in X and Z direction respectively.

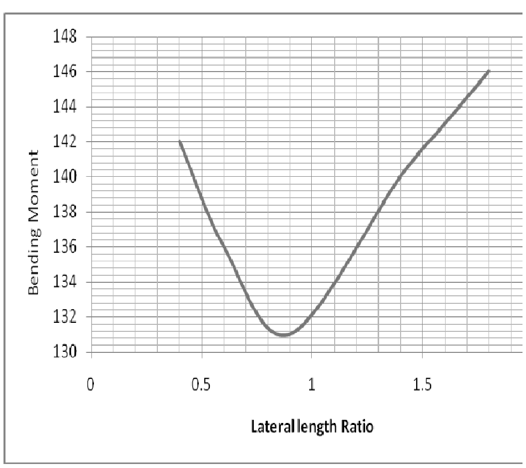


Figure 7: Variation in Maximum Bending Moment for corner column, in the direction parallel to web for H-shaped building.

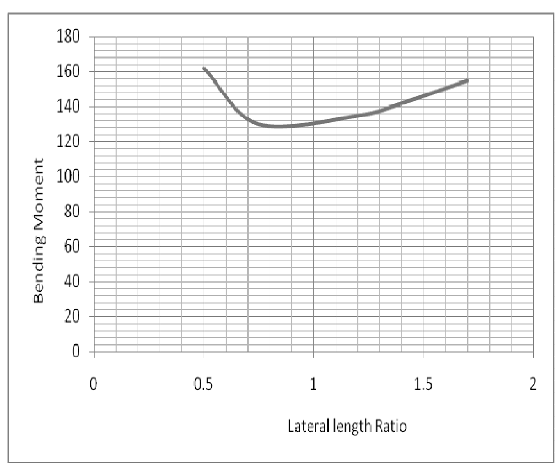


Figure 8: Variation in Bending Moment for outer column, in the direction parallel to web for H-shaped building.

Minimum displacement in x-direction was found for a lateral length ratio of 1.05. Figure 7 and 8 shows the structural response of h-shaped buildings. Figure-7 shows that the values of maximum bending moment decreases with the increase of lateral ratio and after a lateral length ratio of 0.85 maximum bending moment increases for corner column. Again for outer column, the nature of the graph (figure 8) is nearly similar to the corner column but in this case, bending moment varies gradually with the lateral length ratio and for a lateral length ratio of 0.75 minimum value of maximum bending moment was found. Figure 9 and 10 shows the structural response of the u-shaped buildings. Figure 9 shows that the maximum bending moment for u-shape buildings at first decreases with the increase of lateral length and after the length ratio of 0.82.

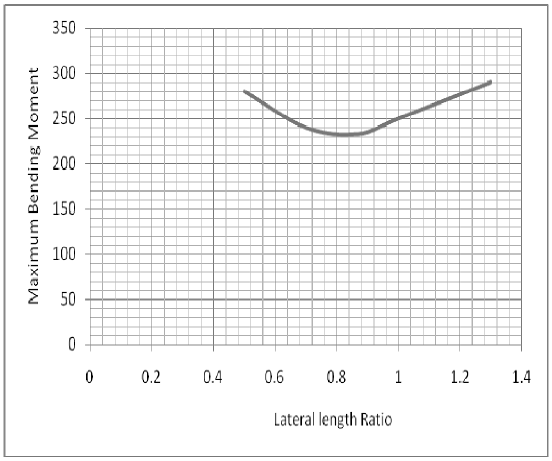


Figure 9: Variation in Maximum Bending Moment with lateral length ratio for U-shaped Building.

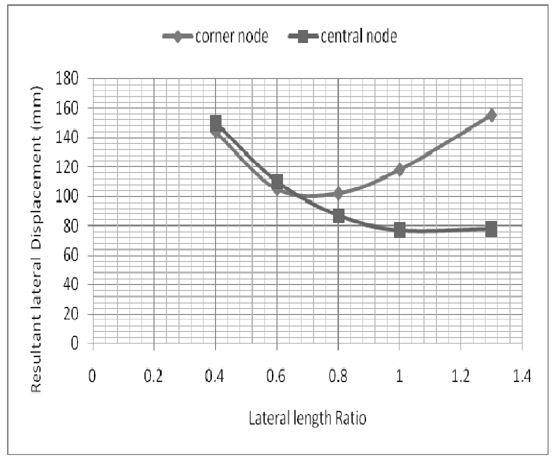


Figure 10: Variation of resultant lateral displacement with lateral length ratio for the top storey of U-shaped building.

Figure 10 shows that the variation of resultant lateral displacement with lateral length ratio for top story. Variation of lateral displacement for corner node is convex in nature and value of minimum lateral displacement was found for a lateral length ratio of 0.55. Also the resultant lateral displacements for central node decrease gradually with the increase of lateral length ratio and the minimum displacement was found at a lateral length ratio of 1.0. For Dynamic analysis, the time period and serviceability check values were also adopted from the analysis of the buildings in ETABS. The structures responded in a way that could be defined as a combination of many special modes. These modes are determined by dynamic analysis. For every mode, a response was perused from the design spectrum, in view of the modal frequency and the modal mass, and they were then combined to give an evaluation of the aggregate response of the structure. In this we need to ascertain the force magnitudes in all directions i.e. X, Y & Z and afterwards see the consequences for the buildings. In Response spectrum analysis, mass participation ratio was adopted 99% which satisfies BNBC code prohibition.

4. CONCLUSIONS

This paper represents a feasibility study of horizontally irregular structures in the current construction industry. This was performed by comparing the three different shaped horizontally irregular buildings. Three horizontally irregular buildings viz. L-shaped, H-shaped and U-shaped buildings were analyzed in a commercial finite element package (ETABS). After analyzing the results of L-shaped buildings i.e. variation of bending moment and top storey displacements, it can be stated that lateral length ratio 1 is the most stable structure among all for L shape plans. While assessing the stability of H shape structure, variation in moment in Z direction for the particular column of ground storey is shown in figure 7 and 8. It can be observed that plan with lateral length ratio of 0.8 has the least value of moment among rest of the plans. This least value is assigning this plan as the most stable structure among all rest of the H shape plans. Now for U-shaped plans, Figure 9 shows the variation of maximum bending moment for any particular column of ground storey. It can be observed that for lateral length ratio 0.82, this value is coming minimum. Now observing the response of variation of resultant of lateral displacement for the top storey nodes, graphs in figure 10 are different from one another. Hence for U shape plans, results are not stating any particular plan as the most stable among all of them. By observing graph of Figure 9 and 10, it can be stated that stability decrease as lateral length ratio increases above 1.

REFERENCES

BNBC (2006). BNBC 875 (Part 2) – 2006 Bangladesh National Building Code of practice for design load(other than earthquake) for buildings and structures.

BNBC (2006). BNBC 875 (Part 3) – 2006 Bangladesh National Building Code of practice for design loads (other than earthquake) for buildings and structures.

BNBC (2006). BNBC 875 (Part 5) – 2006 Bangladesh National Building Code of practice for design loads (other than earthquake) for buildings and structures.

BNBC (2006). BNBC 875 (Part 1) – 2006 Bangladesh National Building Code of practice for design loads (other than earthquake) for buildings and structures.

BNBC (2006). Ductile Detailing of Reinforced Concrete Structures Subjected To Seismic Forces — Code Of Practice.

BNBC (2006). (Part 1)-2006: Bangladesh National Building Code Criteria for Earthquake Resistant Design of Structures, Part 1 – General Provisions and Buildings (Fifth Revision)

BNBC (2006) .Standard plan and reinforced concrete Code of practice.

Gulay. F. Gultan and Calim Gokhan. A Comparative Study of Torsionally Unbalanced Multi – Storey Structures under Seismic Loading.‖ (2001), Istanbul Technical University, Civil Engineering Department, 80626 Maslak, Istanbul, Turkey.

Jain. K., Murti C. V. and Arlekar Jaswant N. (2000). Seismic Response of RC Frame Building with Soft First Storey‖, Indian Institute of Technology, Kanpur, India.