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INFLUENCE OF VERTICALLY IRREGULAR CONFIGURATIONS OF BUILDING ON SEISMIC RESPONSES

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Abstract*- Irregular buildings constitute a large portion of the modern urban infrastructure. When such buildings are located in a high seismic zone, it becomes more than a concern. The presence of irregular frame subjected to earthquake and other ground shaking calamities is matter of concern. In Bangladesh and many other developing countries building with vertical irregularities are being constructed from architectural point of view. Therefore, it is important to know that how the vertical irregular alters the seismic responses of buildings. Vertical irregularities in building configuration can be introduced in a number of ways such as, setback at one side of different height, in both side, in all sides, gradual variation of setback and setback at the corners. However, in the previous studies these issues were not taken into consideration elaborately. Hence, in the present research work, time history dynamic analysis is carried out and total 18 numbers of buildings with different irregularities were taken into consideration to observe the influence of vertical irregularity on seismic responses. Results were mainly compared in terms of floor acceleration and displacement. It was found that the vertical irregularities have significant influence on seismic responses..*

Keywords: Earthquake, Vertically Set-back Irregular Buildings, Static Analysis, Time History Analysis

1. INTRODUCTION

Earthquakes are the most unpredictable and devastating of all natural disasters, which are very difficult to save over engineering properties and life, against it. The buildings with regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation suffer much less damage compared to irregular configurations. But nowadays need and demand of the latest generation and growing population has made the architects or engineers inevitable towards planning of irregular configurations. Most recent earthquakes have shown that the irregular distribution of mass, stiffness and strengths may cause serious damage in structural systems.

Vertical irregularities are characterized by vertical discontinuities in the geometry, distribution of mass, stiffness and strength. However, vertical discontinuity in the geometry is the most common one among these vertical irregularities. Vertical geometric irregularity shall be considered to exist where horizontal dimension of the lateral force resisting system in any story is more than 130 percent of that in an adjacent story. Fig. 1 shows the vertical setback irregularities. Buildings with vertical setback irregularities are susceptible to seismic damage. Fig. 2 shows the failure of 21 storied building at mid height due to presence of setback was observed during Chile earthquake 2010.

Many of researches have already been dedicated regarding vertical irregularities of building; however,

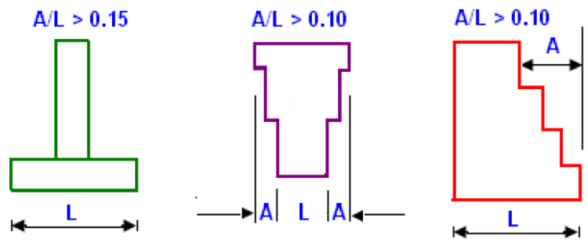


Fig. 1: Vertical setback irregularity [1]

Fig. 2: Failure of buildings due to setback irregularities (Chili, 2010)

they mainly focused on mass, stiffness and strength irregularity [2-3]. In past researches, the vertical setback irregularity was not taken into consideration in details. Therefore, it is important to know how the vertical set back irregularities affect the seismic responses of the buildings. In the present study, total 18 buildings with different type and level of vertical set back irregularities were taken into consideration. The dynamic Time-History analysis was carried out to predict the exact seismic responses under earthquake excitation. Results were compared in terms of displacement and roof acceleration of the building.

2. METHODOLOGY

In the current research, dynamic Time-History analysis was carried out. Time-History analysis is a step-by-step procedure where the loading and the response history are evaluated at successive time increments. During each step the response is evaluated from the initial conditions existing at the beginning of the step. In linear time history analysis, the structural properties are assumed to remain constant and a linear behavior of structure is assumed during the entire loading history. Time history analysis techniques involve the stepwise solution in the time domain of the multi-degree-of freedom equations of motion which represent the actual response of a building. It is the most sophisticated analysis method available to a structural engineer.

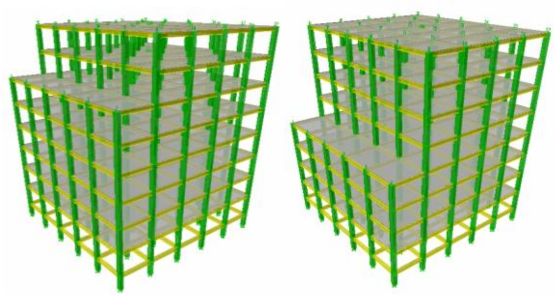
To obtain the dynamic responses by Time-History analysis, one must solve the structure's equation of motion. The general equation of motion is therefore-

$$[M]\{\ddot{D}\}+[C]\{\dot{D}\}+[K]\{D\}=\{F\} \qquad (1)$$

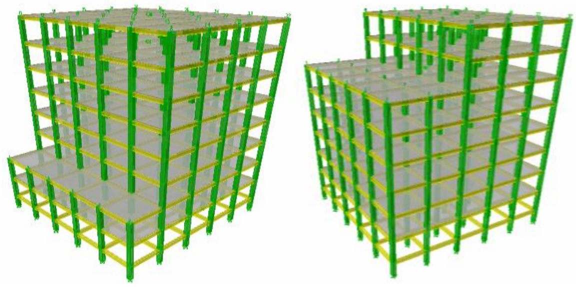
M, is the mass matrix, C is the damping matrix and K is the stiffness matrix. Commercial Finite element based software ETABS was used to conduct the time history analysis..

3. BUILDING MODELING

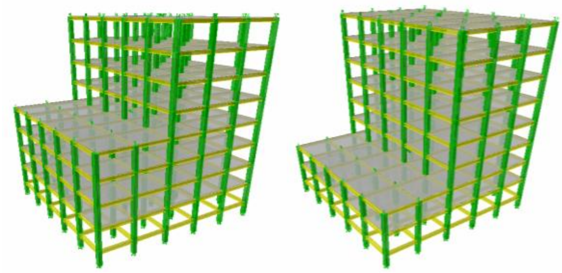
In ETABS, the RC buildings were modeled using frame and shell element. The beam and column were modeled using frame element with RC properties and slab was modeledshell element. The geometric properties of beam, column and slab were maintained same in all the building model. All the buildings were 8 storied with a floor height of 10 ft. The columns were square in shape with 15 in length and beams were 12 in by 15 in. The slab was 5 in thick. The effect of infill wall was ignored in the analysis. Fig. 3 shows the all 18 building model. Two time history data of earthquake in Japan which are known as Tokachi-Oki (2003) and Miyagi-2(2011) were considered as a ground excitation. Tokachi-Oki earthquake data was scaled down approximately 1.65 times and the Miyagi 2 was scaled up around 1.15 times to make the them compatible with the BNBC [4] response spectrum.



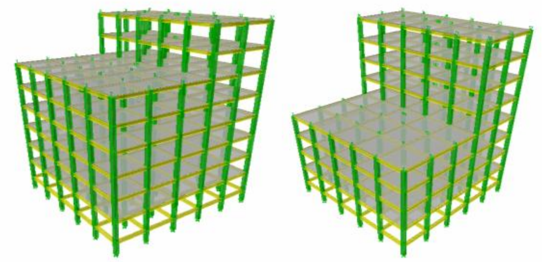
Model- 1.1.2 Model – 1.1.4



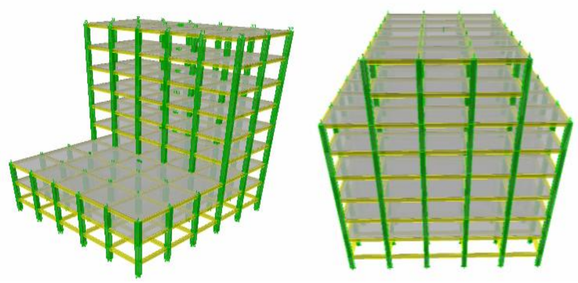
Model – 1.1.6 Model – 1.2.2



Model – 1.2.4 Model – 1.2.6



Model – 1.3.2 Model – 1.3.4



Model – 1.3.6 Model – 2.1.2

Model – 2.1.4 Model – 2.1.6

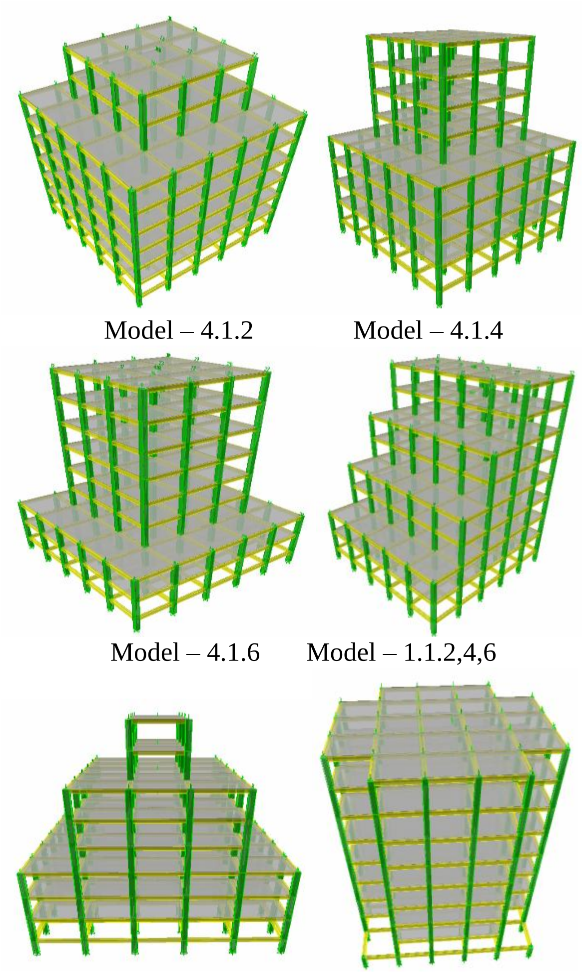


Fig. 3: Considered building model with identity

4. RESULTS AND DISCUSSION

Table 1 compares the static and dynamic displacement of the irregular buildings. As can be seen the displacement obtained from dynamic analysis is much higher than the static analysis. Specially, in case of Tokachi earthquake, the static analysis underestimates the displacement significantly. To understand the effect of vertical setback irregularity, the displacement of roof accelerations are plotted in Fig. 4. As can be seen that the displacement increase with the height of setback. As the setback height increases, the building increases higher displacements both for the Tokachi and Miyagi earthquakes. Along with the height of the setback, the width and side of setback have also influence on displacement. As compared to the setback at four sides, setback at one side has higher displacements (Model-1.3.6). Further, the setback increases with the width of the setback (Model-1.3.6). The Model-1.1.2.4.6 with gradual increase in setback height and width possess also very large magnitude of displacement. In case of modal analysis increase of setback height and width showed abrupt modal responses for shear and bending. Fig. 5 summarizes the roof acceleration of the buildings with vertical irregularities. Similar the displacement, vertical setback irregularities have similar effect on acceleration. Similar to the displacement, Model-1.1.2.4.6 model has higher acceleration. Rather than the side of the setback, the width and height of setback are the more influence parameter. When setback height and width increases compared to adjacent story like model-1.3.2, model-1.3.4, model-1.3.6, model-4.1.6 point acceleration due to earthquake load increase. As a result increased setback configurations face greater story drift at setback section.

5. CONCLUSIONS

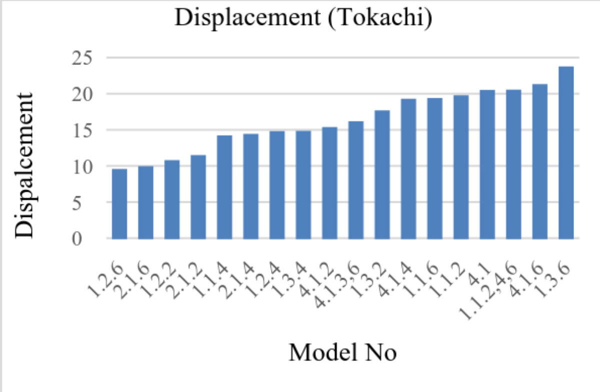
After analyzing the seismic responses of vertically irregular configurations the conclusions can be made:

- For vertically irregular buildings, dynamic Time-History analysis must be carried out to grasp the exact response of the building.
- The setback height, width and side affect the seismic responses of the building.
- As compared to the setback side, the height and width are more influential to deteriorate the seismic responses of the building.

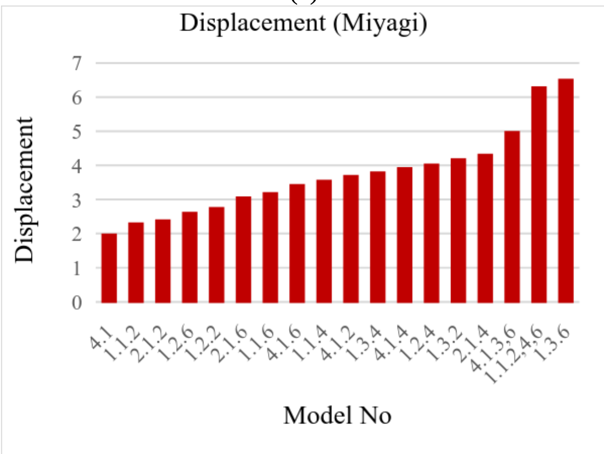
It was found that the setback in one side with a magnitude of more than 60% both in terms of width and height possess the height responses.

Table 1: Maximum top story displacement of models(mm)

Model No	Static Analysis	Time History Analysis	
		Tokachi	Miyagi 2
1.1.2	2.6493	19.65	2.3
1.1.4	2.6581	14.09	3.55
1.1.6	2.7254	19.26	3.19
1.2.2	2.577	10.67	2.75
1.2.4	2.6308	14.69	4.02
1.2.6	2.8012	9.46	2.61
1.3.2	2.541	17.53	4.18
1.3.4	2.7041	14.73	3.79
1.3.6	3.055	23.61	6.51
2.1.2	2.5773	11.36	2.39
2.1.4	2.6626	14.3	4.31
2.1.6	2.8025	9.83	3.06
4.1.2	2.5172	15.25	3.69
4.1.4	2.6825	19.14	3.92
4.1.6	2.9119	21.19	3.42
1.1.2,4,6	2.5483	20.42	6.29
4.1.3,6	2.6112	16.04	4.98
4.1	2.7058	20.36	1.97

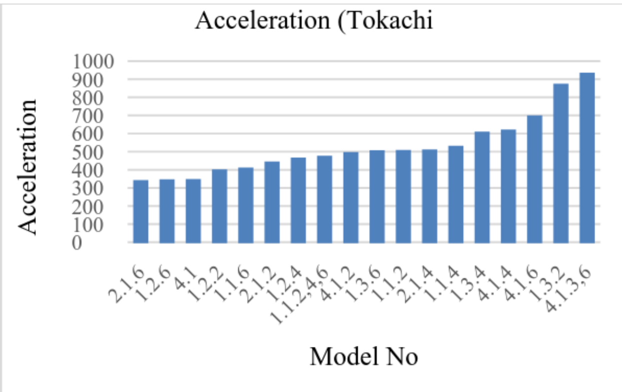


(a)

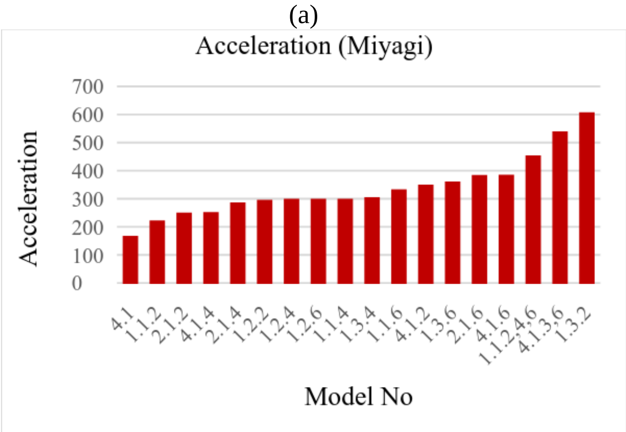


(b)

Fig. 4: Displacement of the irregular buildings for Tokachi (a) and Miyagi (b) earthquakes



(a)



(b)

Fig. 5: Roof acceleration of irregular buildings for Tokachi (a) and Miyagi (b) earthquakes

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