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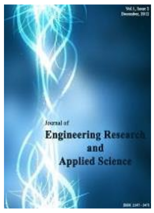

Investigation of the effect of torsional irregularity on earthquake behaviour

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Abstract

One of the major reasons for damage to the buildings during the earthquake is the vertical and plan irregularities in the buildings. Torsional irregularity is a type of irregularity that is included in many earthquake regulations in the world as irregularity. Knowing the factors affecting torsional irregularity by investigating the behavior of torsional irregular buildings is very important for avoiding this irregularity. In this study, the different number of story and the different located shear wall in plan were handled. Earthquake analyzes of these buildings were made separately for the three different earthquake analysis methods defined in Turkish Earthquake Code-2007 (TEC-2007). The variation of the torsional irregularity according to the number of story and the earthquake analysis method was investigated.

Keywords: Seismic analysis; torsional irregularity; time history analysis; equivalent lateral load.

1. Introduction

During the design of buildings, many external effects such as earthquake, wind, snow should be considered. Although the quality of the material used in the construction of the buildings is high quality, the mistakes made during the design can cause unexpected structural behaviors of the total system. Even if the concrete design complies with the current standards, external and production factors also take great importance. [1, 2].

Many large earthquakes have occurred for centuries in Turkey. In these earthquakes, there have been many lives and properties loss. Those losses were generally caused by factors such as material quality, design mistakes. One of these design mistakes is structural irregularities. Many studies have been conducted made after the earthquakes show that the irregularities in the buildings cause the buildings to be severely damaged under the earthquake and wind loads. Therefore, torsional irregularity is included in 39 contemporary earthquake and structural design codes [3,4].

The earthquake load on the building is affected by the center of mass. However, the center of stiffness of the building is the point of reaction under the lateral loads. Torsional irregularities occur because the center of mass and the center of stiffness are not in the same place. Due to torsional irregularity, the building is forced to rotate through the center of stiffness. As a result, torsion moments occur [5].

Torsional irregularity is defined as η_b in TEC-2007. Torsional irregularity is obtained for each storey by formula (1) [6].

$$\eta_{b(i)} = \frac{\Delta_{max}}{\Delta_{ort}} \tag{1}$$

Here, Δ_{max} and Δ_{ort} shows respectively the maximum and average relative storey drift on i. storey. According to TEC-2007, the torsional irregularity of the building is occurred by the value of η_b exceeding 1.20.

In case of torsional irregularity, $\pm$%5 additional eccentricity applied to storey is amplified by multiplying with coefficient D obtained from formula (2) and the analyzes are repeated [5].

$$D = \left(\frac{\eta_b}{1.20}\right)^2 \tag{2}$$

If the torsional irregularity coefficient η_b, which determines the amount of torsion at the building, is greater than 2.00, it is assumed that the building is extreme torsional irregularity. Equivalent earthquake load method cannot be applied for this building [7].

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Several studies have been conducted on irregularities [8-10]. A number of studies have also been carried out on factors affecting torsional irregularity [10-12].

Location of shear wall has a significant effect on the torsional irregularity in the building [4]. Location of shear wall to slide the center of stiffness can cause significant torsion moment in the structure [13].

There is also a significant effect of the local site class on torsional irregularities [14,15]. It was found that the structure affected the earthquake behavior and changed the base shear forces and periods [16].
In this study, the effects of torsional irregularity were investigated by changing the number of story of symmetrical buildings with two different type plans. How the equivalent earthquake load method changes the results of buildings with extreme torsional irregularity according to dynamic methods was evaluated and the code items were evaluated.

2. Material and method

As shown in Figure 1, two different plan types were chosen as Type of A and Type of B. Shear wall is not used on Type of A. Shear wall is used on type of B to occur torsional irregularity. The location of shear wall was chosen by considering the wrong shear wall applied to the buildings in general.

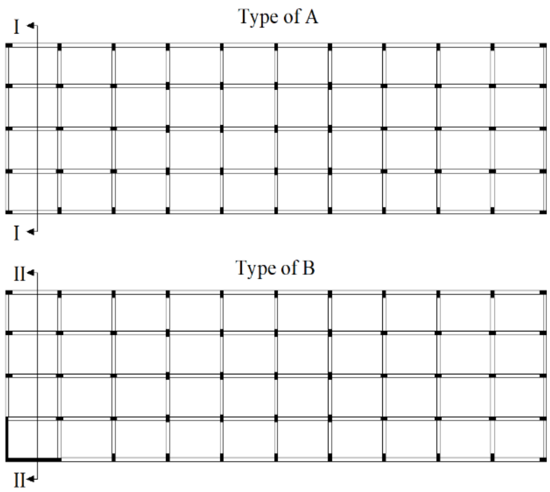

Figure 1. Type of A and B plans.

In both types of A and B, the number of floors was changed to examine the effect of analysis methods and number of storey on torsional irregularity. The cross-sections of type of A and type of B buildings are given in figure 2.

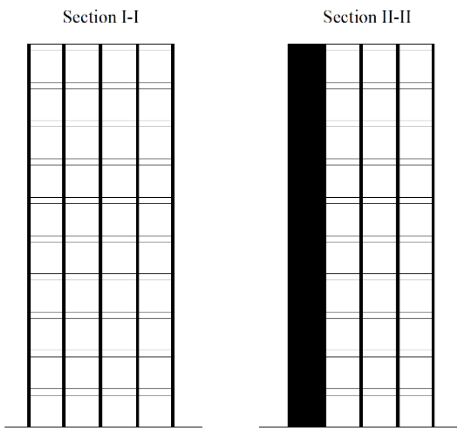

Figure 2. The cross-sections of type of A and B buildings.

In the analysis of the buildings ETABS commercial program was used. Equivalent Earthquake Load Method (EL), Mode Superposition Method (MS) and Time History Analysis Method (TH) were used for seismic analysis. For EL and MS, Z4 local site class, building importance factor 1 and earthquake zone 1 were chosen. For TH analysis, as seen in Figure 3, Düzce earthquake acceleration records are used.

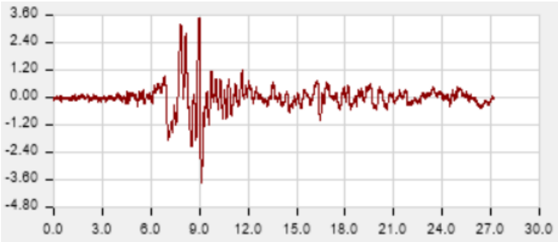

Figure 3. Düzce earthquake acceleration record.

Column dimensions, beam dimensions, slab thickness and shear wall thickness in the building model were chosen 500x250 mm, 500 x 250 mm, 120 mm, and 200 mm respectively. In addition to its own weight, 1.5 kN/m^2 as dead load and 5 kN/m^2 as live load were defined. It is assumed that the columns are connected to the ground as fixed.

3. Results and discussion

The results of the analyzes are given in Table 1 for the natural vibration periods.

Table 1. Natural vibration periods

Type of Building	Number of storey	Natural Vibration Period (X direction)	Natural Vibration Period (Y direction)
A	10	1.372	1.326
	9	1.253	1.212
	8	1.135	1.099
	7	1.018	0.982
	6	0.901	0.874
B	10	1.283	0.919
	9	1.168	0.813
	8	1.056	0.708
	7	0.944	0.605
	6	0.834	0.506

Base shear forces acting on the type of A and B buildings according to the analysis method were found. The results obtained in the x direction for type of A building are given in figure 4.

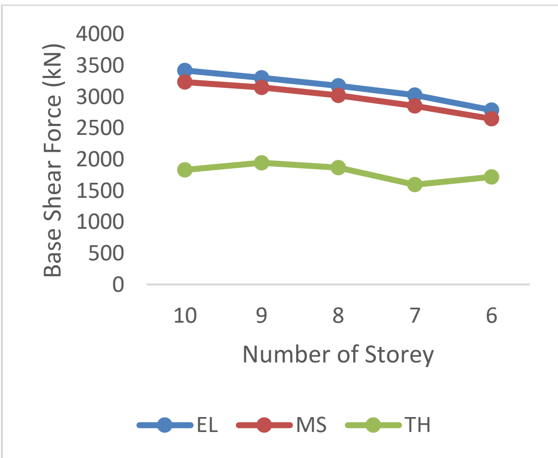

Figure 4. Base shear force in x direction for type of A

The results obtained in the x direction for type of B building are given in figure 5.

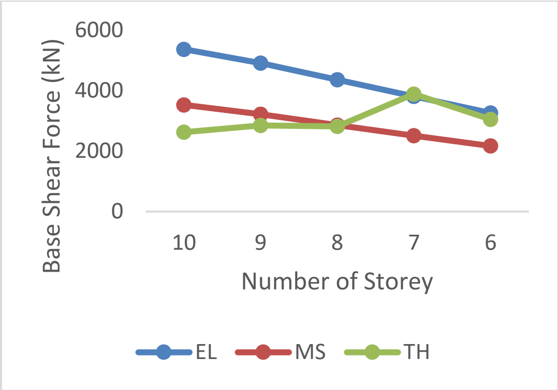

Figure 5. Base shear force in x direction for type of B

The results obtained in the x direction for type of A building are given in figure 6.

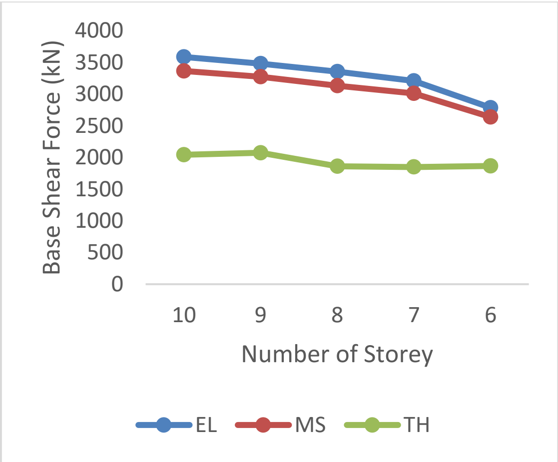

Figure 6. Base shear force in y direction for type of A

The results obtained in the x direction for type of B building are given in figure 7.

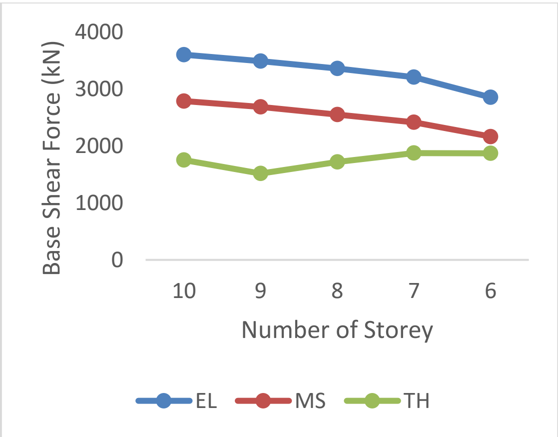

Figure 7. Base shear force in y direction for type of B

Torsional irregularity coefficient for type of A building are given in figure 8.

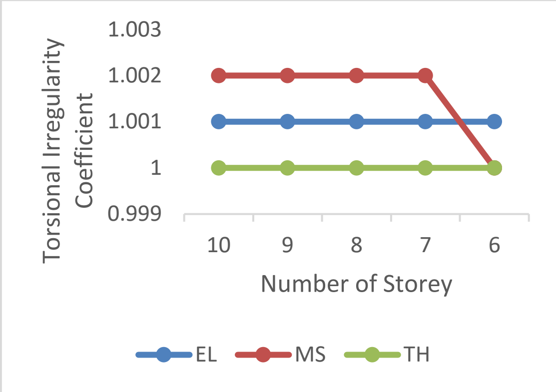

Figure 8. Torsional irregularity coefficient for type of A

Torsional irregularity coefficient for type of B building are given in figure 9.

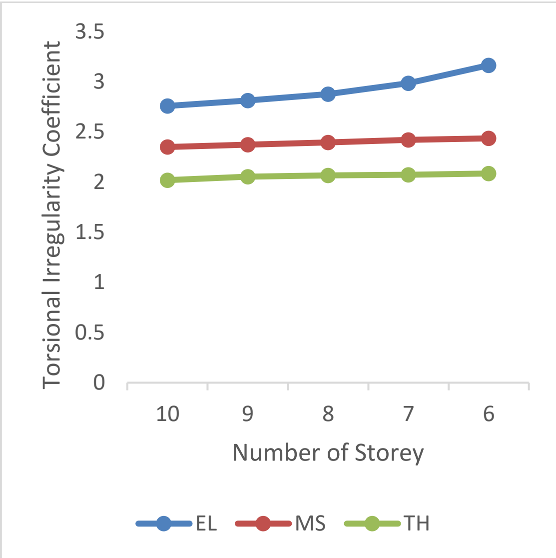

Figure 9. Torsional irregularity coefficient for type of B

4. Conclusions

The results obtained from analysis were presented as graphs on section 3. The following results have been obtained:

- The base shear forces obtained by the EL method in the building with extreme torsional irregularity increase by approximately 50% for each number of storey.
- It was found that the EL method was not suitable for the building with extreme torsional irregularity.
- When the coefficients of torsional irregularity are examined, it is seen that the coefficient of torsional irregularity increases while number of storey decrease.
- The torsional irregularity coefficient increase about 50% in the EL method.

The results obtained from analysis show that the EL method should not be used for buildings with extreme torsional irregularities. The height limit for the use of the EL method at TEC-2007 can be increased up to 30 m. In order to use the EL method, there should be no building irregularities.

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