TORSIONAL IRREGULARITY EFFECTS OF LOCAL SITE CLASSES IN MULTIPLE STOREY STRUCTURES

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ABSTRACT

In this paper, torsional irregularity factors which effect multi storey shear wall-frame systems were investigated according to Turkish Earthquake Code (TEC) 2007. Six type structures which have different story numbers, plan views and shear wall locations were analyzed. These structures are studied according to local site classes in TEC 2007. Thus, importance levels were determined. SAP 2000 package program were used for structural analyses. Equivalent Seismic Load Method and Mode Superposition Method were used for seismic analyses. Torsional irregularity coefficients are comparatively investigated and efficient factors are determined for torsional irregularities maximum values.

Keywords: Torsional irregularity, Local site class, TEC 2007

1. INTRODUCTION

Our country which is in a seismic zone has been exposed to many earthquakes for centuries. The issue is on the agenda because of the possible earthquakes in following years. Turkish Earthquake Code 2007 has been prepared in March 2007 as a result of many studies in recent years.

Torsional irregularity in plane is taken into account in latter day codes. There are precautions and sanctions in 39 codes. Torsional irregularity is seen frequently in structures. On this account, it takes place in TEC-2007 like other codes. Torsional irregularity depends on \( \eta_b \) (torsional irregularity coefficient) in TEC-2007. Torsional irregularity is the ratio of maximum interstory drift value to the average interstory drift value at each story and given in eq. 1.

\[
\eta_b(i) = \frac{(\Delta_i)_{\text{max}}}{(\Delta_i)_{\text{ort}}} \tag{1}
\]

Torsional irregularity occurs when \( \eta_b \) value is between 1,20 and 2,00 in a structure. In this case ±%5 additional eccentricity which is applied in the related floor is multiplied with \( D_i \) coefficient in both directions. Thus, structural system is enforced more and more.

\[
D_i = \left[ \frac{\eta_b(i)}{1.20} \right]^2 \tag{2}
\]

When \( \eta_b \) coefficient exceeds upper limit which is 2,00, dynamic applications shall be used that is defined in TEC-2007.

There have been many studies completed about seismic behavior of irregular structures. In these studies, the factors which are effective on plan and vertical irregularities have been determined \([1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12]\).

Chintanapakdee and Chopra [1] compared the seismic demands for vertically irregular frames determined by the Modal Pushover Analysis method and the nonlinear response history analysis was completed by using an ensemble of 20 ground motions.

Lucchini et. al [2] resulted from both linear and nonlinear dynamic analyses exploring the seismic torsional behaviour of a multi-storey RC frame structure asymmetric in plan and regular in elevation were reported.

Cosenza et al. [3] compared most of the results which exist in the literature, suggested proposals of modification and underlined the importance of further studies in order to evaluate a condition of minimum torsional stiffness.

In addition, in the study of Demir and Dönmez [4], effects of local site classes on torsional irregularity were comprehensively analyzed. Equivalent seismic load method was used for seismic loads.

In this paper, 4 symmetrical structures with different shear wall locations such as A, B, C, D and 2 other asymmetrical structures with different shear wall locations that are E and F defined in local site classes such as Z1, Z2, Z3, Z4 are investigated. Story numbers change between 6, 8, 10 and 12. Equivalent Seismic Load Method (ESLM) and Mode Superposition Method (MSM) are used to analyses structures and determine the torsional irregularity coefficients. Almost 200 structures with different parameters are analyzed in this paper.

By changing horizontal seismic forces and torsional moments in different sites, the structures are analyzed and the change in \( \eta_b \) coefficients are investigated.
2. MATERIAL and METHOD

2.1. Material

While A type buildings are formed from frames, B, C, D, E and F type structures are formed from frames and shear walls. Plan views of 6 type structures named A, B, C, D, E and F are given in figure 1. Members which are hatched with dashed lines represent shear walls.

As it shown in figure 1, shear walls are positioned symmetrically in both directions in A, B and C type structures. In D type structures, shear walls are positioned symmetrically in y direction and in E and F type of structures shear walls are positioned asymmetrically.

Structures are in the 1. level seismic zone. Story heights are 3 meters for all stories. The length of x spans and y spans are respectively 5 m and 3 m. The dimensions of the beams are 30 × 60 cm in all structures. While dimensions of the corner columns are 40 × 40 cm, side columns are 50 × 50 cm and the columns in the middle of the structures are 60 × 50 cm in A, B, C, D type structures. The column dimensions are 50 × 50 cm in E and F type structure. The width of shear walls are 20 cm. Length of shear walls differ from each other in different structures as it shown in Figure 1. Concrete class is C20 and rebar class is S420 in all structures.

2.2. Method

SAP 2000 package program is used for analyses in all structures. Equivalent Seismic Load Method (ESLM) and Mode Superposition Method (MSM) are used for seismic analyses. In Mode Superposition Method, dynamic properties of structures are important and the seismic forces are more reliable. The analyses of structures are performed in four site classes such as Z1, Z2, Z3 and Z4 defined in TEC-2007. While site class Z1 consists of rocks, dense sand, gravel, dense and silt clay, site class Z4 consists of soft layers where ground water level is high, loose sand and dense alluvium layers. Because of this reason, Period values are increased from Z1 to Z4 as it shown in table 1.

Table 1. Spectrum Characteristic Periods ($T_A, T_B$)

<table>
<thead>
<tr>
<th>Local Site Classes</th>
<th>$T_A$ (Second)</th>
<th>$T_B$ (Second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z1</td>
<td>0.10</td>
<td>0.30</td>
</tr>
<tr>
<td>Z2</td>
<td>0.15</td>
<td>0.40</td>
</tr>
<tr>
<td>Z3</td>
<td>0.15</td>
<td>0.60</td>
</tr>
<tr>
<td>Z4</td>
<td>0.20</td>
<td>0.90</td>
</tr>
</tbody>
</table>
When periods of structures are close to the site vibration period, there are more displacements and damages observed. The horizontal force which effects the structure improves the oscillation rate owing to the resonance. Thus, damages occur.

Due to A, B, C type structures and shear walls are symmetrically positioned, torsional moments are applied to the center of mass of each story with ±5% eccentricity in both directions. Shear walls of D type structures and plan views of E and F type of structures are not symmetrically positioned. For this reason, centers of mass do not collide with and centers of rigidity for each structure. In this case, addition eccentricity is calculated according to the eq. 3.

\[ e_d = \alpha \varepsilon_s + \gamma B_s \]  

In TEC-2007, \( \gamma \) coefficient is taken 0.05 and \( \alpha \) coefficient is taken 1.00. Also eccentricity is increased by \( D_i \) coefficient according to the torsional irregularity. \( \varepsilon_s \) represents the torsional effects in the structure due to the eccentricity. \( \gamma B_s \) is used for represents the differences between rigidity, strength, load values and real values of them. Seismic forces are multiplied with additional eccentricity values at y direction in D type structures, and at x and y directions in E and F type of structures. So bigger torsional moment values are calculated and these values are applied to the center of mass with horizontal seismic forces. In structural analyses, structure-base interaction is taken into consideration.

### 3. FINDINGS

The biggest torsional irregularity coefficients for each structure that are obtained after completing the analyses are given in figure 4, 5, 6, 7, 8, 9, 10 and 11.
C TYPE STRUCTURES

Figure 6. $\eta_b$ values of C type buildings

D TYPE STRUCTURES

Figure 7. $\eta_b$ values of D type buildings

E TYPE STRUCTURES

Figure 8. $\eta_b$ values of E type buildings

F TYPE STRUCTURES

Figure 10. $\eta_b$ values of F type buildings

Figure 11. $\eta_b$ values of F type buildings
4. CONCLUSIONS AND SUGGESTIONS

η_b values did not reach 1.20 limit value for A, B, C and D structures at each direction. η_b values of E and F structures are about 2.00 top limit value.

Local site classes did not effect η_b coefficients in symmetrical structures in plan. Because there is no rigidity change in similar type buildings. In addition, it is considered that seismic forces with the effect of site class change impact each story of structures similarly.

Local site classes effect η_b coefficients between 0.01-0.15 values in asymmetrical structures as seen in Figure 8, 9, 10 and 11.

In A, B, C and D type structures, η_b coefficients which are calculated by mode superposition method are %2-3 bigger than equivalent seismic load method. The difference between methods is %3-6 in E and F type structures.

When the results are taken into consideration, plan view, shear walls location, seismic evaluation method, story numbers and local site classes effect η_b values in symmetrical structures.

On the other hand, seismic evaluation method does not effect η_b coefficient as much as other parameters in asymmetrical structures.

Structures are exposed to torsional irregularities due to the seismic effects. Plan geometry of structures should be symmetrical to reduce the torsional irregularity coefficient. If the plan geometry is not able for symmetrical, eccentricity values can be reduced by additional shear walls. By this way, torsional moment values are decreased.

Shear walls shall be located in outer sides in stead of center. Because the shear walls in center of the structure increase the torsional moment values.

5. REFERENCES


