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The importance of accidental design eccentricity in seismic design of steel buildings with dual system under the effect of far- and near-fault ground motions

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ABSTRACT: Seismic responses of buildings are amplified due to torsion. To account for the effects that cause torsion and are not considered in the design process of buildings, the seismic codes introduce “accidental design eccentricity (ADE)”. In this study, the adequacy of the Iranian Standard No. 2800 provisions about the design eccentricity was investigated. To this end, the 5-story torsionally-stiff and torsionally-flexible buildings with dual lateral load resisting system were studied. The mass eccentricity in plan-asymmetric buildings was assumed to be equal to 0.10b and 0.20b where b is the plan dimension. Nonlinear time history analyses were performed using far-field (FF), non-pulse (NP) and pulse-like (FD) near-field records for the models in two cases. In the first case, the effect of the ADE on the seismic demands of symmetric and asymmetric-plan buildings was investigated. Finally, to consider what happens when an actual accidental mass eccentricity (AME) is introduced in an already designed building, the mass center of the buildings was shifted by ±0.05b (b is the dimension of the building perpendicular to the earthquake direction) simultaneously in both directions and the buildings (with and without ADE) were analyzed for the earthquake sets described above. For the buildings investigated in this research, the results indicate that the provision related to the accidental design eccentricity has little influence (less than 10%) on the inelastic seismic responses for torsionally-stiff buildings and can be ignored. Also, the accidental mass eccentricity has more influence (maximum 38%) on the inelastic seismic responses of torsionally-flexible buildings but the accidental design eccentricity has less influence on the reduction of seismic responses. Therefore, it seems that the accidental design eccentricity needs to be modified for torsionally-flexible buildings.

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1. INTRODUCTION

Seismic responses of buildings are amplified due to torsion. To account for the effect of factors that are not considered in the design process of buildings, such as non-uniform ground motion (due to wave travelling effects and motion incoherence) and consequent excitation differences at the support points, the presence of non-structural elements not accounted for in the design, unknown non-symmetric distributions of live loads or differences between actual and design distributions of mass, stiffness and strength, the seismic codes introduce “accidental design eccentricity” (ADE) [1]. This provision in Standard No. 2800 [2] requires that lateral forces should be applied whit an eccentricity at least 5% of plan dimension perpendicular to the ground motion direction multiplied by torsional amplification factor (A_j), in both positive and negative directions.

$$A_j=(\Delta_{max}/(1.2\Delta_{ave}))^2 \quad 1\le A_j\le 3 \quad (1)$$

in which Δ_{max} and Δ_{ave} are the maximum and average displacements at the level considered assuming A_j = 1. In the dynamic analysis, the center mass in each floor should be displaced by a certain amount of accidental design eccentricity (ADE). In this study, the adequacy of the provisions of Standard No. 2800 about the accidental design eccentricity for steel buildings with dual system under the effect of far- and near-fault ground motions was investigated.

2. METHODOLOGY

In this paper, 5-story torsionally-stiff (TS) and torsionally-flexible (TF) buildings with dual lateral load resisting system having moderate steel moment resisting frame with special braced frame in both directions were studied. The story heights were equal to 3.2 m for all buildings. The layouts of the TS and TF buildings are shown in Fig. 1. The dead and live loads were equal to 650 and 200 kg/m^2 on the floor area. For each group of the TS and TF buildings, in addition to the symmetric building (e_m=0.00), asymmetric buildings with bidirectional initial mass eccentricity with e_m=0.10b and e_m=0.20b were designed for the three different ADEs: ADE=0.00, ADE=0.05b and ADE=A_j*0.05b. The buildings studied were designed according to AISC 360-10 [3] and Standard No. 2800 for the seismic category with a very high seismicity hazard level, moderate importance and soil type

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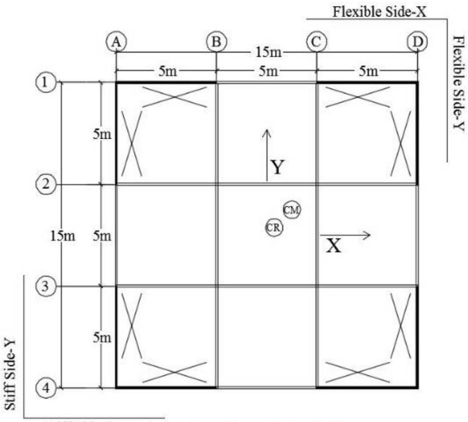
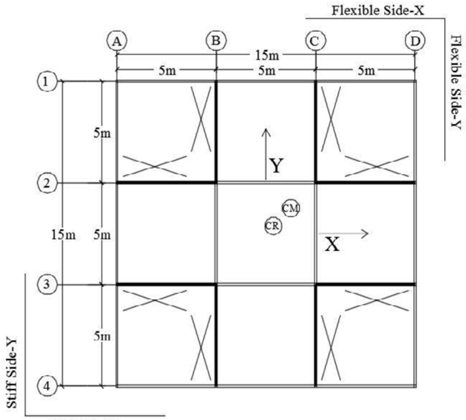


(Torsionally stiff buildings)

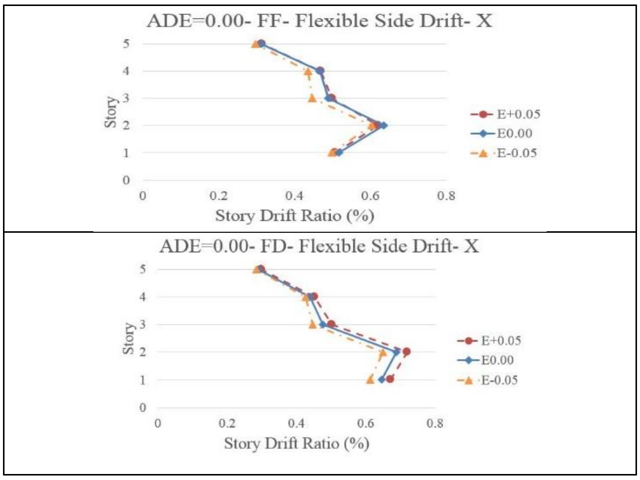


(Torsionally flexible buildings)

Fig. 1. Layout of the buildings.

II. The models, used for both design and analyses, were 3-D with lumped masses and the P–Δ (second order) effects due to gravity loads were included. The frame closer to the center of rigidity (CR) is the "stiff side" and the frame farthest from the CR is the "flexible side".

The non-linear analyses were carried out by means of the program SAP2000 [4] using the three set of ground motion records including near-fault records with forward-directivity pulse (FD), near-fault records without forward directivity pulse (NP) and far-fault (FF) records. The near-fault records were chosen from stations within 20 km of the rupturing fault. The records were selected from the Pacific Earthquake Engineering Research Center database [5]. For this purpose, this investigation was performed in two cases. In the first case, the effects of different ADEs on the ductility demands of the buildings including the symmetric and asymmetric-plan buildings were investigated. Finally, to understand what happens when an actual accidental mass eccentricity (AME) is introduced in an existing (already designed) building, the mass center of all the buildings was shifted by ±0.05L and the buildings were analyzed for the earthquake sets described above and the relevant results were shown in the figures by E. Each set of the ground motion records was scaled according to Standard No. 2800. The two components of each set of records were applied in the form of (X, Y) and (X, -Y) such that the component with pulse or large peak ground motion was applied along the X direction. Material nonlinearity was modelled with the well-known plastic hinge model according to ASCE/SEI 41-13 [6].


ADE=0.00- FF- Flexible Side Drift- X

ADE=0.00- FD- Flexible Side Drift- X

Fig. 2. The effects of AME=0.05b on the story drifts at the flexible side of the symmetric TS buildings.

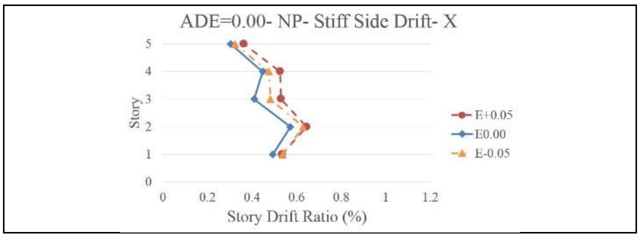

ADE=0.00- NP- Stiff Side Drift- X

Fig. 3. The effects of AME=±0.05b on the story drifts at the flexible side of the symmetric TF buildings.

3. DISCUSSION AND RESULTS

Seismic demands reported in this article include the story drifts and the brace ductility demands in tension and compression. The results show that the amplification factor obtained for the ADE does not affect the design of this type of buildings.

3.1. Torsionally-stiff buildings (TS)

ADE=0.05b was effective only for the building with e_m=0.10b and reduced the seismic responses as a result of the increase in the brace size at the stiff side of the 3rd story. ADE=0.05b was not effective on the symmetric and asymmetric buildings with e_m=0.20b. However, the reduction in the story drifts, as a result of ADE, are small (less than 10%). Applying AME=±0.05b for the cases designed with and without ADE=0.05b shows that the effect of AME=±0.05b on the story drifts for symmetric ones is larger than the other ones. Also, a comparison between the story drifts derived from the three sets of the ground motions indicates that difference between the FD and FF records in the X direction for asymmetric buildings with e_m=0.10b is about 23% and 35% at the stiff and flexible sides, respectively (Fig. 2).

3.2. Torsionally-flexible buildings (TF)

Appling ADE=0.05b did not have an influence on the asymmetric buildings.

Applying ADE=0.05b causes a reduction in the seismic responses as a result of the increase in the brace size of the 4th story. In the symmetric building, applying AME=±0.05b results in an increase in the story drifts in both sides. In the asymmetric building with e_m=0.10b, AME=±0.05b causes the increase and decrease at the flexible and stiff sides, respectively. The maximum increase in the story drifts as a result of AME=-0.05b in the X and Y directions for the symmetric building subjected to the NP records at the stiff side is at least 31 and 38%, respectively (Fig. 3). Also, the story drifts obtained for the FD set is larger than the other records, where these differences increase with an increase in the initial mass eccentricity. In the TF building with e_m=0.20b, the maximum difference between the FD and the other sets (NP, FF) in the X direction for the flexible side amounts to 73.8 and 78.5%, respectively.

4. CONCLUSIONS

1. The results indicate that the provision of the accidental eccentricity in the Standard No. 2800 is valid for torsionally-stiff buildings.
2. Among the torsionally-flexible buildings, the symmetric building has a high sensitivity to the AME and the sensitivity decreases with the increase in the initial mass eccentricity. The AME has much effect on the torsionally-flexible buildings, but the ADE has less effect on the seismic responses. Therefore, it seems that the ADE provision in the Standard No. 2800 needs to be revised.

5. REFERENCES

[1] S. Anagnostopoulos, M. Kyrkos, K. Stathopoulos, Earthquake induced torsion in buildings: critical review and state of the art, Earthquakes and Structures, 8(2) (2015) 305-377.

[2] Standard No. 2800-15. Iranian code of practice for seismic resistant design of buildings. Fourth ed. Iran: Building & Housing Research Center, (2015).

[3] Specification for Structural Steel Buildings (ANSI/AISC 360-10), American Institute of Steel Construction, Chicago-Illinois, (2010).

[4] SAP2000, Computers and structures Inc, Berkeley, CA, USA, (2016).

[5] Peer ground motion database, Pacific Earthquake Engineering Research Center, University of California, Berkeley, CA, http://ngawest2. berkeley. edu, (2017).

[6] ASCE, Sseismic Evalution and Retrofit of Existing Buildings, Standard ASCE/SEI 41–13, in, ASCE Reston, VA, 2013.

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