Influence of over-strength on seismic behavior of multi-story asymmetric building

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1. Introduction

Seismic response of asymmetric structures has been frequently analyzed by means of single-story models. However, it is widely believed that use of more realistic multi-story models is needed in order to investigate effects of the parameters that make behavior of multi-story schemes different from that of single-story systems. This paper examines effects of the overstrength in element cross-sections on the seismic behavior of multi-story asymmetric buildings.

2. Cross-sections overstrength

In real frames overstrength of cross-sections always exists due to the use in design of multiple load combinations (vertical loads with positive or negative horizontal forces). In a plane frame failing in a global mode, at each level, overstrength of dissipative members may be expressed as follows:

$$O_{S,0} = \frac{\sum_{i=1}^{n_c} M_{c,i1}^{B}}{\sum_{i=1}^{n_c} M_{c,i1}^{B,0}} \qquad O_{S,k} = \frac{\sum_{i=1}^{n_b} \left(M_{b,ik}^{L} + M_{b,ik}^{R} \right)}{\sum_{i=1}^{n_b} \left(M_{b,ik}^{L,0} + M_{b,ik}^{R,0} \right)} \tag{1}$$

$M_{b,ik}^{L}$ and $M_{b,ik}^{R}$ represent the flexural strength at the two ends of the ith beam at the kth story, while $M_{c,i1}^{B}$ is the flexural strength at the bottom end of the ith column at the first story. $M_{b,ik}^{L,0}$, $M_{b,ik}^{R,0}$ and $M_{c,i1}^{B,0}$ are seismic bending moments in the same cross-sections.

3. Numerical analyzes

Seismic response of a multi-story asymmetric building has been evaluated. The plan-arrangement of the building is showed in Fig. 1. The system is designed by composing effects of vertical loads with that of seismic forces acting in the mass centers C_M. Aiming to reduce the ductility demand, a further load condition, in which seismic forces are applied in the rigidity centers C_R (no-reduction rule), is used in the design. The results have been normalized with respect to that of the corresponding torsionally balanced system, obtained by the asymmetric system shifting C_M over C_R. Furthermore, such data are analyzed together with those related to the normalized response of the corresponding asymmetric single story-system, in order to evidence differences between the response of asymmetric multi and single-story models. Seismic action is represented by a set of thirty accelerograms artificially generated, matching with EC8 elastic spectrum, and acting along the Y-direction.

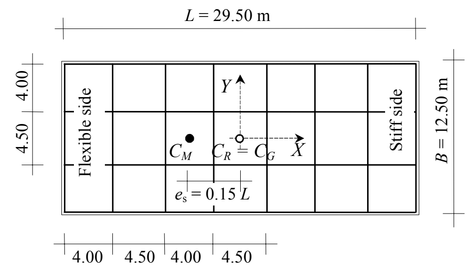

Fig. 1. Plan-arrangement of the analyzed systems.

4. Results

Plan-distributions of *normalised ductility demand* $\bar{d}$ (ratio of the member ductility demand D of the asymmetric system to that of the corresponding member of the torsionally balanced system) were calculated. Fig. 2a shows that ductility demands of asymmetric single-story systems appear close to those of the corresponding torsionally balanced systems ($\bar{d} \leq 1$), while in the upper floors beams of multi-story building (5th and 6th) $\bar{d}$ exceeds unity in the flexible side, contrary to the results obtained from the single-story model. Such behavior is due to the large overstrength provided by vertical loads which do not allow the needed increase in flexural strength of the upper floors beams located on the flexible side (Fig. 2a).

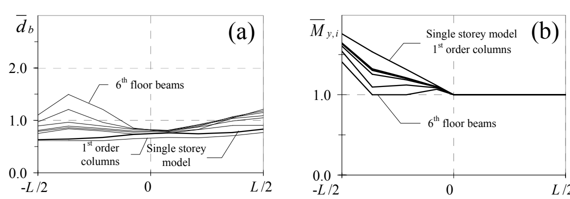

Fig. 2. Single-story vs. multi-story system.

(a) Ductility demand, (b) flexural strength.

5. Conclusions

In actual buildings cross-sections' overstrength may lead to distributions of ductility demands different from those expected according to the results of single-story models. In the examined case, no-reduction rule, which aims at reducing ductility demands of asymmetric systems to those of the corresponding torsionally balanced systems, is unable to improve the seismic performances of the beams of the upper floors located on the flexible side of the structure in multi-story models. Consequently, torsional provisions should be re-checked in light of the behavior of realistic multi-story buildings.