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# EVALUATING THE EFFECT OF SYMMETRY ON SEISMIC BEHAVIOR OF IRREGULAR BUILDINGS IN PLAN

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Although structural properties have important effects on the strength of structures against the earthquake, architectural design also has a key role on the performance of earthquake resistant structures (Naeim, 2001). Generally, seismic codes classify buildings into two categories based on the configuration point of view (geometrical properties of the building): regular and irregular buildings. Of different kinds of irregular configuration, triangular-shaped or wedge-shaped buildings are considered here. In seismic codes such as UBS-97 (1997), there are not any clear criteria for such buildings. A few studies exist which have studied seismic response of vertically irregular building structures (Stefano and Pintucchi, 2008, Trung et al., 2012, Michalis et al., 2006, Chopra and Goel, 2002). In this paper, the effect of symmetry on the nonlinearity behavior of three dimensional buildings is studied. A number of six, ten and fifteen storey concrete buildings are designed based on ACI 318-08 by conventional software program (ETABS 9.5.0) and the capacity spectral method is used to determine operation point of the models. Formation of plastic hinges in different regions is also studied. To account for the structural behavior, the angle α is considered as shown in Figure 1.

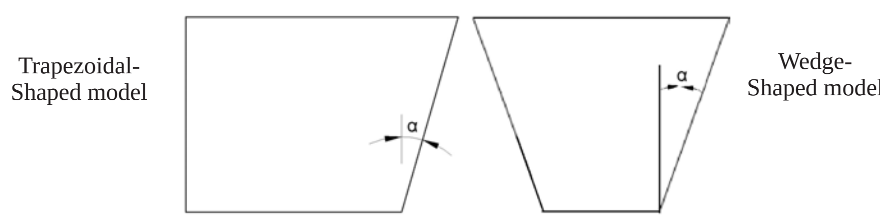


Figure 1. Suggested parameter to investigate the behavior of irregular configuration

According to Figure 1, for six, ten and fifteen storey buildings with symmetric (wedge-shaped) and asymmetric (Trapezoidal-shaped) plan, the effect of symmetry on the behavior of the unparallel systems is studied. All models are considered in a zone with very high seismic risk, type II soil, residential application and the nonlinear static analysis is done to determine the performance point of the structures. The mass center displacement for the highest level of the structures is determined as a performance point of the structure. To investigate the nonlinear behavior of models and providing an opportunity to compare the behavior of different structures, the authors suggest the $N_{bf}$ index (Nonlinearity behavior factor) as follows:

$$N_{bf} = (n_{(A-B)} \times 1 + n_{(B-IO)} \times 1 + n_{(IO-LS)} \times 3 + n_{(LS-CP)} \times 6 + n_{(CP-C)} \times 9) / n_{Total} \quad (1)$$

Where $n_{(A-B)}$, $n_{(B-IO)}$, $n_{(IO-LS)}$, $n_{(LS-CP)}$, $n_{(CP-C)}$ and $n_{Total}$ are total number of formed hinges in different regions. Figure 2 shows the percentage of formed plastic hinged in LS-CP and IO-LS regions for ten storey buildings. As shown in this figure, in buildings with trapezoidal shaped model in plan, increasing α degree leads to reduce the percentage of the formed plastic hinges in IO-LS regions and therefore will increase the percentage of formed plastic hinges in LS-CP region. Also, the same changes in the buildings with wedge shaped model are seen.

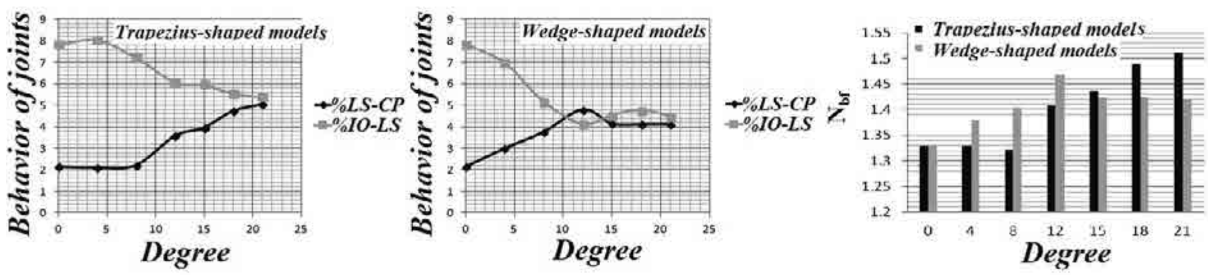


Figure 2. a) The percentage of formed plastic hinges in different zones of the structural performance with respect to $\alpha$ degree for ten storey models, b) variation of $N_{bf}$ index with respect to $\alpha$ degree for symmetric and asymmetric ten storey models

For both shapes, the changes of $N_{bf}$ have also been drawn in Figure 2. As shown in this Figure, in buildings with trapezoidal shaped model, increasing in α degree will lead to an increase in the amount of ductility demand of the structure as well as the percentage of the formed plastic hinges. However, in buildings with wedge shaped model, there are no regular noticeable changes. As shown in Figure 2, in ten storey building, the effect of symmetry is evident on the nonlinearity behavior of wedge-shaped models. In the symmetric wedge-shaped models with $\alpha$ degree greater than 12°, the nonlinearity behavior of the structure will improve with an increase in $\alpha$ degree. However, the wedge-shaped models show critical behavior rather than asymmetric trapezoidal-shaped models.

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