SEISMIC DESIGN MODIFICATION TO PREVENT SOFT STOREY MECHANISM FAILURE

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Most structures with masonry infills that are continuous along their height, which are interrupted in the lowest storey, are damaged by earthquakes. These structures are anticipated to collapse due to the undesirable soft-storey mechanism formed by lateral stiffness of masonry infills in other storeys. Thus, some researchers(Danesh et al., 2010); (Dolsek and Fajfar, 2001) studied the effect of soft-storey formation on the seismic behaviour of steel and RC moment-resisting frames.

A designer may need to consider the above-mentioned subject in the design of special moment resisting steel buildings in which the masonry infills are omitted at the ground-level storey. Since the anticipated failure mechanism for this structure is the soft-storey mechanism, the use of current criteria of seismic provisions is not possible. In this situation, the designer should choose one of the following methods:

- Preventing the interaction between the frame and the masonry infill using specific detailing and then using the criteria of seismic codes.
- Preventing soft-storey mechanism failure by using some special criteria in the design stage.

It is obvious that any professional designer will definitely choose the first method. However, two subjects should be considered:

- In usual building construction, the nonstructural design details are not accurately implemented.
- It is not clear that the details provided for preventing the interaction between the masonry infill and the frame are efficient or not.

Thus, in some real cases, it may be needed for designing a structure in which the masonry infills are omitted at the ground-level storey to use some special criteria to prevent soft-storey mechanism failure. In this paper, special moment-resisting steel frames (SMRSFs), whose continuous masonry infills are interrupted in the lowest storey, are studied. The seismic design criteria presented in the UBC97 standard are utilized. The proposed criteria are presented to design three special moment-resisting steel frames: 5, 8 and 15 storeys. The displacements and storey drifts obtained by the proposed seismic design criteria are compared with nonlinear time-history (NTH) dynamic analysis results as real structure responses.

Proposed design criteria for smrsf to prevent soft-storey mechanism failure in the lowest storey(ALINOURI, 2010):

Step 1: SMRSF structure is designed according to the criteria of common seismic design codes, e.g. UBC97, using ductile-compact sections/ignoring the frame-infill interaction.

Step 2: Analytical natural period related to the first vibration mode of the structure is calculated. This period is based on the mathematical model of beam and column sections determined in the previous section as well as modelling the lateral behaviour of masonry infills.

Step 3: Static base shear is determined by using the following equation. Vibration period (T1) related to the first mode shape of the structure was calculated in step 2:

$$V_M = \frac{S_{a\,T_1}}{R_M = 6} W$$

Step 4: Distribution of base shear, which is calculated in the previous step, along the structure height proportional to the weight of each storey.

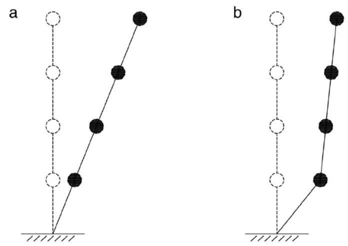

Figure 1. Idealized vibration mode shapes of structure collapse due to (a) general failure mechanism and (b) soft-storey failure mechanism in the lowest storey

Step 5: Check/design of steel members based on load combinations of design codes considering the lateral loading changes in the proposed method.

Step 6: Special check/design of the columns in the lowest storey by multiplying the earthquake load in design load combination in below coefficient:

$$\kappa = \frac{6}{9\left(1 - 1.7\frac{P_{\text{u}}}{P_{\text{cl}}}\right)} \leq 3$$

Step 7: Determination of realistic storey displacements based on Equation 3.3 and check of real drifts with allowable values of seismic design codes.

$$\Delta_R = \frac{6}{\kappa} \times \Delta_{\text{el}}$$

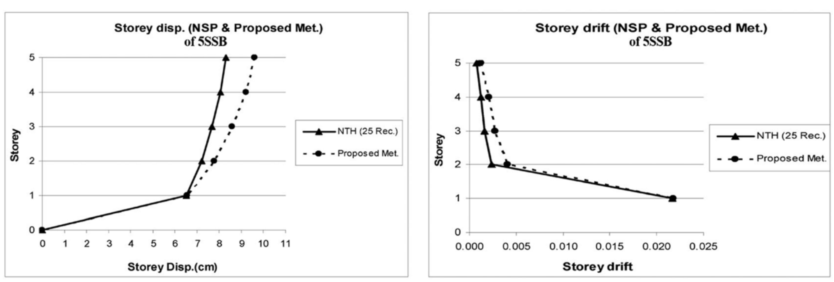

Figure 2. Comparison between storey displacements and inter-storey drift in 5SSB calculated by NTH and step 7 of the proposed method

It can be concluded that the results of storey displacement and inter-storey drift responses obtained based on the proposed design method are very close to the responses obtained by NTH analysis method. It means that the proposed seismic design criterion, which is presented in Part 3 of this article, can accurately predict the behaviour of SMRSF with continuous masonry infills along the height, which are interrupted in the lowest storey.

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