Effects of Backup Frame on Earthquake Responses of Steel Structures with Buckling-restrained Braces

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1 Introduction

Buckling-restrained braced frame (BRBF) system exhibits very good and stable hysteretic behavior, however, it may undertake very large story drifts after the BRB yields. An additional backup frame is beneficial to compensate for large drift after brace yielding. Effects of the additional backup frame on the earthquake responses of BRBF are examined.

2 System studied

As shown in Fig. 1, the analytical model consists of three parts: the brace-column-beam, the leaning columns used to carry gravity, and the backup frame which remains elastic in the system. The backup frame is used to compensate for the P-Δ effects and provide the system with additional lateral stiffness.

The main parameter studied is the stiffness ratio between the backup frame and the brace, defined as K_f/K_b. In order to keep the total stiffness of the system constant, the braced frame stiffness decreases when the backup frame stiffness increases.

3 Analysis of models combined with BRBs

Models and input

The building models here are two chevron-braced frames, a 4-story and a 12-story, combined with BRBs. Design of the two models follows the Japan Building Standard Law (BSL). Three earthquake records, 1940 El-Centro, 1968 Hachinohe and 1952 Taft in two horizontal directions are scaled to different levels defined as Levels 1-4 with PGVs corresponding to 0.25, 0.5, 0.75, 1.0 m/s respectively.

Analytical results:

Fig.2 shows the medians of absolute maximum story drift angles (SDAs) of the 4-story model having the elastic backup frame. For purely pinned frames, the median is much larger than those of other cases. Median SDA has a minimum under each input level, e.g. under input Level 3, about 30% of backup frame stiffness ratio shows minimum SDAs. Before this point, although the median decreases with the stiffness ratio increases, a few percent of the backup frame stiffness ratio decreases the median SDA significantly. If the backup frame stiffness ratio exceeds the point, the median SDA remains almost constant and then increases for large stiffness ratios.

Values of COVs represent uniformity of story drift distribution along the height. Fig.3 shows that for purely pinned frames, COV values are rather larger than those of other cases. With the increases of the backup frame stiffness, COV values decrease. This indicates that SDAs become more uniformly distributed along the height. 12-story model results have the same trend as those of the 4-story model.

4 Conclusions

BRBF systems without backup frames have a trend of large drifts and drift concentration in some stories after braces yield. A few percent of the backup frame stiffness can decrease both drifts and the concentration significantly. A less then 10% of backup frame stiffness ratio is sufficient to ensure uniformity.

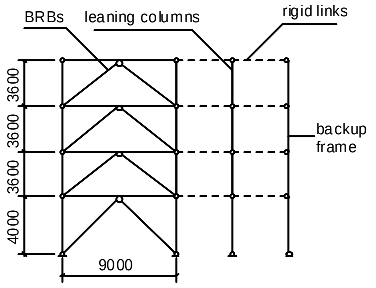

Fig.1 Analytical model (unit:mm)

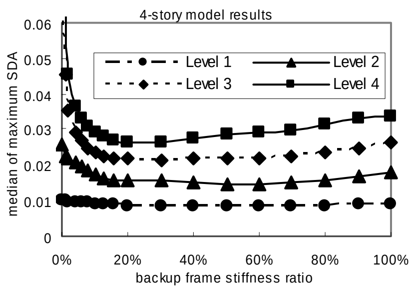

Fig.2 Median of SDAs

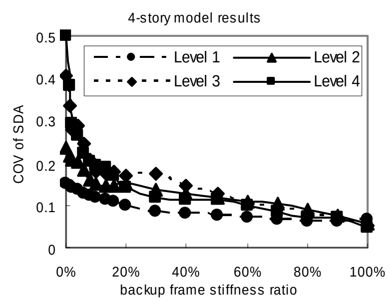

Fig.3 COV of SDAs