NUMERICAL ANALYSIS OF COLLAPSE BEHAVIOR FOR STEEL MOMENT FRAMES

Seiji MUKAIDE
Assistant Professor
Osaka University
Osaka, Japan
mukaide@arch.eng.osaka-u.ac.jp

Seiji Mukaide, born 1978, received his engineering degree from Osaka University. His main area of research is related to steel structure of buildings in strong seismic regions.

Motohide TADA
Professor
Osaka University
Osaka, Japan
tada@arch.eng.osaka-u.ac.jp

Motohide Tada, born 1958, received his engineering degree from Osaka University. His main area of research is related to steel structure of buildings in strong seismic regions.

Summary

In this paper, parametric analyses are conducted with fishbone-shaped models considering the strength deterioration of members in order to investigate the complete-collapse behavior of steel moment frames. The column overstrength factor and width–thickness ratio are adopted as parameters. In most of the cases, the collapse mechanism varies from the total-collapse type to the story-collapse type due to strength deterioration by local buckling. The analytical results show that the collapse mechanism at the time of complete collapse affects the energy capacity.

Keywords: seismic response analysis; complete collapse; collapse mechanism; column overstrength factor.

1. Introduction

An accurate prediction of earthquakes cannot be realized with current technology, and exceedingly large ground motions sometimes cause severe damage. Therefore, it is beneficial to evaluate the safety margin against complete collapse under larger ground motions than the current seismic code. In this paper, parametric analyses with fishbone-shaped models are conducted in order to investigate the effect of strength deterioration on the complete-collapse behavior of steel moment frames systematically. Local buckling is considered a cause of strength deterioration.

2. Analysis Plan

Five-story fishbone-shaped frames are employed for the response analysis. In this model, the plastic deformation of structural members in each story is represented by springs at the member ends. A Kato–Akiyama skeleton curve [1] is employed for the restoring force characteristics of the columns and beams and is able to represent the strength degradation due to local buckling. In addition, the Kato–Akiyama hysteretic rule [1] is employed. The column bases of the first story are fixed. To design a number of models delivering average performance in Japan, an uncomplicated design method is employed. The model parameters include the base shear coefficient (C_b), the column overstrength factor (*COF*), and the width–thickness ratio for the columns (FA+, FA, FB, FC) and beams (FA, FB, FC). The width–thickness ratios for FA, FB, and FC are equal to the limits of the ductility ranks in the Japanese code.

The frames are analyzed using a program which features inelastic modeling and geometric non-linearities. Three kinds of earthquakes (El Centro 1940 NS, Taft 1952 EW, and Hachinohe 1968 EW) are employed in the numerical analyses. These are scaled by increasing the peak ground velocity (PGV) by 0,1 m/s such that the frame collapses completely. The analytical results (as shown later) are based on the condition of the lowest PGV involving complete collapse.

3. Analysis Results

More than 1200 response analyses are conducted. According to the investigation into the collapse mechanisms for all cases, the collapse process is generally as follows. For the case of higher *COF*, a total-collapse mechanism occurs at first, and all of the stories collapse completely with the same mechanism. On the other hand, for the case of lower *COF*, a total-collapse mechanism also occurs at first; however, the ensuing behavior is different from the former. The collapse mechanism varies from the total-collapse type to the story-collapse type due to strength deterioration.

In this paper, the damage-causing earthquake input energy (E_{dm}) and its equivalent velocity (V_{dm}) for the case where the frames collapse are employed as indicators for evaluating the ultimate seismic performance of the frames [2]. Plots of V_{dm} versus the *COF* relationship are shown in Fig. 1. The open and closed symbols represent the story-collapse and total-collapse types, respectively. Notice that V_{dm} for the story-collapse type increases linearly, and V_{dm} for the total-collapse type is almost constant with increasing *COF* regardless of the seismic excitations. This is because the energy absorbed both before and after varying the full-collapse type increases with increasing *COF* in the story-collapse type cases. Obviously, the more stories that collapse completely, the more energy is absorbed. Even though the ranges of the full-collapse stories are the same, the frames with higher *COF* keep a total-collapse mechanism for a longer time and absorb more energy. On the other hand, the location and deformation of the plastic hinges remain unchanged in the cases of the total-collapse type; therefore, V_{dm} is on the same level despite the *COF*.

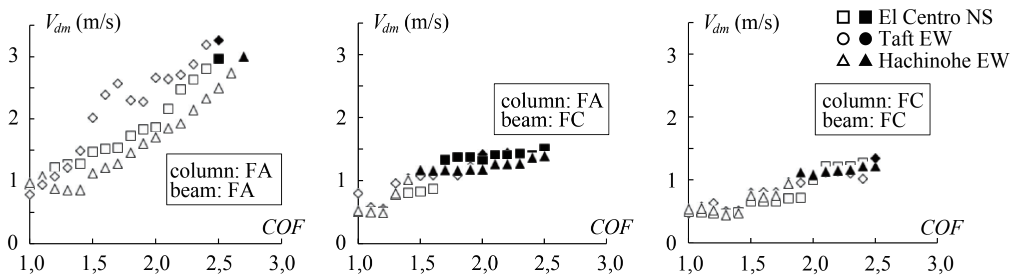

Fig. 1: V_{dm} vs COF relationship (C_b = 0,25)

4. Conclusion

The major findings obtained in this study are as follows:

1. In a number of cases, the collapse mechanism varies from the total-collapse type to the story-collapse type. The change in mechanism is initiated by the moving of inflection points due to strength deterioration.

2. The V_{dm} for the story-collapse type increases linearly, and the V_{dm} for the total-collapse type is almost constant with increasing *COF* regardless of the seismic excitations. In addition, V_{dm} tends to increase with higher column and beam ranks except for some cases.

References

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