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One-axis dynamic experiment and pushover analysis of precast concrete frame structure

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ABSTRACT

In this study, one-axis dynamic experiment was conducted for a precast concrete frame structure to evaluate its seismic performance. Test models were designed according to ACI 352R-02 and KCI 2012 special moment frame requirement. A Chi-Chi earthquake ground motion of 1999 (PGA = 0.79 g) was applied as excitation in the experiment. Major issues in the determination of stability of the precast concrete frame structure under earthquake would be the integrity of their connections. By comparing experimental result and pushover analysis result, particularly the part of column-base and beam-column connections, structural performance was evaluated.

1. INTRODUCTION

Various studies are being carried out to secure seismic performance of structures due to the recent increase in the number and size of earthquakes in Korea. Li et al. (2017) introduced a comparison of static pushover and dynamic analyses using reinforced concrete (RC) building shaking table experiments. It was revealed that the pushover analysis could provide reasonable estimation of the structural responses when the structure was not severely damaged.

In precast concrete frame construction, all the members are manufactured separately and then united. As a result, connection integrity is an important factor in seismic design. In this study, one-axis dynamic experiment was conducted by applying a real earthquake ground motion of 1999 Chi-Chi Earthquake to the precast frame. The specimen was designed to yield first at beam-column joints and at column-base. Load-deformation

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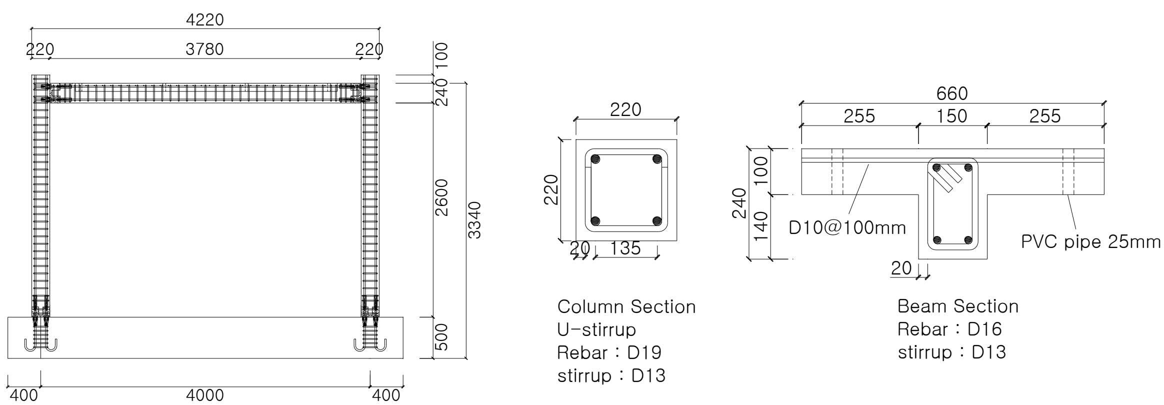
hysteresis loops can be compared with pushover analysis results to examine the seismic performance of the frame structure.

2. TEST SPECIMEN AND METHOD

2.1 Test specimen

A precast concrete test specimen was designed following ACI 352R-02, even though the specimen had 100% pure dry connection without the use of monolithic connection. Only the gap between the column and beam was grout-filled after the steel connector was inserted into the socket embedded in the column and fastened. A design objective was to induce plastic hinge in beam-column joints and at column-base so that a strong column-weak beam concept was applied by adjusting the relation between the column nominal moment capacity and beam nominal moment capacity. The full scale specimen is illustrated in Figs. 1(a) to 1(c).



(a) Full scale frame specimen (b) Column section (c) Beam section

Fig. 1 Specimen details

2.2 Test method

An input earthquake ground motion was a 1999 Chi-Chi Earthquake record as shown in Fig. 2, where peak ground acceleration (PGA) was 0.79g. Deformation and acceleration of the specimen was measured by linear variable displacement transducers (LVDTs) and accelerometers, respectively.

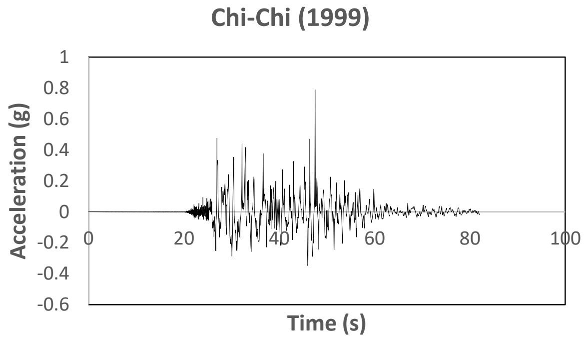


Fig. 2 Ground motion of 1999 Chi-Chi Eaerthquake

3. TEST RESULT AND PUSHOVER ANALYSIS RESULT

3.1 Test result

Fig. 3 represents load-deformation hysteresis loops of the specimen after the experiment was conducted. In the positive direction (right direction), at maximum load of 49.95 kN, drift ratio was 2.53%. Conversely, in the negative direction (left direction), at maximum load of 53.94 kN, drift ratio was 2.75%.

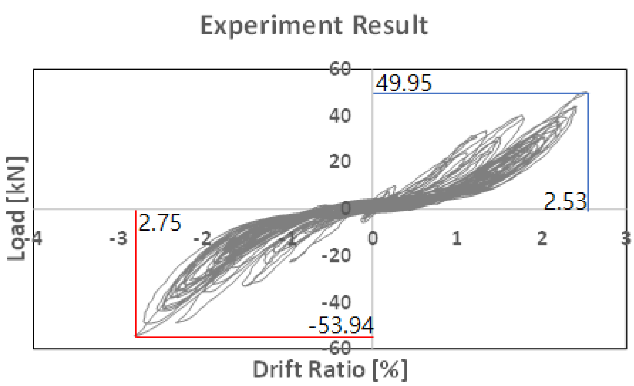


Fig. 3 Experiment result

3.2 Pushover analysis result

Pushover analysis was performed using Midas Gen program. Four hinges were defined at joints (column-base & beam-column connections). The push-over analysis result is shown in Fig. 4.

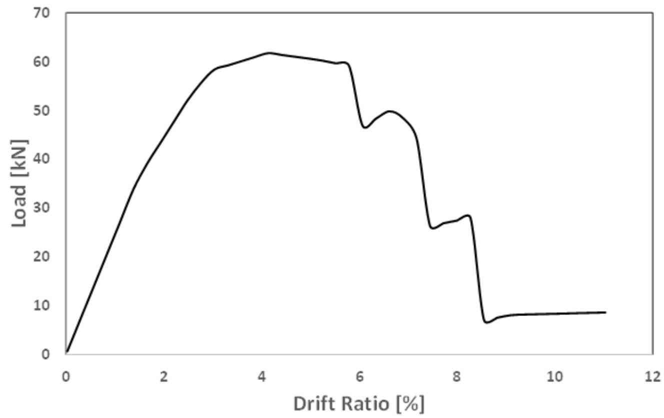


Fig. 4 Pushover analysis result

Fig. 4 shows that plastic hinges occurred at 3 points and subsequently the slope dramatically decreased. Each of the hinges failed at a load of 59 kN, 44 kN, and 28 kN, respectively, and the drift ratio at the moment was 5.8%, 7.2%, and 8.3%.

3.3 Comparison of experiment and pushover analysis results

Comparison of experiment and pushover analysis results is made in Fig. 5. By comparing the experimental result and pushover analysis result, the dynamic performance level of the specimen was found to be similar to the quasi-static performance level at least up to 2.75% drift level. This indicates that the frame behaved just like an RC frame with monolithic connection, as the modeling was done assuming the rigid RC connection.

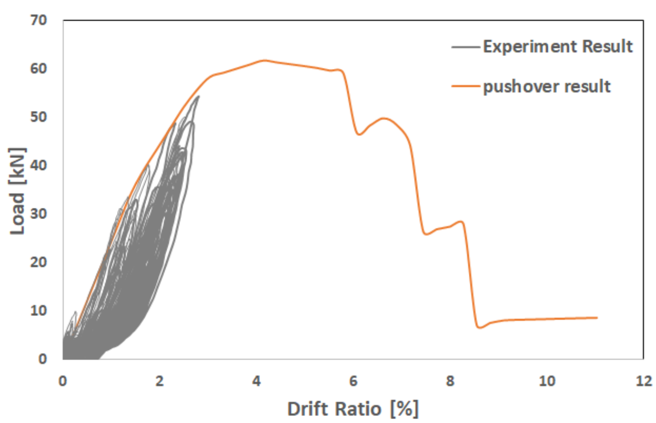


Fig. 5 Experiment and pushover analysis results

3. CONCLUSIONS

A precast concrete frame structure with pure dry connection was tested on the shaking table in one-axis direction. A 1999 Chi-Chi Earthquake ground motion was applied, and the damage on the structure developed according to the intensity of earthquake ground motion was observed. The structure experienced the elastic and plastic stages of deformations without a loss of capacity or collapse. For further research on the behavior of the precast frame structure, a pushover analysis was conducted. From the studies, the following conclusions can be drawn:

(1) The precast concrete frame structure endured a 1999 Chi-Chi earthquake without a loss of lateral load carrying capacity or collapse, and maintained stable ductile behavior until the end of one-axis shaking with PGA of 0.79g. The drift ratio of the structure of up to 2.75% was recorded, which occurred at the maximum load. This is above the allowable maximum drift ratio (1.5%) of a frame structure that should retain sufficient seismic capacity.

(2) The pushover analysis result shows that the structure's performance is similar to the quasi-static performance of a rigid moment frame up to 2.75% drift level.

(3) Further research would be needed on the plastic motion, energy dissipation ability and reduction of structure stiffness according to the degree of cracks.

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