ABSTRACT

This experiment examined the lateral load-displacement response and punching failure load of an interior slab-column connection subjected to constant gravity loading combined with cyclic lateral loading. The experimentally obtained lateral load-displacement curve was compared to an analytical relationship based on an effective slab width model, and slab moment capacities. Experimental and theoretical load-displacement relationships were used to calculate Inter-story drifts, which were then compared to the ACI maximum inter-story drift, which is associated with punching failure. The predicted punching failure load was based on ACI 318-05 requirements for unbalanced moment transfer at the slab-column connection using a flexural transfer width of \( c_{3h} \) and an eccentric shear stress model. Punching failure occurred after twenty cycles at a drift of 0.335.

OBJECTIVES

A slab-column connection was subjected to a constant gravity load and a cyclic lateral load, and the results of the experiment were used to:

- Determine the lateral load-displacement relationship, and to compare this to the analytical results obtained with an effective slab width model and slab moment capacities.
- Determine the punching behavior of the specimen, and compare this to the analytical results calculated with ACI requirements for unbalanced moment transfer.
- Calculate inter-story drift from the analytical load-displacement relationship, and compare this to the ACI maximum inter-story drift, which predicts punching failure.

TEST OVERVIEW

The test specimen was designed to be representative of an interior slab-column connection in a building, and was subjected to a relatively constant gravity load as well as cyclic lateral loading. The slab was made of reinforced concrete, and the column was constructed with two hollow steel sections welded together and bolted to the top and bottom of the slab. The slab was held with hinge connections along opposite sides in order to allow for the flexing behavior that occurs when buildings are subjected to lateral loading. Axial (gravity) load was applied to the bottom of the column, and lateral load was applied to the top of the column. The experimental set-up is shown in figure 1 below.

INSTRUMENTATION & PROCEDURE

The specimen was initially subjected to a constant axial (gravity) load. A cyclic lateral load was then applied to the top of the column. The lateral load was applied based on predetermined displacement increments, calculated to be multiples of the yield displacement (Figure 8).

A hydraulic cylinder and a manual hand pump were used to apply a constant axial load to the bottom of the column to simulate gravity loading. An electric hydraulic pump and a two-way hydraulic cylinder were used to apply a cyclic lateral load to the top of the column (Figure 7). A displacement transducer was attached to the top of the column to measure lateral displacement (Figure 6).

ANALYTICAL RESULTS & FAILURE EVALUATION

Analytical Load-Displacement Relationship for Top of Column

<table>
<thead>
<tr>
<th>Top Steel Yield</th>
<th>Lateral Load</th>
<th>Lateral Displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.002 ton</td>
<td>10.0 kips</td>
<td>0.15 inches</td>
</tr>
</tbody>
</table>

Displacements were calculated using Virtual Work, and only account for the dislocations due to elastic deformation. For this reason, the displacement at bottom steel yield may underestimate the actual displacement, and the displacement at punching failure was not calculated.

Punching Failure Load Evaluation:

- Theoretical capacity to transfer unbalanced moment: \( f_{unbalanced} \)
- Theoretical capacity to transfer unbalanced moment through flexure: \( f_{flexural} \)
- Capacity to transfer unbalanced moment through eccentric shear: \( f_{shear} \)
- Punching failure load: \( f_{punch} \)

TEST RESULTS

The applied lateral load was plotted against the measured lateral displacement (Figure 11). Points corresponding to the theoretical values of first and second yield are shown as blue circles. The theoretical yielding load is shown as a horizontal green dashed line. The theoretical punching failure load is shown as a red dashed line. Figure 12 is a representation of the cracking distribution in the specimen. Figures 13 and 14 are pictures of the specimen at failure.

CONCLUSIONS

- The analytical load-displacement relationship underestimated the lateral load capacity and punching failure load of the specimen. This could be because the analytical relationship only considered the contribution for lateral load capacity from the column strip. Also, the reinforcement capacity was estimated as its yield strength, when in fact strain hardening probably occurred, increasing the capacity of the connection to transfer unbalanced moment through flexure.
- The ACI maximum inter-story drift is a conservative measure for preventing punching failures, as the specimen reached inter-story drifts much larger than the this maximum before reaching punching failure.