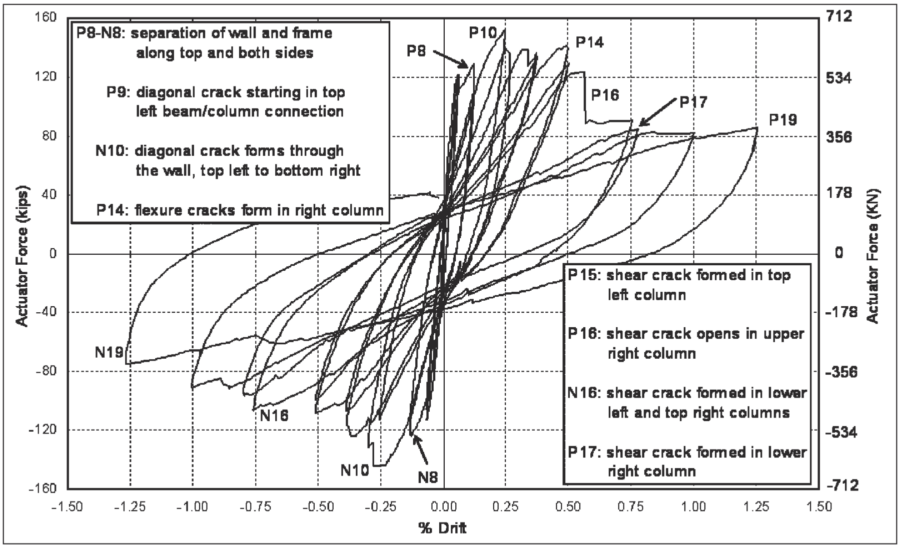


Fig. 9—Solid infilled frame Test S lateral force versus drift response.

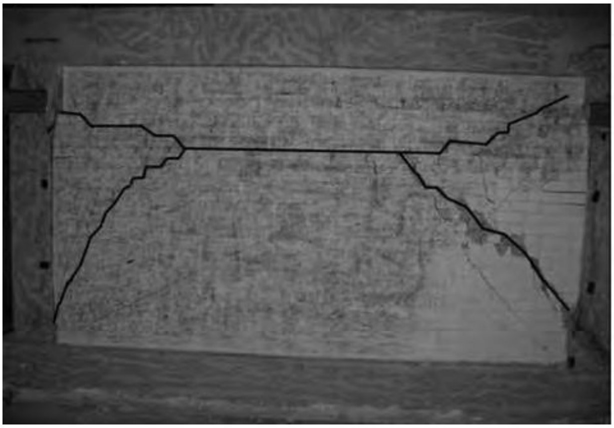


Fig. 10—Test S final crack pattern.

Fig. 11—Test S top right column shear.

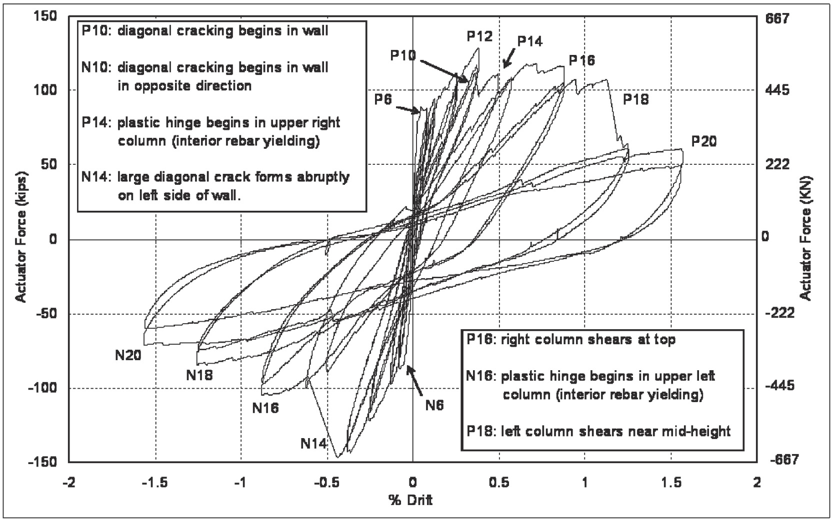
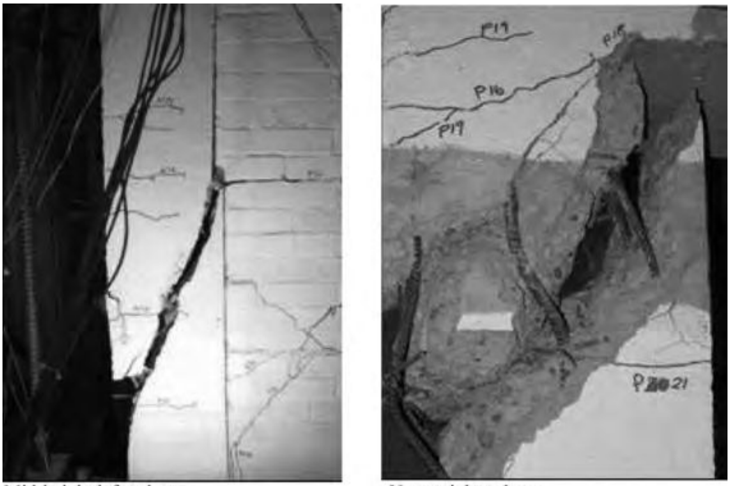


Fig. 12—Infilled frame Test SW lateral force versus drift response.

Fig. 13—Test SW final crack pattern of infilled frame with eccentric window opening.



Mid-height left column

Upper right column

Fig. 14—Test SW column shear failures.

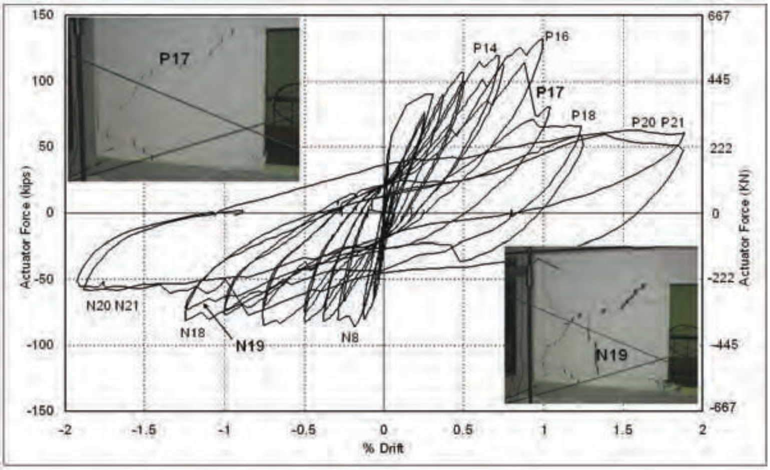


Fig. 15—Infilled frame Test D lateral force versus drift response.

Fig. 16—Test D final crack pattern of infilled frame with eccentric door opening.

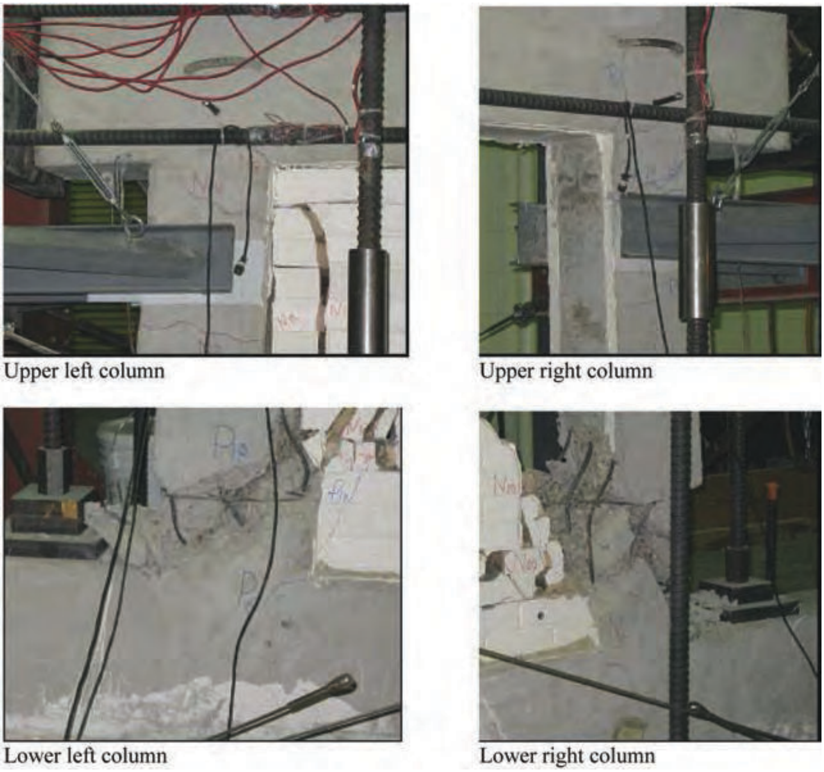


Fig. 17—Test D post test views of column shear cracks.

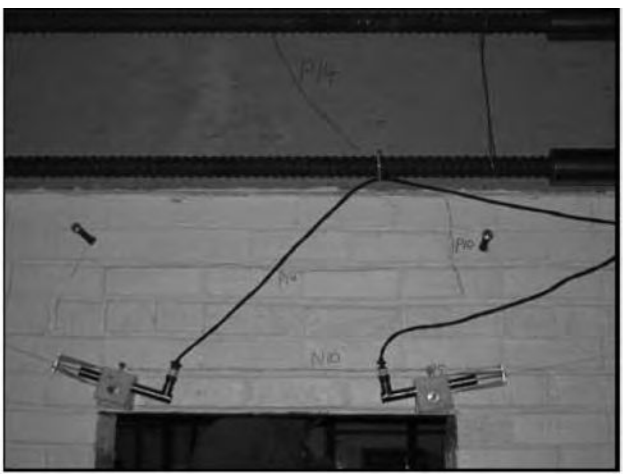


Fig. 18—Test D shear crack in reinforced concrete beam over doorway.

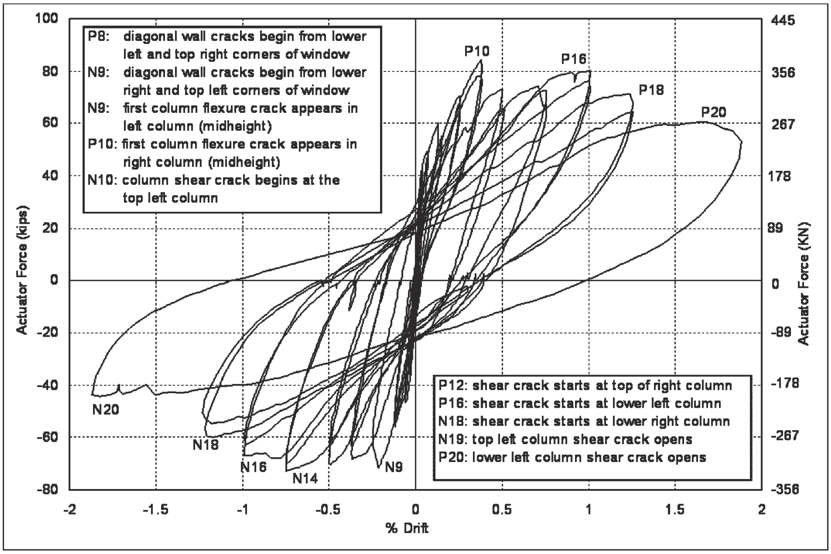


Fig. 19—Infilled frame Test LW lateral force versus drift response.

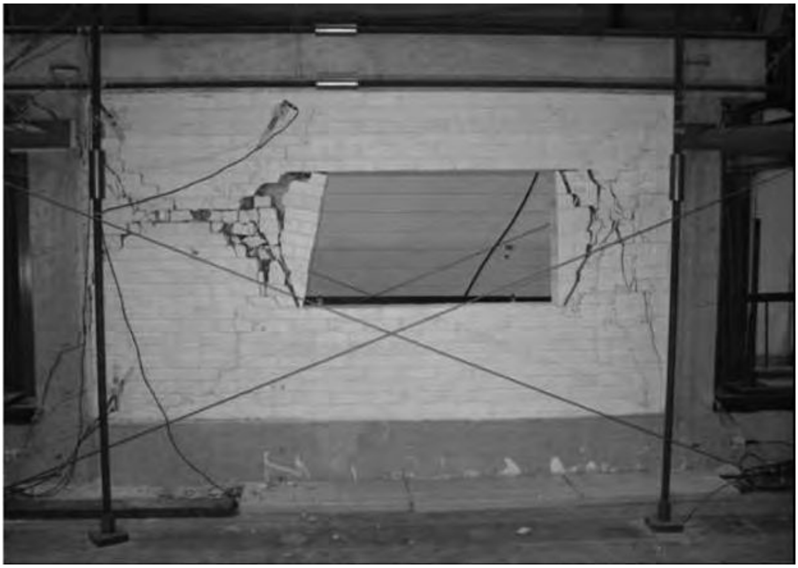


Fig. 20—Test LW final crack pattern of infilled frame with large eccentric window opening.

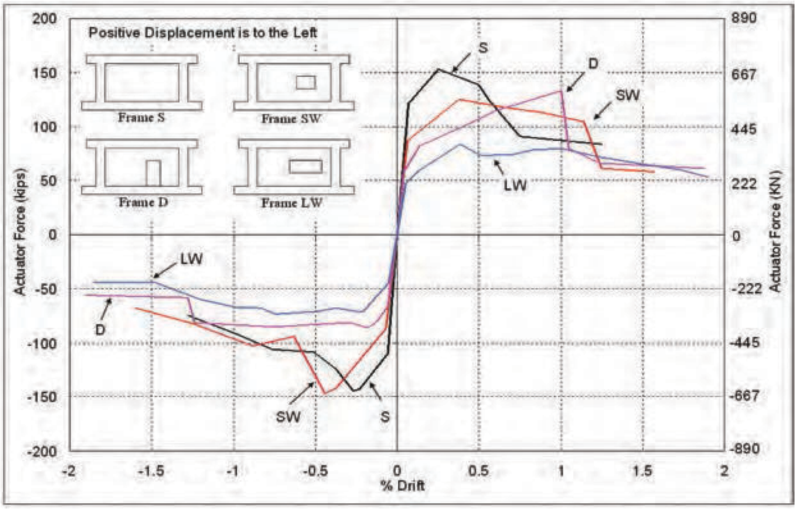


Fig. 21—The effect of openings.

SP-265—10

Finite Element Analysis of Reinforced Concrete Joints Subjected to Multi-Axial Loading

by H. Noguchi, T. Kashiwazaki, and K. Miura

Synopsis: The authors conducted a three-dimensional finite element analysis of interior beam-column specimens with orthogonal beams under bilateral load, and of planar frame specimens under unilateral load. Comparisons were made between finite element modelling and experimental results and analytical investigations of stress conditions using bond characteristics of beam/column reinforcement and structural frame types as analytical parameters. The internal stress states, which are difficult to understand from laboratory testing, were investigated. The simulated stiffnesses were somewhat high compared with experiment results, but the maximum strength correlated well with the experiment. By examining compressive principal stress fields for diagonal cross sections, the authors show that the compressive strut region is big for test specimens with bonded interfaces, the strut region is narrower for specimens without bonded interfaces, and regions that do not carry stress exist. Distribution of shear stress within joints was shown for planar frame and interior beam-column joint specimens, and differences between specimens with and without bonded interfaces were investigated.

Keywords: beams; bond; columns; deformation; earthquake-resistant structures; finite element analysis; joints; multi-axial loading; reinforced concrete; shear properties; structural design; three-dimensional.

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INTRODUCTION

During an earthquake, an extremely large shear force acts on a reinforced concrete interior beam-column joint with a beam reinforcement passing through the joint. Within the joint, anchoring of the beam reinforcement in the interior of the joint is straight, and strain is inverted from the region of tension to the region of compression, resulting in large bond stress. Degradation of beam reinforcement bond within the joint has a large effect on its hysteretic characteristics and shear resistance mechanisms; however, previous experiments into degradation of beam reinforcement bond in the joint mostly examined planar frames under unilateral load.

Therefore, in this study, the authors conducted analyses on interior beam-column joint specimens with orthogonal beams under bilateral load and of planar frame specimens under unilateral load. Comparisons were made between experimental results and analytical investigations of stress conditions using bond characteristics of beam/column reinforcement and structural frame types as analytical parameters.

ANALYSIS OVERVIEW

Analysis test specimens

Analyses were conducted on the following four specimens conducted by Kishida et al. (2005): MP1 (planar frame, bonded interface); MP2 (planar frame, insulated bond); MT1 (interior beam-column joint, bonded interface); and MT2 (interior beam-column joint, insulated bond). Analyses were also conducted on the following two imaginary specimens: MP3 (planar frame, completely insulated bond) and MT3 (interior beam-column joint, completely insulated bond) in which the bonds within the joints were completely insulated. The "MP" denotes planar frame specimens, and "MT" denotes interior beam-column joint specimens. The labels 1, 2, and 3 each denote bonded interface, insulated bond, and completely insulated bond, respectively. With all specimens, the beam cross sections were 250 x 400 mm (9.75 x 15.6 in.), the column cross sections