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AXIAL FAILURE OF REINFORCED CONCRETE COLUMNS CONTAINING TIES WITH INADEQUATE SEISMIC DETAILING

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ABSTRACT

Axial failure of columns can lead to collapse of a building. Columns in reinforced concrete buildings constructed prior to the enforcement of modern seismic design provisions may contain inadequately detailed ties at large spacings. Columns containing inadequate ties may experience shear and axial failures when subjected to displacement reversals caused by earthquake ground motions. Engineers must be able to identify columns that may experience axial failure when subjected to earthquake ground motions in order to evaluate the safety of buildings in seismic regions.

A total of eight tests were carried out on reinforced concrete column specimens. The columns were similar to columns found in buildings constructed before the 1971 San Fernando earthquake. They contained inadequately detailed ties that do not conform to modern seismic design provisions. The ties contained 90-degree hooks and were placed at large spacings. All specimens were designed to experience shear failure prior to developing maximum flexural capacity. The parameters varied in this study included axial force level, column height, amount of longitudinal reinforcement, amount and spacing of ties, and displacement protocol.

All columns had a square 18 in. x 18 in. cross section and 8 longitudinal reinforcing bars. Specimens were subjected to cycles of lateral displacement reversals while under constant axial load. Cycling was continued until the specimen was unable to carry the axial load. Specimens were tested either with a uniaxial or a biaxial displacement protocol. Table 1 lists the specimens tested in this study. Table 2 lists the primary results from the tests.

Upon examination of the test results the following conclusions were drawn:

- Actual shear strengths were close to those calculated using Equation 11-10 from ACI 318 (2005)

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- The drift ratio at which axial failure occurs is affected by the number and direction of the displacement cycles applied after shear failure
- Columns containing ties with inadequate detailing cannot be relied upon to sustain axial load after experiencing shear failure

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Table 1: Specifications of Tested Columns

Specimen ID	Long. Reinf.	Trans. Reinf.	Aspect Ratio	P/f'_cA_g	Displacement Protocol
#1	(8) #7 (ρ_l = 1.5%)	(1) #3 @ 18" (ρ_t = 0.07%)	1.9	0.37	Uniaxial
#2	(8) #7 (ρ_l = 1.5%)	(1) #2 @ 8" (ρ_t = 0.07%)	1.9	0.38	Uniaxial
#3	(8) #7 (ρ_l = 1.5%)	(1) #3 @ 18" (ρ_t = 0.07%)	1.9	0.21	Biaxial
#4	(8) #9 (ρ_l = 2.5%)	(1) #3 @ 18" (ρ_t = 0.07%)	1.9	0.43	Uniaxial
#5	(8) #9 (ρ_l = 2.5%)	(1) #3 @ 18" (ρ_t = 0.07%)	1.9	0.46	Biaxial
#6	(8) #9 (ρ_l = 2.5%)	(2) #3 @ 12" (ρ_t = 0.18 %)	3.7	0.11	Biaxial
#7	(8) #9 (ρ_l = 2.5%)	(2) #3 @ 12" (ρ_t = 0.18%)	3.7	0.11	Biaxial
#8	(8) #9 (ρ_l = 2.5%)	(1) #3 @ 12" (ρ_t = 0.10%)	3.7	0.11	Biaxial

Table 2: Primary Test Results

Specimen ID	Maximum Lateral Force (kips)	Drift Ratio at Shear Failure (%)	Maximum Drift Ratio (%)
#1	127	1.1	1.3
#2	118	0.9	2.3
#3	126	0.9	1.3
#4	161	0.7	1.8
#5	157	0.7	1.0
#6	75	1.5	2.3
#7	75	1.8	2.8
#8	76	1.5	2.0

References

ACI Committee 318. (2005). *Building Code Requirements for Structural Concrete and Commentary ACI 318-05.* American Concrete Institute: Farmington Hills, MI.