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Conventional and High-Strength Hooked Bars—Part 1: Anchorage Tests

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This paper presents the results of an experimental study on the anchorage strength of conventional and high-strength steel hooked bars. Three hundred and thirty-seven exterior beam-column joint specimens were tested with compressive strengths ranging from 4300 to 16,500 psi (30 to 114 MPa). Parameters investigated included the number of hooked bars per specimen, bar diameter, side cover, amount of confining reinforcement, hooked bar spacing, hook bend angle, hook placement, and embedment length. Bar stresses at failure ranged from 22,800 to 144,100 psi (157 and 994 MPa). The majority of the hooked bars failed by a combination of front and side failure, with front failure being the dominant failure mode. Test results show that development lengths of hooked bars calculated based on ACI 318-14 are very conservative for No. 5 (No. 16) bars and become progressively less conservative with increasing bar size and concrete compressive strength.

Keywords: anchorage; beam-column joints; bond and development; high-strength concrete; high-strength steel; hooks; reinforced concrete; reinforcement.

INTRODUCTION

Provisions for calculating the development length of hooked bars in U.S. design codes, such as the ACI 318-14, "Building Code Requirements for Structural Concrete"; ACI 349-06, "Code Requirements for Nuclear Safety-Related Concrete Structures"; and the "AASHTO LRFD Bridge Design Specifications" (AASHTO 2012) are based primarily on studies performed in the 1970s by Minor and Jirsa (1975), Marques and Jirsa (1975), and Pinc et al. (1977). These studies included only a small number of specimens containing standard hooks and a limited range of material properties (Grade 60 [420] reinforcing steel with yield strengths of 64 and 68 ksi [441 and 469 MPa] and concrete compressive strengths between 3750 and 5400 psi [26 and 37 MPa]). Neither high-strength steel bars nor high-strength concrete, now commonly available in construction practice, were included in these studies.

The main objective of this paper is to present the results of a study of key parameters affecting the anchorage strength of standard hooked bars with a much wider range of material properties. For the purpose of this study, standard hooked bars are defined according to the provisions in Section 25.3 of ACI 318-14. Due to the magnitude of the study, the results are presented in a series of papers. The specific objectives of this paper are to describe the experimental program, provide detailed information about the observed mode of failure of the specimens, and present an evaluation of the experimental results in the context of the development length provisions for hooked bars in ACI 318-14. A second paper will present a statistical analysis of the test results and formulate equations to characterize hooked bar anchorage strength for normal and high-strength materials. Subsequent papers will evaluate specific parameters affecting hooked bar anchorage strength and develop code change proposals.

RESEARCH SIGNIFICANCE

The use of high-strength steel and concrete is becoming more common in the construction industry due to benefits such as lower congestion, smaller member dimensions, and increased useable floor area. Current provisions in ACI 318-14 for hooked bar anchorage are based on limited test results that include a single grade of reinforcement and a narrow range of concrete compressive strengths. An experimental program with an expanded range of material properties was necessary to develop a better understanding of the main parameters that affect anchorage strength and to formulate code provisions applicable to the full range of material strengths available in present-day reinforced concrete construction.

EXPERIMENTAL PROGRAM

A total of 337 beam-column joint specimens—276 with two hooked bars and 61 with three or more hooked bars—were tested to investigate the anchorage strength of hooked bars (Searle et al. 2014; Sperry et al. 2015a,b). The parameters of the study were bar size, bar stress at failure, embedment length, side cover, amount of confining reinforcement, location of the hooked bar (inside or outside the column core and position within the column depth), concrete compressive strength, hooked bar size, hook spacing, number of hooks, and hook bend angle (90- or 180-degree). No. 5, 8, and 11 (No. 16, 25, and 36) hooked bars were tested in normalweight concrete with compressive strengths ranging from 4300 to 16,500 psi (29.6 to 114 MPa). Nominal clear cover from the outside of the bar to the outside of the column (side covers) ranged from 1.5 to 4 in. (38 to 102 mm) and the center-to-center spacing of the hooked bars ranged from 3 to 11 bar diameters d_b, where d_b is the diameter of the hooked bar. Measured bar stresses at failure ranged from 22,800 to 144,100 psi (157 to 994 MPa). Confining reinforcement ranged from one No. 3 (No. 10) hoop to the amount of confining reinforcement needed to satisfy the

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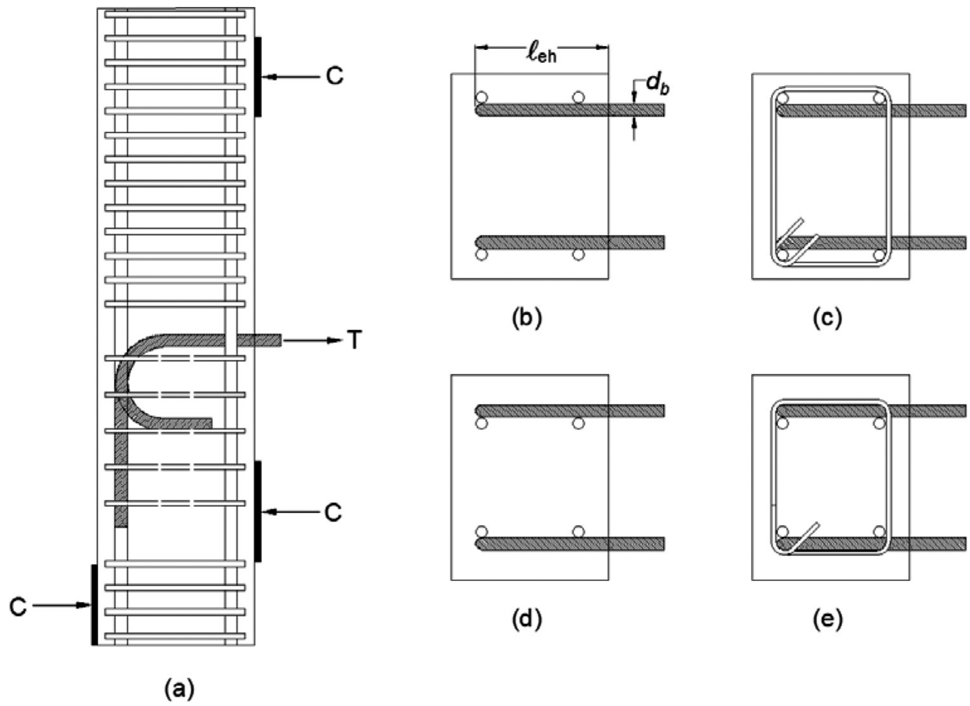

Fig. 1—Schematic of typical specimen: (a) side view of specimen; (b) cross section of specimen with hooks inside column core and without confining reinforcement; (c) cross section of specimen with hooks inside column core and with confining reinforcement; (d) cross section of specimen with hooks outside column core and without confining reinforcement; and (e) cross section of specimen with hooks outside column core and with confining reinforcement.

requirements in Section 18.8.3 of ACI 318-14 for joints of special moment frames. Results for these tests are reported and used in conjunction with other studies to evaluate the applicability of design provisions for anchorage strength in ACI 318-14 to a much wider range of materials than those used for developing the design provisions in the 1970s.

Test specimens

A typical beam-column joint specimen used to evaluate the anchorage strength of hooked bars is shown in Fig. 1 (refer to Appendix A* for full specimen details). The specimens, configured to represent exterior beam-column joints and cast without the beam, were similar to those used in the studies by Marques and Jirsa (1975) and Pinc et al. (1977). The majority of specimens with two standard hooks in this study (214 of the 337 specimens tested) had the same out-to-out spacing for each bar size—8, 12, and 16.5 in. (203, 305, and 419 mm) for specimens with No. 5, No. 8, and No. 11 (No. 16, No. 25, and No. 36) hooked bars, respectively. The out-to-out spacing varied for specimens with more than two hooked bars (multiple-hook specimens) and for two-hook specimens where the effect of close hook spacing was investigated. Column depth equaled the sum of the tail cover (nominally 2 in. [50 mm]) and the embedment length (3.5 to 11.25 in. [89 to 286 mm] for No. 5 [No. 16] bars, 5.8 to 19.5 in. [147 to 495 mm] for No. 8 [No. 25] bars, and 10.1 to 26.3 in. [257 to 668 mm] for No. 11 [No. 36] bars). For the purposes of this paper, embedment length ℓ_{eh} refers to the distance measured from the front of the column face to the back of the tail of the hook, while development length ℓ_{dh} refers to the minimum length of anchorage required by Section 25.4.3 of ACI 318-14 to ensure that a bar can develop its yield strength. Embedment lengths ℓ_{eh} were chosen to ensure anchorage failure prior to bar yield or fracture. This objective was initially accomplished by using an embedment length equal to 80% of the development length calculated with the provisions in ACI 318-14; as the study progressed and experimental data became available, embedment lengths were determined based on results from the previous tests.

For the first group of specimens, forces acting in the statically indeterminate test specimen (Fig. 1) were calculated with assumptions that indicated large shear demands in the beam-column joint. For those specimens, crossties were placed in the center of the column oriented in the direction of the beam longitudinal reinforcement (Fig. A1 in Appendix A). No. 3 (No. 10) longitudinal reinforcing bars were added at the center of the column to hold the crossties in place. Reaction measurements taken during the tests showed that the columns experienced lower joint shear and higher column moment demands than originally assumed. The use of crossties was found to be unnecessary and was discontinued in later tests. Specimens without crossties are shown in Fig. 1(b) to 1(e). Moment demands in the columns were recalculated for all specimens to ensure that the flexural capacity of the column was not exceeded at anchorage failure. Multiple and closely-spaced hooked bar specimens are described by Sperry et al. (2015a).

For the majority of specimens, the hooks were placed inside the column longitudinal reinforcement (that is, within

*The Appendix is available at **www.concrete.org/publications** in PDF format, appended to the online version of the published paper. It is also available in hard copy from ACI headquarters for a fee equal to the cost of reproduction plus handling at the time of the request.

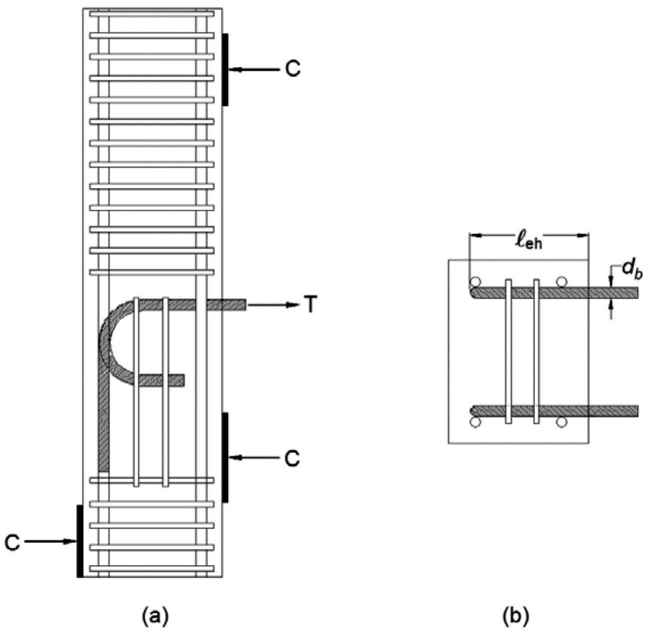

Fig. 2—Details of specimen with vertical ties: (a) side view; and (b) cross section.

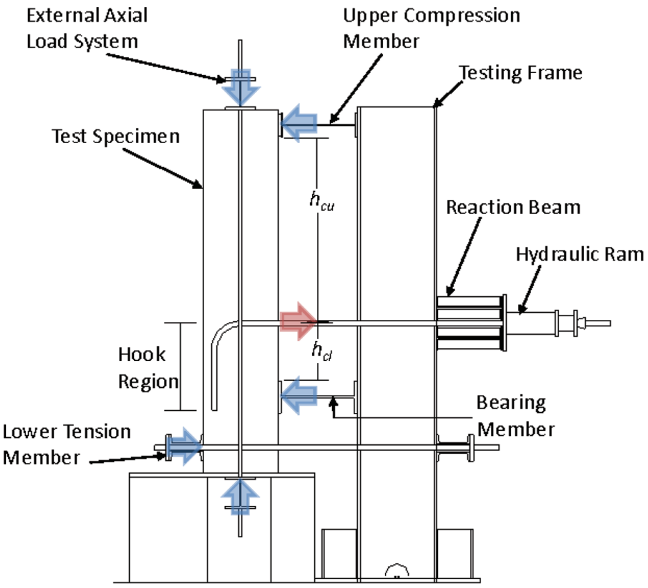

Fig. 3—Testing frame and forces applied to specimens during testing.

the column core). Some specimens were tested with hooks placed outside the column core (Fig. 1(d) and 1(e)) to simulate a hook in unconfined concrete, as would occur at the free end of a cantilever beam. The width of the specimen, side cover, and hook spacing were kept the same; only the location of the column longitudinal reinforcement changed between specimens. Additional discussion of the effects of hooked bar placement is presented by Sperry et al. (2015a).

The majority of the specimens contained one of three quantities of horizontal confining reinforcement (perpendicular to column axis): 1) no confining reinforcement; 2) two No. 3 (No. 10) hoops spaced at $8d_b$ (d_b is diameter of hooked bar) for No. 5 and No. 8 (No. 16 and No. 25) hooked bars, and $8.5d_b$ for No. 11 (No. 36) hooked bars; or 3) No. 3 (No. 10) hoops spaced at $3d_b$ along the tail and the bend of the hook. According to the provisions in Section 25.4.3 of ACI 318-14, the minimum amount of confining reinforcement permitting use of the 0.8 modification factor in development length equation for hooked bars is No. 3 (No. 10) ties or stirrups spaced at $3d_b$. For No. 5 and No. 8 (No. 16 and No. 25) standard hooks, this requirement amounts to five No. 3 (No. 10) hoops spaced along the length of the tail and bend of a 90-degree hook, while for a No. 11 (No. 36) standard hook, this requirement amounts to six No. 3 (No. 10) hoops. For Cases 2 and 3 (refer to Fig. 1(a)), the first hoop was placed at a distance of $2d_b$ from the top of the hooked bar ($1.5d_b$ from the center of the hooked bar). Additional specimens were constructed with other confining reinforcement configurations ranging from a single No. 3 (No. 10) hoop to confinement meeting the requirements of ACI 318-14 Section 18.8.3 for joints in special moment frames (four or five No. 4 [No. 13] hoops with No. 4 [No. 13] crossties in both directions). In addition, five specimens were tested with vertical hoops, as shown in Fig. 2. Of the five, one contained two No. 3 (No. 10) hoops, two contained four No. 3 (No. 10) hoops, and two contained five No. 3 (No. 10) hoops. The latter two cases satisfied the requirements for the use of the 0.8 modification factor in Section 25.4.3 of ACI 318-14. Due to the large number of specimens in the study, details about specimen dimensions, material strengths, and reinforcement configurations are presented in Appendix A and are also available elsewhere (Sperry et al. 2015a,b).

Table 1—Location of reaction forces

	Size of hooked bar		
	No. 5	No. 8	No. 11
Specimen height, in.	52-3/4	52-3/4	96
Distance from center of hook to top of bearing member flange, h_{cl}, in.*	5.25	10	19.5
Distance from center of hook to bottom of upper compression member flange, h_{cu}, in.*	18.5	18.5	48.5

*Refer to Fig. 3.

Notes: 1 in. = 25.4 mm; No. 5 (No. 16); No. 8 (No. 25); No. 11 (No. 36).

Specimen heights were chosen so that reactions from the test frame did not interfere with the hook region during testing, as shown in Fig. 3. A height of 52-3/4 in. (1340 mm) was used for the specimens with No. 5 or No. 8 (No. 16 or No. 25) hooked bars, and 96 in. (2440 mm) for the specimens with No. 11 (No. 36) hooked bars. The distance from the centerline of the hooked bars to the bearing supports (h_{cu} and h_{cl} in Fig. 3) is provided in Table 1.

Material properties

Specimens were cast using non-air-entrained ready mixed concrete with nominal compressive strengths of 5000, 8000, 12,000, and 15,000 psi (34, 55, 83, and 103 MPa). Measured compressive strengths corresponding to the average from three 6 x 12 in. (150 x 300 mm) cylinders ranged from 4300 to 16,500 psi (30 to 114 MPa). Concrete cylinders were cast using steel molds, subjected to the same curing conditions as the joint specimens, and tested on the same day as the joint specimens in accordance with the provisions in ASTM C39. Concrete mixture proportions are shown in Table 2. The concrete contained Type I/II portland cement, crushed limestone or granite with a maximum size of 3/4 in. (19 mm), Kansas River sand, and a high-range water-reducing admixture (HRWRA). Pea gravel was incorporated in the 12,000 psi (83 MPa) concrete mixture to improve workability. Class C fly ash and silica fume were added as supplementary cementitious materials for the 15,000 psi (103 MPa) concrete. Polycarboxylate-based HRWRAs were used in all concrete mixtures.

ASTM A615 Grade 80 (550 MPa) and A1035 Grade 120 (830 MPa) reinforcement was used for the hooked bars. The majority of specimens were cast with hooked bars made of A1035 steel to ensure that anchorage strength was not limited by steel strength. The properties of the hooked bars are presented in Table 3. Column longitudinal reinforcement was predominantly ASTM A615 Grade 60 (420 MPa) bars; for some specimens, the flexural demand required the use of ASTM A1035 Grade 120 (830 MPa) bars. All column confining reinforcement was ASTM A615 Grade 60 (420 MPa).

Table 2—Concrete mixture proportions

Material	Quantity (based on SSD aggregate)			
Design compressive strength, psi	5000	8000	12,000	15,000
Type I/II cement, lb/yd^3	600	700	750	760
Class C fly ash, lb/yd^3	—	—	—	160
Silica fume, lb/yd^3	—	—	—	100
Water, lb/yd^3	263	225	217	233
Crushed limestone, lb/yd^3	1734	1683	1796	—
Granite, lb/yd^3	—	—	—	1693
Pea gravel, lb/yd^3	—	—	316	—
Kansas river sand, lb/yd^3	1396	1375	1050	1138
Estimated air content, %	1	1	1	1
High-range water-reducing admixture*, oz (U.S.)	30	171	104	205
w/*cm*	0.44	0.32	0.29	0.23

*Polycarboxylate-based.

Notes: 1 psi = 0.006895 MPa; 1 lb/yd^3 = 0.593 kg/m^3; 1 oz = 29.6 mL.

Test procedure

Specimens were tested using a self-reacting system configured to simulate the forces in a beam-column joint (Fig. 3). The test frame is a modified version of the apparatus used by Marques and Jirsa (1975). Reaction locations on the testing apparatus were adjusted as needed to accommodate the different specimen sizes in the experimental program (Table 1). The vertical dimensions of the upper compression member (refer to Fig. 3) and the bearing member were 6-5/8 and 8-3/8 in. (168 and 213 mm), respectively.

Most specimens with No. 5 and No. 8 (No. 16 and No. 25) hooked bars were subjected to a constant axial load of 30,000 lb (133 kN), which, depending on column cross section dimensions, corresponded to axial stresses between 77 and 460 psi (0.53 to 3.17 MPa). In early tests, a constant force of 80,000 lb (356 kN) was used instead, corresponding to axial stresses ranging between 260 and 1040 psi (1.79 to 7.17 MPa). In specimens with No. 11 (No. 36) hooked bars, the applied axial load corresponded to a constant axial stress of 280 psi (1.93 MPa). These axial stresses were chosen based on the capacity of the loading system. Marques and Jirsa (1975) found that changes in axial stress up to 3000 psi (21 MPa) resulted in negligible changes in the anchorage strength of the hooked bars.

Load was applied monotonically to the hooked bars using hydraulic jacks to simulate tensile forces in the beam reinforcement at the face of a beam-column joint. The bearing member located below the hooked bars (Fig. 3) simulated the compression zone of the beam, and the horizontal reactions at the top and bottom of the specimen were used to prevent overturning of the specimen. A detailed description of the test frame and testing procedure is provided by Peckover and Darwin (2013).

TEST RESULTS

Cracking patterns

Figure 4 shows the crack progression observed in the specimens. Cracking almost always began with a horizontal crack on the front face of the column, at the level of the hooked bars, extending for a short distance around the side of the column (Fig. 4(a)). This cracking pattern was likely associated with slip of the straight portion of the hooked bar. As the load increased, the horizontal crack continued to propagate along the side face of the column until the tip

Table 3—Hooked bar properties

Bar size	ASTM designation	Yield strength, ksi*	Nominal diameter, in.	Average rib spacing, in.	Average rib height		Gap width		Relative rib area†
					ASTM, in.	ACI 408R-03, in.	Side 1, in.	Side 2, in.	
5	A615	88	0.625	0.417	0.031	0.029	0.179	0.169	0.060
5	A1035	122	0.625	0.391	0.038	0.034	0.200	0.175	0.073
8	A615	88	1	0.666	0.059	0.056	0.146	0.155	0.073
8	A1035‡	120	1	0.686	0.068	0.065	0.186	0.181	0.084
8	A1035§	122	1	0.574	0.057	0.052	0.160	0.157	0.078
8	A1035‖	122	1	0.666	0.056	0.059	0.146	0.155	0.073
11	A615	84	1.41	0.894	0.080	0.074	0.204	0.196	0.069
11	A1035	123	1.41	0.830	0.098	0.088	0.248	0.220	0.085

*From mill test report; †Per ACI 408R-03; ‡Heat 1; §Heat 2; ‖Heat 3; Notes: 1 in. = 25.4 mm; 1 ksi = 6.895 MPa; No. 5 (No. 16); No. 8 (No. 25); No. 11 (No. 36).

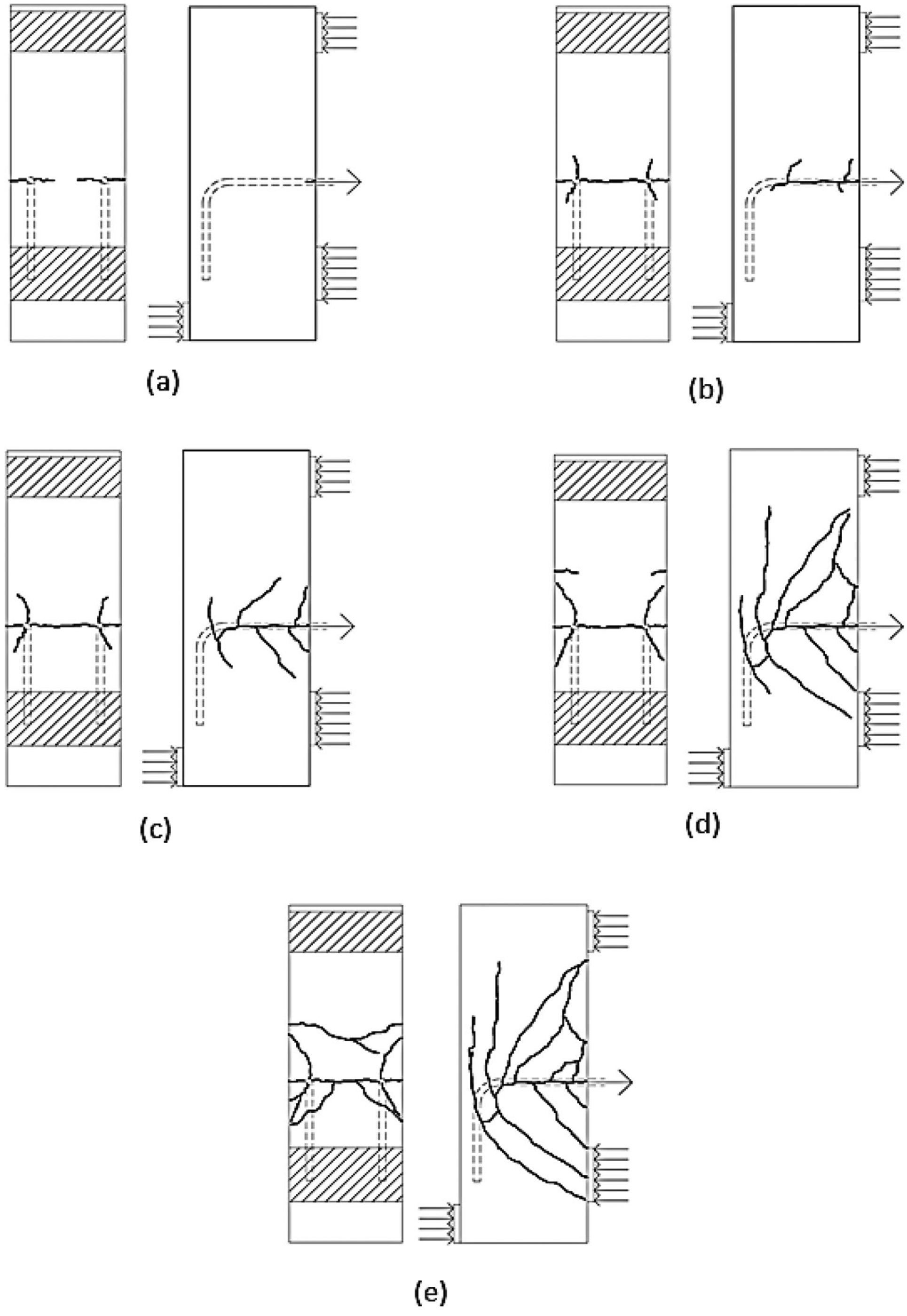

Fig. 4—Front and side views of specimens indicating typical crack progression from: (a) low loads to (e) failure.

of the crack reached the approximate location of the bend of the hooked bar (Fig. 4(b)). At this stage of loading, radial cracks formed on the front face of the column, initiating from the hooked bars. Vertical and inclined cracks also formed, fanning out from the horizontal crack on the side face of the column. These cracks continued to propagate toward the front of the column (Fig. 4(c)). Cracks below the level of the hooked bar propagated toward the compression reaction (Fig. 4(d)). Cracks above the level of the hooked bar propagated toward a point just below the top reaction of the column. Near failure (Fig. 4(e)), inclined cracks on the side faces extended perpendicular to the sides, through the column width, and widened as concrete pulled out of the front face. The amount of cracking and spalling varied depending on the failure mode. The transition from initial splitting (Fig. 4(a)) to inclined cracks on the sides of the column that extended through the column width (Fig. 4(b) to 4(e)) suggests that the hooked portion of the bar provided the primary anchorage after slip occurred along the straight portion of the bar.

Failure modes

Five failure modes were observed as shown in Fig. 5: front pullout, front blowout, side splitting, side blowout, and tail kickout. The failure mode for each specimen is identified in Tables A.1 to A.7 of Appendix A.

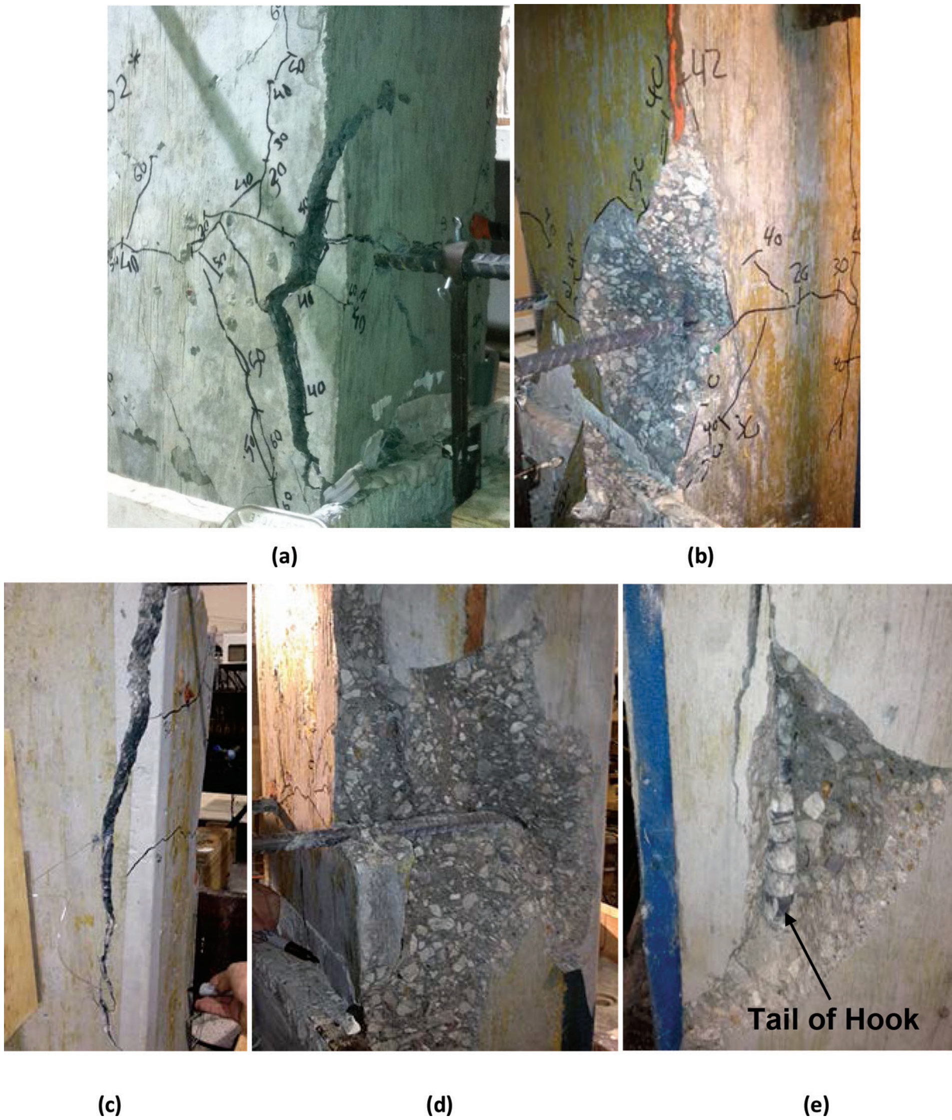

Fig. 5—Failure modes: (a) front pullout; (b) front blowout; (c) side splitting; (d) side blowout; and (e) tail kickout.

Front pullout (Fig. 5(a)) was characterized by a mass of concrete being pulled forward with the hooked bar from the front face of the column. This failure mode was often coupled with side splitting or side blowout.

Front blowout (Fig. 5(b)) was similar to front pullout, except that it was more sudden in nature, with a larger release of energy than front pullout. Likewise, front blowout was associated with spalling of the concrete on the front face of the column at failure. This failure mode was often coupled with side blowout or side splitting.

Side splitting (Fig. 5(c)) occurred when the concrete cover on the side of the hooked bar separated from the column as the hooked bar lost anchorage strength. The splitting plane for this failure mode coincided with the vertical plane passing through the straight and bent portions of the hooked bar. In most specimens with side splitting failure, a long vertical crack was observed on the back face of the column. This failure mode was often coupled with front pullout or front blowout.

Side blowout (Fig. 5(d)) was more sudden in nature than side splitting, akin to front blowout having a higher release of energy at failure than front pullout. The loss of concrete side cover to the outside reinforcement on the column was often greater than observed in side splitting. In specimens with confining reinforcement, the hoops were exposed after failure; otherwise, the hooked bar was exposed after failure. This failure mode was often coupled with front blowout or front pullout. Both side splitting and side blowout suggest that the hooked bar causes a crack in the plane of the hook as the bar slips.

Tail kickout (Fig. 5(e)) was observed in approximately 5% of the specimens containing hooked bars with 90-degree bend angles. Tail kickout occurred when the tail extension pushed the concrete cover off the back of the column, exposing the tail of the hooked bar. This behavior was commonly observed in specimens without confining reinforcement, primarily for No. 8 or No. 11 (No. 25 or No. 36) hooked bars. Only one No. 5 (No. 16) hooked bar exhibited this failure mode. Tail kickout was often sudden in nature and was observed in conjunction with other failure modes—in all cases, it appeared to be a secondary failure, occurring only after a front or side failure.

In addition to the failure modes previously described, five specimens (four with No. 5 [No. 16] hooked bars and one with No. 11 [No. 36] hooked bars, identified in Appendix A) failed

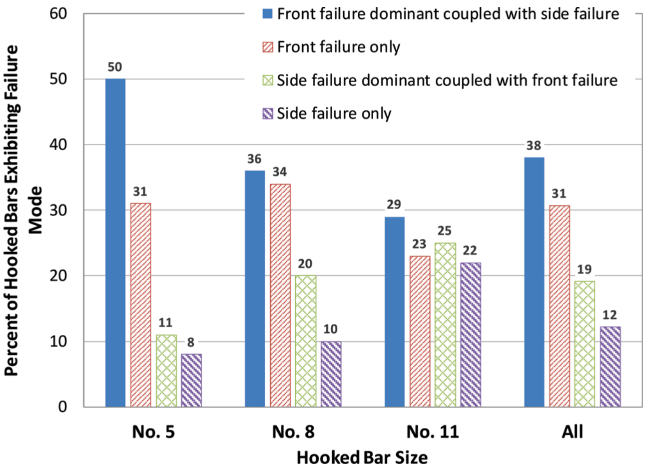

Fig. 6—Percent of hooked bars exhibiting each failure mode: No. 5 (No. 16), No. 8 (No. 25), and No. 11 (No. 36).

due to fracture of the hooked bars or yielding of column longitudinal reinforcement. Also, some tests were terminated prior to failure as a safety precaution when the stress in the hooked bar approached the tensile strength of the steel. These specimens were not considered to have undergone an anchorage failure of the hooked bar and were excluded from subsequent data analyses.

Figure 6 shows the percentage of hooked bars exhibiting each anchorage failure mode. Percentages were calculated based on the mode of failure of the individual hooked bars because hooked bars in the same specimen could exhibit different modes of failure. For simplicity, front pullout and front blowout were combined into "front failures"; side splitting and side blowout were combined into "side failures". When multiple failure modes were observed, the dominant failure mode was distinguished based on the relative amount of cracking and concrete movement observed on the side and front faces of the specimen after failure. The dominant failure mode was defined as a front failure if the front face of the column exhibited greater damage; otherwise, the dominant failure mode was defined as a side failure. Due to the nature of the failures, the distinction between a dominant front and a dominant side failure was subjective.

Coupled front and side failures were observed for the majority of the hooked bars (57% for the full set of bars, corresponding to 38% with front failure dominant plus 19% with side failure dominant; refer to "All" in Fig. 6). For hooked bars exhibiting a single mode of failure, more bars exhibited front failures (31%) than side failures (12%).

Eighty-one percent of the No. 5 (No. 16) hooked bars exhibited front failure as the primary failure mode (50% exhibited a front failure coupled with side failure, and 31% exhibited a front failure only), and 19% exhibited side failure as the primary failure mode. Seventy percent of the No. 8 (No. 25) hooked bars exhibited front failure as the primary failure mode (36% with front failure coupled with side failure, and 34% exhibited front failure only). Only 52% of the No. 11 (No. 36) hooked bars exhibited front failure as the primary failure mode (29% exhibited front failure coupled with side failure, and 23% exhibited front failure only). This indicates that the percentage of hooked bars exhibiting side failures as the primary failure mode increased as the bar size increased. This trend is attributed to the fact that the side cover was kept constant for the majority of the specimens; thus, the ratio of cover to bar diameter decreased as bar size increased. Regardless of this trend, front failure coupled with a secondary side failure was observed to be the most common mode of failure for all bar sizes in the study, and 69% of the full set of bars exhibited front failure as the primary failure mode. These results indicate that front failure plays an important role in the behavior of hooked anchorage, which is in direct contrast to the findings by Marques and Jirsa (1975) and Pinc et al. (1977), who described side splitting as the primary failure mode for all specimens.

Comparison of test results with ACI 318-14

The bar forces on the specimens are presented in Appendix A. The reported values include the maximum total force applied to a specimen divided by the number of hooked bars under load and the maximum force recorded for each hooked bar, which, in general, did not coincide with the maximum load on the specimen for both bars. The latter—the average bar force at the peak load—is treated as the failure load per hooked bar and is used to calculate the average bar stress at failure. Test results from this and earlier studies were compared with anchorage strengths derived from the provisions for hooked bars in ACI 318-14. The data set used for this analysis includes test results from this study as well as data from 36 tests performed by Marques and Jirsa (1975), Pinc et al. (1977), Hamad et al. (1993), Ramirez and Russell (2008), and Lee and Park (2010) (Table A.7 in Appendix A). Included in this evaluation were specimens with two hooked bars cast inside the column core (that is, the region bounded by the column longitudinal reinforcement) with side cover ranging from 2.5 to 3.5 in. (64 to 89 mm). Excluded from the analysis were specimens with more than two hooked bars, hooked bars cast outside the column core, hooked bars anchored outside the compression region of the column (hooked bars anchored in the middle of the column), and hooked bars anchored in columns with high longitudinal reinforcement ratios (>0.04). Results for these specimens will be included in future papers.

A regression analysis technique based on dummy variables (Draper and Smith 1981), referred to in this paper as a dummy variables analysis, was used to identify trends in the data. Dummy variables analysis is a least-squares regression analysis method that allows differences in populations to be taken into account when formulating relationships between principal variables. For example, the effect of embedment length ℓ_{eh} on the bar force at failure, T, can be found for different bar sizes based on the assumption that the effect of *changes* in ℓ_{eh} on *changes* in T (slope of the regression line) is the same for all the bar sizes considered, but that the absolute value of T for a given ℓ_{eh} differs for each bar size, resulting in different intercepts for the individual regression lines.

ACI provisions—In accordance with Section 25.4.3.1(a) of ACI 318-14, the development length of a hooked bar, ℓ_{dh} (in. or mm), is expressed as a function of the yield strength of the reinforcement, f_y (psi or MPa), the compressive strength of the concrete, f_c' (psi or MPa), and the bar diameter d_b (in. or mm)

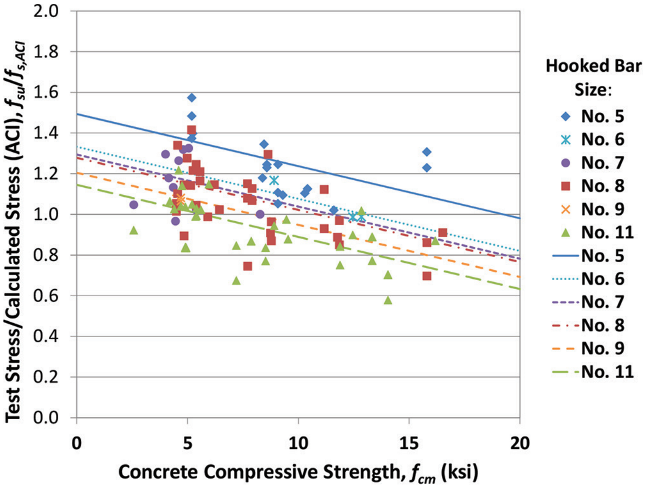

Fig. 7—Ratio of test-to-calculated stress $f_{su}/f_{s,ACI}$ *versus* f_{cm} *for hooked bars without confining reinforcement: No. 5 (No. 16), No. 6 (No. 19), No. 7 (No. 22), No. 8 (No. 25), No. 9 (No. 29), and No. 11 (No. 36). (Note: 1 ksi = 6.895 MPa.)*

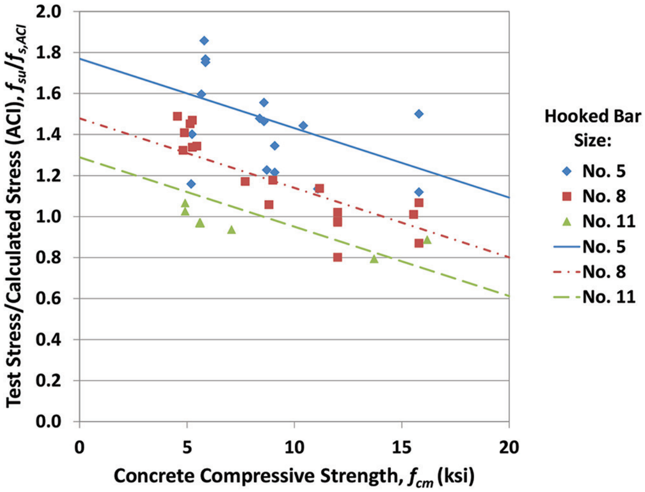

Fig. 8—Ratio of test-to-calculated stress $f_{su}/f_{s,ACI}$ *versus* f_{cm} *for hooked bars with two No. 3 ties in the joint region: No. 5 (No. 16), No. 8 (No. 25), and No. 11 (No. 36). (Note: 1 ksi = 6.895 MPa.)*

$$\ell_{dh} = \left(\frac{f_y \psi_e \psi_c \psi_r}{50\lambda\sqrt{f_c'}}\right) d_b \quad \text{(in.-lb)}$$

$$\ell_{dh} = \left(\frac{0.24 f_y \psi_e \psi_c \psi_r}{\lambda\sqrt{f_c'}}\right) d_b \quad \text{(SI)} \tag{1}$$

As shown in Eq. (1), the expression for ℓ_{dh} also includes factors for the effects of epoxy coating (ψ_e) concrete cover (ψ_c), confining reinforcement (ψ_r), and lightweight concrete (λ). The development length ℓ_{dh} represents the minimum embedment length required to develop the yield strength of the bar. The parameter ℓ_{dh} in Eq. (1) is most useful in the context of design. For the purpose of evaluating test results, it is more helpful to calculate the bar stress at failure based on Eq. (1), designated $f_{s,ACI}$ in this study as a function of the embedment length ℓ_{eh}. To solve Eq. (1) for $f_{s,ACI}$, the development length ℓ_{dh} was replaced by the embedment length ℓ_{eh}, yield strength f_y was replaced by bar stress $f_{s,ACI}$, and the specified compressive strength f_c' was replaced by the measured compressive strength f_{cm}. Because all of the specimens in this study were constructed with uncoated bars and normalweight concrete, ψ_e and λ were taken as 1.0, giving

$$f_{s,ACI} = \frac{50\ell_{eh}\sqrt{f_{cm}}}{\psi_c \psi_r d_b} \quad \text{(in.-lb)}$$

$$f_{s,ACI} = \frac{\ell_{eh}\sqrt{f_{cm}}}{0.24\psi_c \psi_r d_b} \quad \text{(SI)} \tag{2}$$

The cover factor ψ_c equals 0.7 for No. 11 (No. 36) and smaller bars with at least 2.5 in. (65 mm) of clear cover to the side of the hook and 2 in. (50 mm) of clear cover to the tail of the hook, and 1.0 otherwise. The confining reinforcement factor ψ_r equals 0.8 for hooked bars with confining reinforcement spaced no further than $3d_b$ apart, and 1.0 otherwise. In accordance with Section 25.4.1.4 of ACI 318-14, confining reinforcement may be parallel or perpendicular to the straight portion of hooked bars with a 90-degree bend angle and perpendicular to the straight portion of hooked bars with a 180-degree bend angle.

Comparisons—Figures 7 through 9 show the ratio of average bar stress at failure f_{su} to $f_{s,ACI}$ plotted versus the measured concrete compressive strength f_{cm}. Each data point represents an individual test, and the trend lines were obtained using a dummy variables analysis of the test results grouped in sets according to hooked bar size. Figure 7 shows the results for hooked bars without confining reinforcement in the joint region. Figure 8 shows the results for hooked bars with two No. 3 (No. 10) hoops in the joint region, and Fig. 9 shows the results for hooked bars with No. 3 (No. 10) hoops spaced at $3d_b$ as confining reinforcement.

The values for ℓ_{eh} and f_{cm} used in Eq. (2) to calculate $f_{s,ACI}$ were those measured, not the nominal values. The upper limit on $\sqrt{f_c'}$ of 100 psi, corresponding to f_c' = 10,000 psi (8.3 MPa, corresponding to f_c' = 69 MPa) in Section 25.4.1.4 of ACI 318-14, and the upper limit on f_y of 80 ksi (550 MPa) in Section 20.2.2.4 of ACI 318-14 were not applied. The figures include results for specimens with 2.5 and 3.5 in. (65 and 90 mm) clear side cover as well as hooked bars with 90- and 180-degree bend angles. These specimens were grouped in the same set based on the observation by Sperry et al. (2015a,b) that the anchorage strength of hooked bars was not sensitive to differences in clear side cover between 2.5 and 3.5 in. (65 and 90 mm) or bend angle between 90 and 180 degrees.

Because the nominal dimensions of the specimens provided at least a 2.5 in. (65 mm) side cover and a 2 in. (50 mm) tail cover, the cover factor ψ_c = 0.7 was applied in the calculations of $f_{s,ACI}$ for all specimens, although some specimens, due to fabrication tolerances, had actual side and tail covers slightly less than 2.5 and 2 in. (65 and 50 mm), respectively. The values of $f_{s,ACI}$ shown in Fig. 9 include the confining reinforcement factor ψ_r = 0.8. This factor was

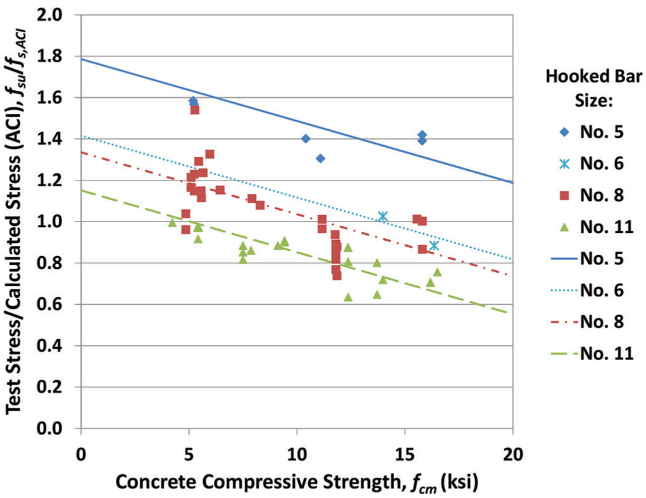

Fig. 9—Ratio of test-to-calculated stress $f_{su}/f_{s,ACI}$ *versus* f_{cm} *for hooked bars with No. 3 ties spaced at* $3d_b$ *or less as confining reinforcement: No. 5 (No. 16), No. 6 (No. 19), No. 8 (No. 25), and No. 11 (No. 36). (Note: 1 ksi = 6.895 MPa.)*

applied alike to hooked bars with 90- and 180-degree bend angles based on the observation by Sperry et al. (2015a,b) that hooks with both bend angles were strengthened equally by confining reinforcement, independent of the orientation of the confining reinforcement.

Hooked bars without confining reinforcement in joint region—Figure 7 includes results for 99 beam-column joint specimens without confining reinforcement in the joint region (10 from Marques and Jirsa [1975], six from Pinc et al. [1977], six from Hamad et al. [1993], seven from Ramirez and Russell [2008], two from Lee and Park [2010], and 68 from the current investigation). Although test data for high-strength concrete are not available for all bar sizes, the trend lines from the dummy variables analysis indicate that the ratio $f_{su}/f_{s,ACI}$ decreases with increasing compressive strength. The trend lines also show that $f_{su}/f_{s,ACI}$ decreases with increasing bar size. The trend line for the ratio of $f_{su}/f_{s,ACI}$ is lower than 1.0 for No. 6 (No. 19) hooked bars with concrete compressive strength f_{cm} higher than approximately 13,500 psi (93.1 MPa). Likewise, $f_{su}/f_{s,ACI}$ is lower than 1.0 for No. 7 and No. 8 (No. 22 and No. 25) hooked bars for f_{cm} above approximately 11,500 psi (79.3 MPa), for No. 9 (No. 29) hooked bars for f_{cm} above approximately 8000 psi (55.2 MPa), and for No. 11 (No. 36) hooked bars for f_{cm} above approximately 6000 psi (41.4 MPa). For the latter two cases, the $f_{su}/f_{s,ACI}$ ratio is lower than 1.0 at concrete compressive strengths below the 10,000 psi (69 MPa) limit on f_c' used to calculate development length in ACI 318-14. These results indicate that current code provisions for development length of hooked bars, originally developed based on experimental results from specimens with concrete compressive strengths between 3750 and 5400 psi (25.9 and 37.2 MPa), may result in unconservatively low development lengths when extrapolated to No. 9 (No. 29) and larger bars in concrete with compressive strengths as low as 6000 psi (41 MPa).

Hooked bars confined by two hoops in joint region—Figure 8 shows experimental results from this study for 50 beam-column joints with two hooked bars and two No. 3 (No. 10) column hoops in the joint region. Similar to the specimens without confining reinforcement in the joint region, the ratio $f_{su}/f_{s,ACI}$ decreases as bar size and concrete compressive strength increase. The values of $f_{su}/f_{s,ACI}$ shown in Fig. 8 are higher than those shown in Fig. 7, an indication that even a small amount of horizontal confining reinforcement in the joint region contributes to an increase in anchorage strength, which is an effect that is not recognized in the provisions for development length of hooked bars in ACI 318-14 (Eq. (1)).

As shown in Fig. 8, the trend line for specimens with No. 8 (No. 25) hooked bars is below 1.0 for compressive strengths above approximately 14,500 psi (100 MPa), and for No. 11 (No. 36) bars for compressive strengths above approximately 9000 psi (62 MPa). Similar to hooked bars without confining reinforcement in the joint region, these results indicate that the provisions for development length of hooked bars in ACI 318-14 do not accurately reflect the effects of concrete compressive strength and bar diameter on anchorage strength. According to the test results, in members with small amounts of confining reinforcement, the provisions in ACI 318-14 can lead to unconservative development lengths for No. 11 (No. 36) hooked bars in concrete with compressive strengths above 9000 psi (62.1 MPa). While these results are still of concern, the problem is much less significant than for members without confining reinforcement.

Hooked bars confined by hoops spaced at $3d_b$ *in joint region*—Figure 9 shows results from tests of 58 beam column joints (one from Hamad et al. [1993], four from Ramirez and Russell [2008], and 53 from the current investigation) with No. 3 (No. 10) hoops spaced at $3d_b$ or less within the joint region. The provisions in Section 25.4.3.2 of ACI 318-14 allow the use of $\psi_r = 0.8$ when calculating the development length of hooked bars with a confining reinforcement spacing of $3d_b$ or less. Similar to the results shown in Fig. 7, the parallel trend lines from the dummy variables analysis have a negative slope and their intercepts decrease with increasing bar size.

For the specimens with No. 6 (No. 19) hooked bars, the trend line for $f_{su}/f_{s,ACI}$ reaches a value of 1.0 at a compressive strength of approximately 14,500 psi (100 MPa). For the specimens with No. 8 and 11 (No. 25 and 36) hooked bars, the trend lines reach a value of 1.0 at concrete compressive strengths of approximately 11,000 and 5000 psi (76 and 34 MPa), respectively. The test results shown in Fig. 9, thus, indicate that eliminating the upper limit on f_c' of 10,000 psi (69 MPa) for calculating hook development length ℓ_{dh} (Eq. (1)) would produce unsafe designs for No. 8 (No. 25) hooked bars with concrete compressive strengths greater than 11,000 psi (76 MPa). Even without a change in the limit on f_c', the application of development length modification factors for cover and confining reinforcement (ψ_c and ψ_r) to Eq. (1) produces anchorage strengths that can be unconservative for No. 11 (No. 36) hooked bars cast in concrete with compressive strengths as low as 5000 psi (34 MPa), representing a large percentage of the concrete used in current practice.

Summary of comparisons—Figures 7 through 9 show that for all three cases presented here, specimens without confining reinforcement (Fig. 7), specimens with two No. 3 (No. 10) hoops in the joint region (Fig. 8), and specimens with No. 3 (No. 10) hoops (confining reinforcement) spaced at $3d_b$ or less within the joint region (Fig. 9), the trend lines for $f_{su}/f_{s,\text{ACI}}$ decrease with increasing bar size and concrete compressive strength. Anchorage strength of hooked bars calculated based on the design provisions in ACI 318-14 can be unconservative for No. 11 (No. 36) bars with concrete compressive strengths as low as 5,000 psi (34 MPa). These observations indicate that the provisions in ACI 318-14 for the design of hooked bars, originally developed based on a small number of specimens with Grade 60 (420) reinforcing steel and concrete compressive strengths between 3750 and 5400 psi (26 and 37 MPa), should be adjusted to expand their applicability and reflect more accurately the effects of concrete compressive strength and bar size over the much broader range of values used in present-day construction.

SUMMARY AND CONCLUSIONS

Tests of 337 simulated exterior beam-column joints were conducted to study the anchorage strength of hooked bars. Of the 337 specimens, 276 contained two hooked bars and 61 contained more than two hooked bars. The subset of 171 beam-column joint specimens with two hooked bars cast inside the column core, combined with the results of 36 tests from other studies, were used to evaluate the applicability of current code equations to high-strength steel or concrete. The effects on anchorage strength of concrete side cover, hook bend angle, hooked bar spacing, hooked bar placement, and confining reinforcement orientation, although evaluated experimentally, are not discussed in this paper. Specimens were constructed with No. 5, No. 8, and No. 11 (No. 16, No. 25, and No. 36) hooked bars with either 90- or 180-degree bend angles. The nominal clear concrete side cover ranged from 1.5 to 4 in. (38 to 102 mm), with most specimens having a side cover between 2.5 and 3.5 in. (65 to 90 mm). The hooked bar center-to-center spacing ranged from $3d_b$ to $11d_b$. Specimens were cast with normalweight concrete with compressive strengths ranging from 4300 to 16,500 psi (30 to 114 MPa). Measured bar stresses at failure ranged from 22,800 to 144,100 psi (157 to 994 MPa). Specimens were fabricated with different amounts of confining reinforcement to evaluate its effect on hooked bar anchorage strength. Confining reinforcement ranged from one No. 3 (No. 10) hoop to the amount of confining reinforcement needed to satisfy the requirements in Section 18.8.3 of ACI 318-14 for joints of special moment frames. Measured anchorage strengths were compared with bar stresses calculated based on the development length provisions for hooked bars in Section 25.4.3 of ACI 318-14.

The following conclusions are based on the data and analysis presented herein:

1. Both front and side failures were observed in the majority of hooked bars, with front failure being the dominant failure mode for the largest percentage of the tests.

2. Front failure played an important role in the behavior of the hooked bars tested, in contrast to findings of previous studies.

3. The percentage of hooked bars exhibiting side failure as the primary failure mode increased with increasing hooked bar size.

4. Anchorage strengths calculated based on the provisions of ACI 318-14, incorporating the modification factor for concrete cover, overestimated measured strengths for larger hooked bars. Similarly, when applied to the wider range of material properties evaluated in this study, calculated anchorage strengths overestimated the effects of concrete compressive strength and confining reinforcement on the anchorage strength of hooked bars in tension.

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APPENDIX A

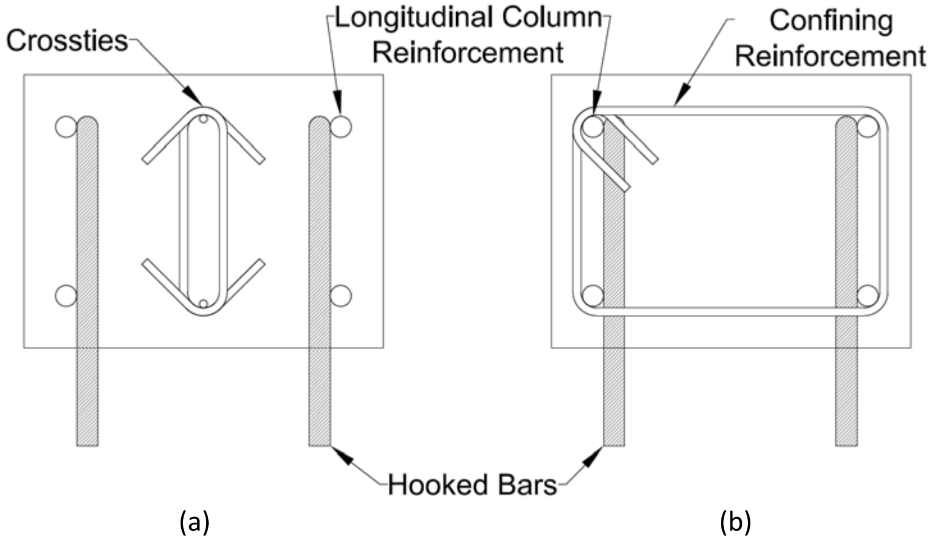


Fig. A1–Cross-section of specimens (a) with crossties and no confining reinforcement and (b) without crossties and with confining reinforcement

NOTATION AND DATA TABLES

A_h	Area of hooked bar
$A_{tr,l}$	Area of single leg of transverse reinforcement inside hook region
A_s	Area of longitudinal steel in the column
A_{cti}	Total area of cross-ties inside the hook region
b	Column width
c_h	Clear spacing between hooked bars, inside-to-inside spacing
c_{so}	Clear cover measured from the side of the hook to the side of the column
$c_{so,\text{avg}}$	Average clear cover of the hooked bars
c_{th}	Clear cover measured from the tail of the hook to the back of the column
d_b	Nominal diameter of the hooked bar
d_{cto}	Nominal bar diameter of cross-ties outside the hook region
d_{tr}	Nominal bar diameter of transverse reinforcement inside the hook region
d_s	Nominal bar diameter of transverse reinforcing steel outside the hook region
f'_c	Specified concrete compressive strength
f_{cm}	Measured average concrete compressive strength
$f_{s,\text{ACI}}$	Stress in hook as calculated by Section 25.4.3 of ACI 318-14
$f_{su,\text{max}}$	Maximum stress on individual hooked bar
f_{su}	Average peak stress on hooked bars at failure
f_{yt}	Nominal yield strength of transverse reinforcement
f_{ys}	Nominal yield strength of longitudinal reinforcing steel in the column
h_c	Width of bearing member flange
h_{cl}	Height measured from the center of the hook to the top of the bearing member flange
h_{cu}	Height measured from the center of the hook to the bottom of the upper compression member
ℓ_{dh}	Development length in tension of deformed bar standard hook, measured from outside end of hook, point of tangency, toward critical section
ℓ_{eh}	Embedment length measured from outside end of hook, point of tangency, to front face of the column
$\ell_{eh,\text{avg}}$	Average embedment length of hooked bars
n	Number of hooked bars confined by N legs
N	Effective number of legs of confining reinforcement in joint region
N_{cti}	Total number of cross-ties used as supplemental reinforcement inside the hook region
N_{cto}	Number of cross-ties used per layer as supplemental reinforcement outside the hook region and spaced at s_s
N_h	Number of hooked bars loaded simultaneously
N_{tr}	Number of stirrups/ties crossing the hook
T	Average load on hooked bars at failure
T_{ind}	Load on individual hooked bar at failure
T_{max}	Maximum load on individual hooked bar
T_{total}	Sum of loads on hooked bars at failure
R_r	Relative rib area
s_{cti}	Center-to-center spacing of cross-ties in the hook region
s_{tr}	Center-to-center spacing of transverse reinforcement in the hook region
s_s	Center-to-center spacing of stirrups/ties outside the hook region

Failure types

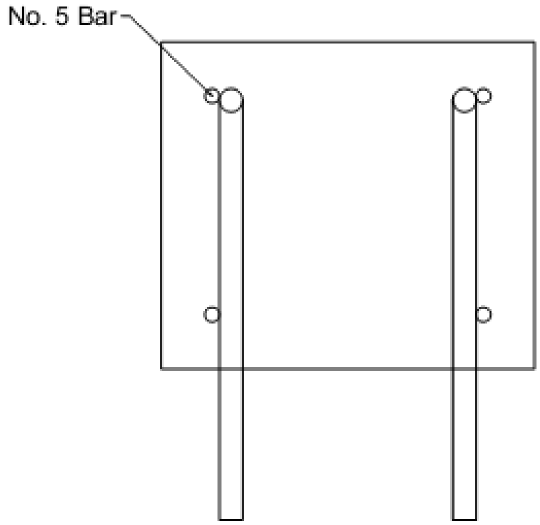
FP Front pullout
FB Front blowout
SS Side splitting
SB Side blowout
TK Tail kickout
FL Flexural failure of column
BY Yield or fracture of hooked bars

Specimen identification

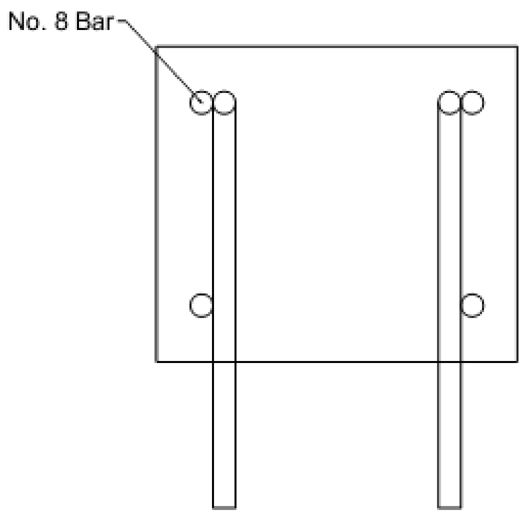
(A@B) C-D-E-F#G-H-I-J-Kx(L)

A Number of hooks in the specimen
B Clear spacing between hooks in terms of bar diameter
(A@B = blank, indicates standard 2-hook specimen)
C ASTM in.-lb bar size
D Nominal compressive strength of concrete
E Angle of bend
F Number of bars used as transverse reinforcement within the hook region
G ASTM in.-lb bar size of transverse reinforcement
(if F#G = 0 = no transverse reinforcement)
H Hooked bars placed inside (i) or outside (o) of longitudinal reinforcement
I Nominal value of c_{so}
J Nominal value of c_{th}
K Nominal value of ℓ_{eh}
x Replication in a series, blank (or a), b, c, etc.
L Replication not in a series

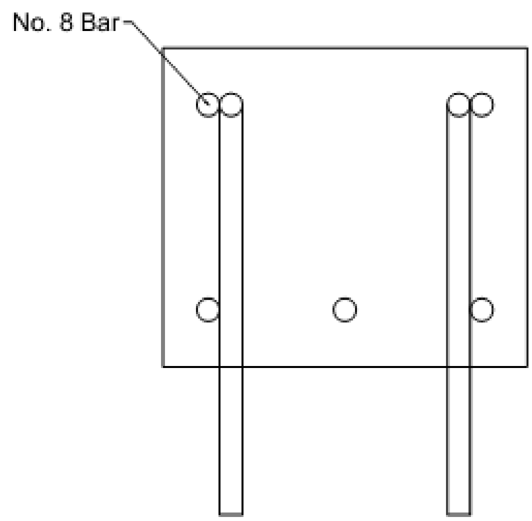
<u>**LONGITUDINAL COLUMN STEEL LAYOUTS**</u>



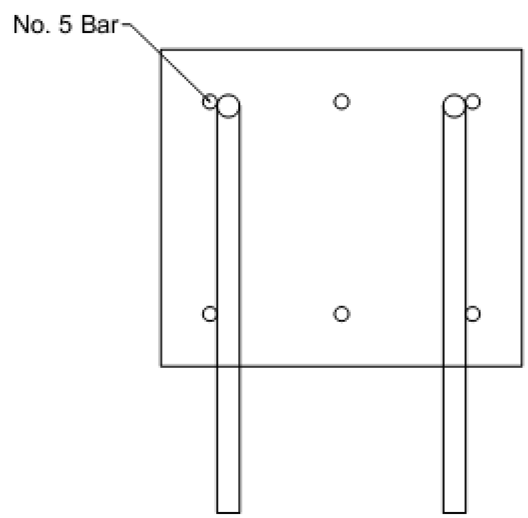
Layout A1: Longitudinal column reinforcement-4 No. 5 bars. Transverse reinforcement not shown.



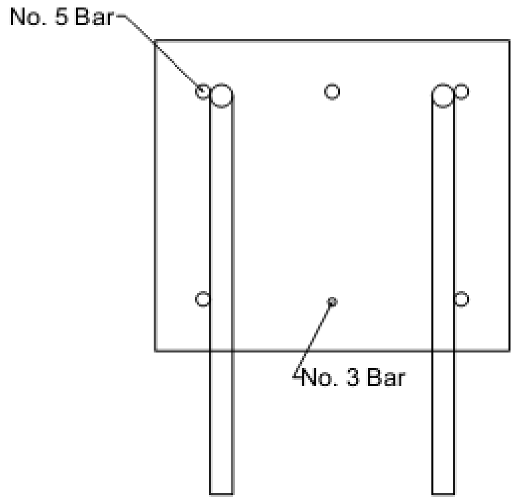
Layout A2: Longitudinal column reinforcement-4 No. 8 bars. Transverse reinforcement not shown.



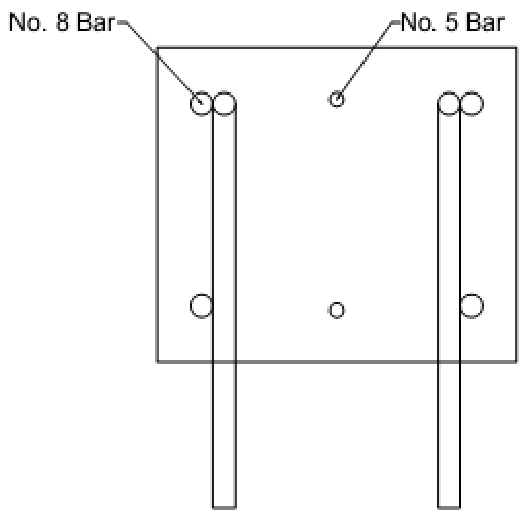
Layout A3: Longitudinal column reinforcement-5 No. 8 bars. Transverse reinforcement not shown.



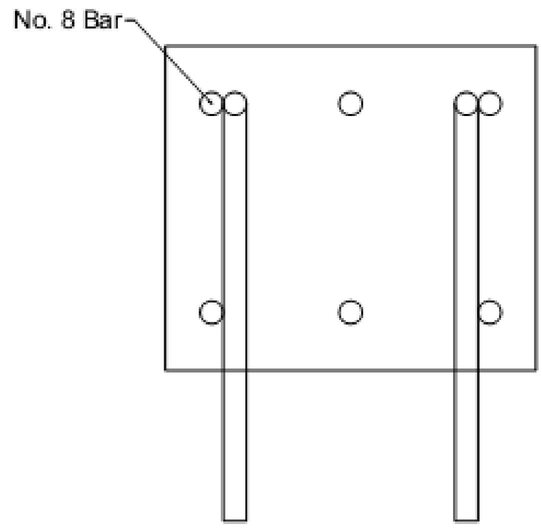
Layout A4: Longitudinal column reinforcement-6 No. 5 bars. Transverse reinforcement not shown.



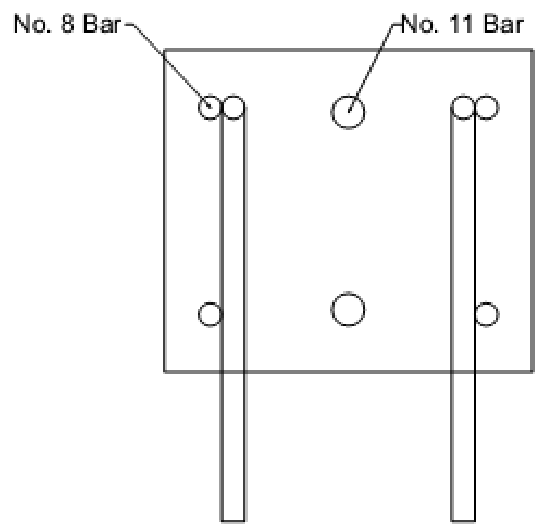
Layout A5: Longitudinal column reinforcement-5 No. 5 bars + 1 No. 3 bar. Transverse reinforcement not shown.



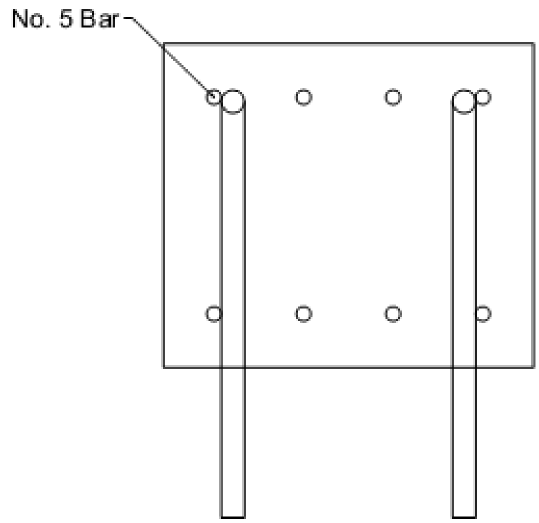
Layout A6: Longitudinal column reinforcement-4 No. 8 bars + 2 No. 5 bars. Transverse reinforcement not shown.



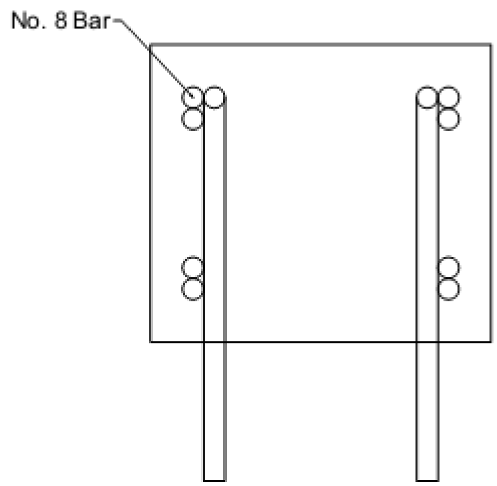
Layout A7: Longitudinal column reinforcement-6 No. 8 bars. Transverse reinforcement not shown.



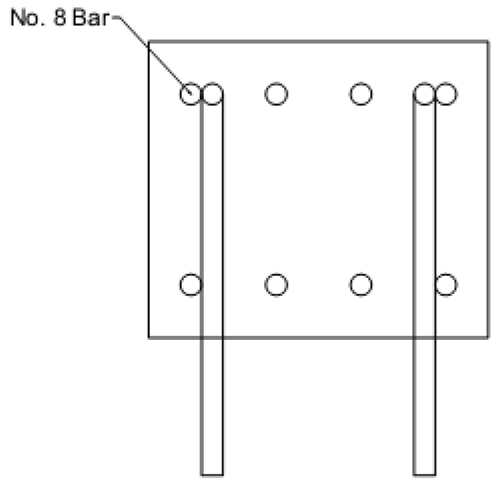
Layout A8: Longitudinal column reinforcement-4 No. 8 bars + 2 No. 11 bars. Transverse reinforcement not shown.



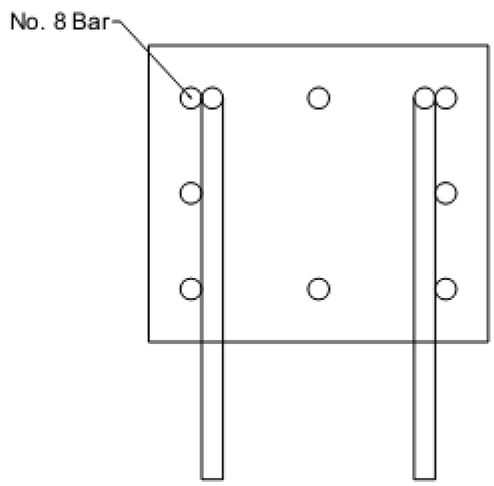
Layout A9: Longitudinal column reinforcement-8 No. 5 bars. Transverse reinforcement not shown.



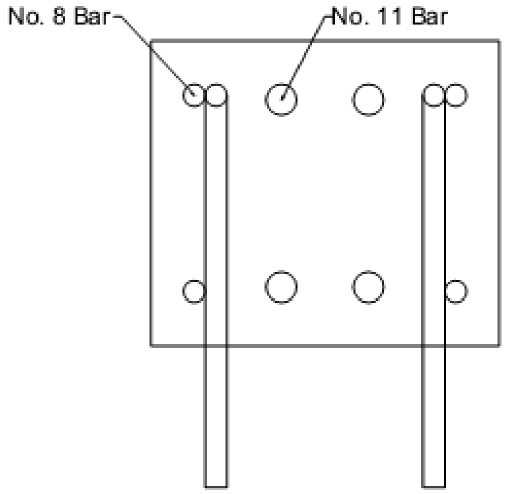
Layout A10: Longitudinal column reinforcement-8 No. 8 bars (four bundles of two bars each). Transverse reinforcement not shown.



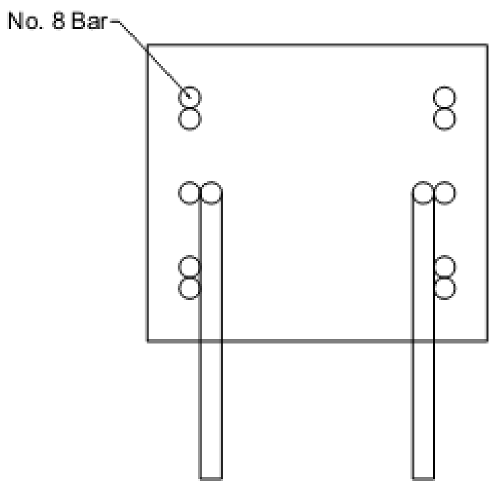
Layout A11: Longitudinal column reinforcement-8 No. 8 bars (distributed across two column faces). Transverse reinforcement not shown.



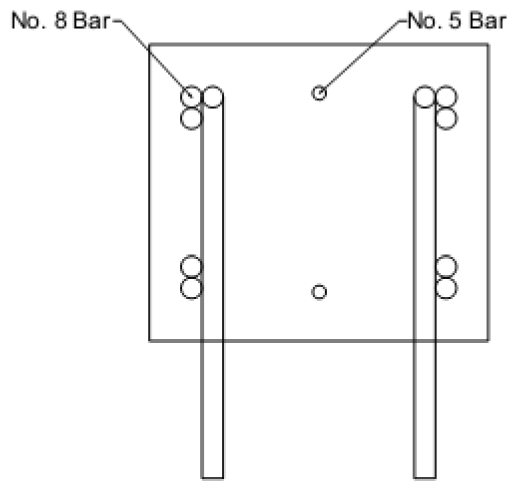
Layout A12: Longitudinal column reinforcement-8 No. 8 bars (distributed across four column faces). Transverse reinforcement not shown.



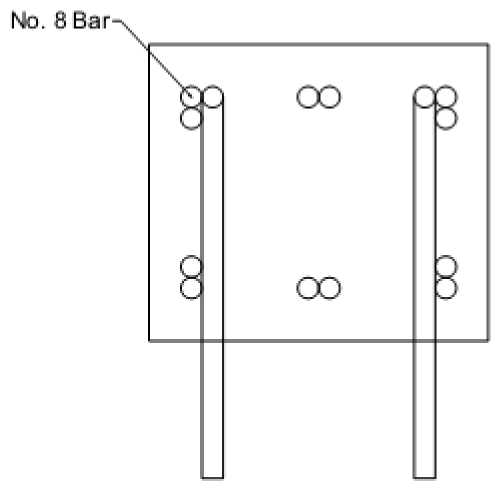
Layout A13: Longitudinal column reinforcement-4 No. 8 bars + 4 No. 11 bars. Transverse reinforcement not shown.



Layout A14: Longitudinal column reinforcement-10 No. 8 bars. Transverse reinforcement not shown.



Layout A15: Longitudinal column reinforcement-8 No. 8 bars + 2 No. 5 bars. Transverse reinforcement not shown.



Layout A16: Longitudinal column reinforcement-12 No. 8 bars. Transverse reinforcement not shown.

Note: In that tables that follow, *1 lb = 4.448 N*, *1 psi = 0.006895 MPa, 1 in. = 25.4 mm*

Table A.1 Comprehensive test results and data for No. 5 specimens with two hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
1	5-5-90-0-o-1.5-2-5	A B	90°	-	A615	5.0 5.0	5.0	4930	4	0.625
2	5-5-90-0-o-1.5-2-6.5	A B	90°	-	A1035	6.5 5.9	6.2	5650	6	0.625
3	5-5-90-0-o-1.5-2-8	B	90°	-	A1035	7.9	7.9	5650	6	0.625
4	5-5-90-0-o-2.5-2-5	A B	90°	-	A615	4.8 4.8	4.8	4930	4	0.625
5	5-5-90-0-o-2.5-2-8	A	90°	-	A1035	9.0	9.0	5780	7	0.625
6	5-5-180-0-o-1.5-2-9.5	A B	180°	-	A1035	9.6 9.3	9.4	4420	7	0.625
7	5-5-180-0-o-1.5-2-11.25	A	180°	-	A1035	11.3	11.3	4520	8	0.625
8	5-5-180-0-o-2.5-2-9.5	A B	180°	-	A1035	9.5 9.5	9.5	4520	8	0.625
9	5-5-90-0-i-2.5-2-10	A B	90°	-	A1035	9.4 9.4	9.4	5230	6	0.625
10	5-5-90-0-i-2.5-2-7	A B	90°	-	A1035	6.9 7.0	6.9	5190	7	0.625
11	5-8-90-0-i-2.5-2-6	A B	90°	-	A615	6.8 6.8	6.8	8450	14	0.625
12	5-8-90-0-i-2.5-2-6(1)	A B	90°	-	A1035	6.1 6.5	6.3	9080	11	0.625
13	5-8-90-0-i-2.5-2-8	A B	90°	-	A1035	8.0 7.5	7.8	8580	15	0.625
14	(2@4) 5-8-90-0-i-2.5-2-6	A B	90°	-	A1035	5.8 6.0	5.9	6950	18	0.625
15	(2@6) 5-8-90-0-i-2.5-2-6	A B	90°	-	A1035	6.0 6.0	6.0	6950	18	0.625
16	5-12-90-0-i-2.5-2-10	A B	90°	-	A1035	10.0 11.0	10.5	10290	14	0.625
17	5-12-90-0-i-2.5-2-5	A B	90°	-	A1035	5.1 4.8	4.9	11600	84	0.625
18	5-15-90-0-i-2.5-2-5.5	A B	90°	-	A1035	6.1 5.8	5.9	15800	62	0.625
19	5-15-90-0-i-2.5-2-7.5	A B	90°	-	A1035	7.3 7.3	7.3	15800	62	0.625
20	5-5-90-0-i-3.5-2-10	A B	90°	-	A1035	10.5 10.4	10.4	5190	7	0.625
21	5-5-90-0-i-3.5-2-7	A B	90°	-	A1035	7.5 7.6	7.6	5190	7	0.625
22	5-8-90-0-i-3.5-2-6	A B	90°	-	A615	6.3 6.4	6.3	8580	15	0.625
23	5-8-90-0-i-3.5-2-6(1)	A B	90°	-	A1035	6.5 6.6	6.6	9300	13	0.625
24	5-8-90-0-i-3.5-2-8	A B	90°	-	A1035	8.6 8.5	8.6	8380	13	0.625
25	5-12-90-0-i-3.5-2-5	A B	90°	-	A1035	5.5 5.4	5.4	10410	15	0.625
26	5-12-90-0-i-3.5-2-10	A B	90°	-	A1035	10.1 10.0	10.1	11600	84	0.625

[1]Specimen had full stirrups around the longitudinal bars in the hook region but not around the hooked bars

Table A.1 Cont. Comprehensive test results and data for No. 5 specimens with two hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout[o]
1	A B	0.077	11.3	7.0	5.25	8.375	1.5 1.8	1.6	2.0 2.0	6.8	2	80	A1
2	A B	0.073	11.0	8.6	5.25	8.375	1.5 1.6	1.6	2.0 2.8	6.6	2	80	A4
3	B	0.073	11.9	10.0	5.25	8.375	1.5	1.5	2.1	6.6	2	80	A1
4	A B	0.077	12.6	6.9	5.25	8.375	2.5 2.5	2.5	2.1 2.1	6.4	2	80	A1
5	A	0.073	12.1	10.8	5.25	8.375	2.6	2.6	1.5	6.6	2	80	A1
6	A B	0.077	10.9	11.6	5.25	8.375	1.6 1.6	1.6	2.1 2.1	6.4	2	80	A1
7	A	0.077	11.4	13.3	5.25	8.375	1.8	1.8	2.3	6.6	2	80	A1
8	A B	0.077	12.9	11.3	5.25	8.375	2.5 2.5	2.5	1.9 1.8	6.6	2	80	A4
9	A B	0.073	13.1	12.3	5.25	8.375	2.8 2.6	2.7	2.9 2.9	6.4	2	30	A4
10	A B	0.073	13.0	9.6	5.25	8.375	2.5 2.5	2.5	2.8 2.6	6.8	2	30	A1
11	A B	0.073	13.0	8.0	5.25	8.375	2.8 2.6	2.7	1.3 1.3	6.4	2	80	A1
12	A B	0.073	13.3	8.8	5.25	8.375	2.5 2.5	2.5	2.6 2.3	7.0	2	30	A1
13	A B	0.073	13.1	10.0	5.25	8.375	2.5 2.8	2.6	2.0 2.5	6.6	2	80	A1
14	A B	0.073	9.5	8.0	5.25	8.375	2.7 3.7	3.2	2.3 2.0	1.9	2 2	30	A2
15	A B	0.073	9.6	8.0	5.25	8.375	2.6 2.7	2.6	2.0 2.0	3.1	2 2	30	A2
16	A B	0.073	12.8	12.5	5.25	8.375	2.4 2.5	2.4	2.5 1.5	6.6	2	30	A4
17	A B	0.073	13.0	7.3	5.25	8.375	2.6 2.6	2.6	2.1 2.5	6.5	2	30	A1
18	A B	0.073	12.6	7.7	5.25	8.375	2.4 2.4	2.4	1.6 1.9	6.6	2	30	A1
19	A B	0.073	12.9	9.8	5.25	8.375	2.5 2.5	2.5	2.6 2.6	6.6	2	30	A2
20	A B	0.073	14.8	12.3	5.25	8.375	3.5 3.5	3.5	1.8 1.9	6.5	2	30	A4
21	A B	0.073	15.1	8.8	5.25	8.375	3.4 3.5	3.4	1.3 1.1	7.0	2	30	A1
22	A B	0.073	15.0	8.0	5.38	8.375	3.6 3.5	3.6	1.8 1.6	6.6	2	80	A1
23	A B	0.073	15.6	8.6	5.25	8.375	3.8 3.8	3.8	2.1 1.9	6.9	2	30	A1
24	A B	0.060	15.5	10.0	5.25	8.375	3.6 3.5	3.6	1.4 1.5	7.1	2	80	A1
25	A B	0.073	15.5	7.2	5.25	8.375	3.6 3.6	3.6	1.7 1.8	7.0	2	30	A1
26	A B	0.073	15.0	12.1	5.25	8.375	3.5 3.5	3.5	2.5 1.5	6.8	2	30	A4

[1]Specimen had full stirrups around the longitudinal bars in the hook region but not around the hooked bars

[o] Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.1 Cont. Comprehensive test results and data for No. 5 specimens with two hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type
1	A	14139	14029	28137	14069	45609	45382	40122	-	FP/SB
	B	19575	14108			63147			-	FP/SB
2	A	20758	17440	35627	17813	66962	57463	53261	-	FP
	B	18187	18187			58667			-	FP/SB
3	B	23455	23455	23455	23455	75663	75663	67650	-	SB
4	A	19559	19559	38566	19283	63094	62204	38116	-	FP/SB
	B	23982	19007			77362			-	FP/SB
5	A	30340	30340	30340	30340	97870	97870	78198	-	SB
6	A	35211	28603	58973	29486	113585	95117	71707	-	FP
	B	30370	30370			97968			-	FP/SB
7	A	32374	32374	32374	32374	104432	104432	86440	-	FP/SB
8	A	40406	40351	60255	30128	130342	97186	72994	-	FP
	B	24657	19904			79538			-	FP
9	A	37404	34303	67166	33583	120656	108333	77484	-	FP/SS
	B	32864	32864			106012			-	FP/SS
10	A	26607	26607	52529	26265	85831	84724	57119	-	FP/SS
	B	26095	25922			84176			0.192	FP/SS
11	A	27578	27102	59140	29570	88961	95387	70913	-	FB/SB
	B	32135	32038			103663			-	SB/FB
12	A	21741	21741	44849	22425	70131	72338	68744	0.296	FP
	B	24995	23109			80630			.330(.030)	FP
13	A	31878	31469	63347	31673	102831	102172	82042	-	SS/FP
	B	35934	31878			115915			-	SS/FP
14	A	23217	23089	44706	22353	74893	72106	55975	-	FP
	B	21747	21617			70152			-	FP
15	A	25504	25052	47902	23951	82272	77261	57166	-	FP/SS
	B	24013	22850			77463			-	FP/SS
16	A	40823	40823	83314	41657	131688	134377	121728	0.191	SB
	B	42491	42491			137066			-	FB/SB/TK
17	A	19389	19389	38441	19220	62546	62001	60775	-	FP/SS
	B	23171	19051			74745			-	FP
18	A	36163	32648	65021	32511	116656	104873	85295	-	FP
	B	32373	32373			104430			-	FB
19	A	42470	42464	84441	42221	137001	136196	104150	-	FB
	B	41977	41977			135410			-	*
20	A	43228	43228	83855	41927	139446	135250	85935	-	SB/FP
	B	41140	40626			132710			-	SB/FP
21	A	27197	27197	53033	26516	87732	85537	62265	-	SS
	B	25884	25836			83498			-	FP/SS
22	A	25129	25129	50950	25475	81060	82178	66825	-	FP/SS
	B	29054	25822			93723			-	FP/SS
23	A	24440	24440	49083	24541	78838	79166	72327	0.152	FP/SS
	B	27541	24643			88842			.178(.150)	FP/SS
24	A	39109	31179	65490	32745	126159	105629	89581	-	FB/SS
	B	34311	34311			110679			-	SS
25	A	22045	22040	44241	22121	71114	71357	63404	-	FP
	B	23158	22201			74702			-	FP
26	A	46085	46016	90864	45432	148661	146556	123859	-	BY
	B	46076	44849			148400			-	BY

*Test terminated prior to failure of second hooked bar

[1]Specimen had full stirrups around the longitudinal bars in the hook region but not around the hooked bars

Table A.1 Cont. Comprehensive test results and data for No. 5 specimens with two hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.^{2}	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
1	A B	60	-	-	-	-	0.88	4[1]	2.5	0.375	2.50	-	-	1.27	60
2	A B	60	-	-	-	-	0.88	4[1]	2.5	0.375	2.50	-	-	1.89	60
3	B	60	-	-	-	-	0.88	4[1]	2.5	0.375	2.50	-	-	1.27	60
4	A B	60	-	-	-	-	0.88	4[1]	2.5	0.375	2.50	-	-	1.27	60
5	A	60	-	-	-	-	0.88	4[1]	2.5	0.375	2.50	-	-	1.27	60
6	A B	60	-	-	-	-	0.22	1[1]	4.0	0.375	4.00	-	-	1.27	60
7	A	60	-	-	-	-	0.22	1[1]	4.0	0.375	4.0	-	-	1.27	60
8	A B	60	-	-	-	-	0.22	1[1]	4.0	0.375	4.00	-	-	1.89	60
9	A B	60	-	-	-	-	0.33	3	3.0	0.375	3.00	-	-	1.89	60
10	A B	60	-	-	-	-	0.80	4	2.5	0.500	3.50	-	-	1.27	60
11	A B	60	-	-	-	-	0.80	4	4.0	0.500	4.00	-	-	1.27	60
12	A B	60	-	-	-	-	0.66	6	3.0	0.500	3.00	-	-	1.27	60
13	A B	60	-	-	-	-	0.80	4	4.0	0.500	4.00	-	-	1.27	60
14	A B	60	-	-	-	-	-	-	-	0.375	3.00	-	-	3.16	60
15	A B	60	-	-	-	-	-	-	-	0.375	3.00	-	-	3.16	60
16	A B	60	-	-	-	-	0.11	1	7.0	0.375	5.00	-	-	1.89	60
17	A B	60	-	-	-	-	0.66	6	2.5	0.500	3.00	-	-	1.27	60
18	A B	60	-	-	-	-	-	-	-	0.375	2.50	-	-	1.27	60
19	A B	60	-	-	-	-	-	-	-	0.375	3.50	-	-	3.16	60
20	A B	60	-	-	-	-	0.33	3	3.0	0.375	3.00	-	-	1.89	60
21	A B	60	-	-	-	-	0.80	4	2.5	0.375	3.50	-	-	1.27	60
22	A B	60	-	-	-	-	0.80	4	4.0	0.500	4.00	-	-	1.27	60
23	A B	60	-	-	-	-	0.66	6	3.0	0.500	3.00	-	-	1.27	60
24	A B	60	-	-	-	-	0.80	4	4.0	0.500	4.00	-	-	1.27	60
25	A B	60	-	-	-	-	0.66	6	2.5	0.500	3.00	-	-	1.27	60
26	A B	60	-	-	-	-	0.11	1	7.0	0.375	5.00	-	-	1.89	60

[1]Specimen had full stirrups around the longitudinal bars in the hook region but not around the hooked bars

Table A.1 Cont. Comprehensive test results and data for No. 5 specimens with two hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
27	5-8-180-0-i-2.5-2-7	A B	180°	-	A1035	7.4 7.1	7.3	9080	11	0.625
28	5-8-180-0-i-3.5-2-7	A B	180°	-	A1035	7.4 7.3	7.3	9080	11	0.625
29	5-5-90-1#3-i-2.5-2-8	A B	90°	Para	A1035	8.0 7.6	7.8	5310	6	0.625
30	5-5-90-1#3-i-2.5-2-6	A B	90°	Para	A615	4.8 5.5	5.1	5800	9	0.625
31	5-8-90-1#3-i-2.5-2-6	A B	90°	Para	A615	6.0 6.3	6.1	8450	14	0.625
32	5-8-90-1#3-i-2.5-2-6(1)	A B	90°	Para	A1035	6.1 5.6	5.9	9300	13	0.625
33	5-8-90-1#3-i-3.5-2-6	A B	90°	Para	A1035	6.0 6.0	6.0	8710	16	0.625
34	5-8-90-1#3-i-3.5-2-6(1)	A B	90°	Para	A1035	6.3 6.3	6.3	9190	12	0.625
35	5-5-180-1#3-i-2.5-2-8	A B	180°	Para	A1035	8.0 7.8	7.9	5670	7	0.625
36	5-5-180-1#3-i-2.5-2-6	A B	180°	Para	A615	6.0 6.0	6.0	5800	9	0.625
37	5-8-180-1#3-i-2.5-2-7	A B	180°	Para	A1035	7.1 7.3	7.2	9300	13	0.625
38	5-8-180-1#3-i-3.5-2-7	A B	180°	Para	A1035	7.1 6.8	6.9	9190	12	0.625
39	5-5-90-1#4-i-2.5-2-8	A B	90°	Para	A1035	7.4 7.8	7.6	5310	6	0.625
40	5-5-90-1#4-i-2.5-2-6	A B	90°	Para	A615	5.3 5.8	5.5	5860	8	0.625
41	5-8-90-1#4-i-2.5-2-6	A B	90°	Para	A1035	5.9 6.0	6.0	9300	13	0.625
42	5-8-90-1#4-i-3.5-2-6	A B	90°	Para	A1035	6.0 7.0	6.5	9190	12	0.625
43	5-5-180-1#4-i-2.5-2-8	A B	180°	Para	A1035	8.0 8.0	8.0	5310	6	0.625
44	5-5-180-1#4-i-2.5-2-6	A B	180°	Para	A615	6.5 6.0	6.3	5670	7	0.625
45	5-5-180-2#3-o-1.5-2-11.25	A B	180°	Para	A1035	11.6 11.5	11.6	4420	7	0.625
46	5-5-180-2#3-o-1.5-2-9.5	B	180°	Para	A1035	8.8	8.8	4520	8	0.625
47	5-5-180-2#3-o-2.5-2-9.5	A B	180°	Para	A1035	9.1 9.3	9.2	4420	7	0.625
48	5-5-180-2#3-o-2.5-2-11.25	A B	180°	Para	A1035	11.1 11.4	11.3	4520	8	0.625
49	5-5-90-2#3-i-2.5-2-8	A B	90°	Para	A1035	8.0 7.5	7.8	5860	8	0.625
50	5-5-90-2#3-i-2.5-2-6	A B	90°	Para	A615	6.0 5.8	5.9	5800	9	0.625
51	5-8-90-2#3-i-2.5-2-6	A B	90°	Para	A1035	6.0 6.0	6.0	8580	15	0.625
52	5-8-90-2#3-i-2.5-2-8	A B	90°	Para	A1035	8.3 8.5	8.4	8380	13	0.625

[1]Specimen had full stirrups around the longitudinal bars in the hook region but not around the hooked bars

Table A.1 Cont. Comprehensive test results and data for No. 5 specimens with two hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout°
27	A B	0.073	12.6	9.5	5.25	8.375	2.5 2.6	2.6	2.1 2.4	6.3	2	30	A1
28	A B	0.073	15.4	9.3	5.25	8.375	3.6 3.4	3.5	1.9 2.0	7.1	2	30	A1
29	A B	0.073	13.1	10.4	5.25	8.375	2.5 2.5	2.5	2.4 2.8	6.9	2	80	A1
30	A B	0.060	13.1	8.0	5.25	8.375	2.5 2.5	2.5	3.3 2.5	6.9	2	80	A1
31	A B	0.060	12.9	8.0	5.25	8.375	2.5 2.5	2.5	2.0 1.8	6.6	2	80	A1
32	A B	0.073	13.1	8.3	5.25	8.375	2.6 2.8	2.7	2.1 2.6	6.5	2	30	A1
33	A B	0.060	15.3	8.0	5.25	8.375	3.6 3.6	3.6	2.0 2.0	6.8	2	80	A1
34	A B	0.073	15.3	8.6	5.25	8.375	3.8 3.5	3.6	2.4 2.4	6.8	2	30	A1
35	A B	0.073	13.0	10.3	5.25	8.375	2.6 2.5	2.6	2.3 2.5	6.6	2	80	A1
36	A B	0.060	13.1	8.0	5.25	8.375	2.6 2.6	2.6	2.0 2.0	6.6	2	80	A1
37	A B	0.073	12.8	9.5	5.25	8.375	2.5 2.5	2.5	2.4 2.3	6.5	2	30	A1
38	A B	0.073	15.3	9.3	5.25	8.375	3.5 3.5	3.5	2.1 2.5	7.0	2	30	A1
39	A B	0.073	13.1	10.1	9.25	8.375	2.5 2.5	2.5	2.8 2.4	6.9	2	80	A1
40	A B	0.060	12.9	8.0	5.25	8.375	2.5 2.5	2.5	2.8 2.3	6.6	2	80	A1
41	A B	0.073	12.9	8.8	5.25	8.375	2.5 2.8	2.6	2.8 2.8	6.4	2	30	A1
42	A B	0.073	15.1	9.0	5.25	8.375	3.6 3.5	3.6	3.0 2.0	6.8	2	30	A1
43	A B	0.073	12.9	10.0	5.25	8.375	2.5 2.5	2.5	2.0 2.0	6.6	2	80	A1
44	A B	0.060	13.0	8.5	5.25	8.375	2.5 2.6	2.6	2.0 2.5	6.6	2	80	A1
45	A B	0.077	11.0	13.4	5.25	8.375	1.6 1.5	1.6	1.9 1.9	6.6	2	80	A4
46	B	0.08	12.0	11.0	5.25	8.375	1.6	1.6	2.4	6.6	2	80	A1
47	A B	0.077	12.9	11.3	5.25	8.375	2.5 2.5	2.5	2.1 2.0	6.6	2	80	A4
48	A B	0.077	13.1	13.6	5.25	8.375	2.5 2.8	2.6	2.5 2.1	6.6	2	80	A4
49	A B	0.073	12.9	10.0	5.38	8.375	2.5 2.5	2.5	2.0 2.5	6.6	2	80	A1
50	A B	0.060	13.1	8.5	5.25	8.375	2.6 2.6	2.6	2.5 2.8	6.6	2	80	A1
51	A B	0.073	13.0	8.0	5.25	8.375	2.8 2.9	2.8	2.0 2.0	6.1	2	80	A1
52	A B	0.073	12.9	10.0	5.25	8.375	2.6 2.5	2.6	1.8 1.5	6.5	2	80	A5

[1]Specimen had full stirrups around the longitudinal bars in the hook region but not around the hooked bars

° Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.1 Cont. Comprehensive test results and data for No. 5 specimens with two hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{su,ACI}$ psi	Slip at Failure in.	Failure Type
27	A B	26722 35215	26722 27495	54217	27108	86199 113596	87446	78954	0.194 .146(.016)	FP/SS SB/FP
28	A B	34057 31441	30094 31414	61508	30754	109860 101422	99206	79634	0.251 .237(.021)	SS/FP FP/SS
29	A B	32860 37440	32628 33645	66273	33136	106001 120776	106892	65062	- -	FP SB/FB
30	A B	20038 29285	19968 19863	39830	19915	64639 94469	64242	44607	- -	SS SS/FP
31	A B	26203 27858	26172 26974	53146	26573	84524 89865	85719	64347	- -	FP SS
32	A B	29328 25430	29328 25430	54758	27379	94606 82032	88319	64750	- -	FP/SS FP/SS
33	A B	41369 31173	28996 31173	60169	30084	133448 100558	97046	63996	- -	FP/SS FP/SS
34	A B	28967 26270	25617 26194	51811	25905	93441 84741	83565	68475	0.239 0.158	FP/SS FP/SS
35	A B	36570 39949	36332 36565	72896	36448	117967 128867	117575	67769	- -	SS SS/FP
36	A B	29091 24285	23661 24171	47832	23916	93843 78338	77148	52222	- -	SS/FP FP/SS
37	A B	34198 35367	34198 31621	65819	32909	110316 114087	106159	79216	0.373 .261(.035)	FP/SS FP/SS
38	A B	35824 28925	35733 25266	60999	30500	115563 93305	98386	76007	0.205 0.238	FP FP
39	A B	35739 27537	27537 27537	55074	27537	115288 88829	88829	62980	- -	FP/SS SB
40	A B	21633 26769	21535 21379	42914	21457	69782 86352	69217	48118	- -	SS SS
41	A B	23854 27932	23854 24731	48585	24292	76947 90103	78363	65783	0.25 0.22	FP FP/SS
42	A B	25266 25221	25261 25221	50482	25241	81504 81359	81423	71214	- -	FP/SS FP/SS
43	A B	43142 38421	38421 38421	76842	38421	139167 123938	123938	66624	- -	FP/SS FP
44	A B	25321 22912	23275 22679	45954	22977	81681 73909	74119	53785	- -	FP/SS FP
45	A B	48319 43017	43085 43017	86101	43051	155868 138764	138873	87853	- -	FP/SB FP/SB
46	B	20282	20282	20282	20282	65426	65426	67231	-	FP/SB
47	A B	35466 43930	35466 43930	79396	39698	114406 141710	128058	69807	- -	FP/SB FP
48	A B	43621 42484	42165 42484	84648	42324	140714 137044	136530	86440	- -	FP FP/SB
49	A B	37932 38949	37807 36500	74307	37154	122360 125642	119850	67802	- -	SS/FP SS/FP
50	A B	31846 29191	29697 29191	58888	29444	102730 94164	94980	51134	- -	FP/SS FP/SS
51	A B	33454 30874	30402 30874	61277	30638	107916 99595	98833	63517	- -	FP/SS FP/SS
52	A B	39822 40545	39791 40545	80336	40168	128457 130600	129574	87619	- -	FP/SS FP/SS

[1]Specimen had full stirrups around the longitudinal bars in the hook region but not around the hooked bars

Table A.1 Cont. Comprehensive test results and data for No. 5 specimens with two hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.^{2}	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
27	A B	60	-	-	-	-	0.22	2	4.0	0.500	3.00	-	-	1.27	60
28	A B	60	-	-	-	-	0.22	2	4.0	0.500	3.00	-	-	1.27	60
29	A B	60	0.38	0.11	1	5.00	0.44	4	6.0	0.375	4.00	-	-	1.27	60
30	A B	60	0.38	0.11	1	5.00	0.44	4	6.0	0.375	4.00	-	-	1.27	60
31	A B	60	0.38	0.11	1	5.00	0.80	4	6.0	0.500	4.00	-	-	1.27	60
32	A B	60	0.38	0.11	1	6.00	0.66	6	3.0	0.500	3.00	-	-	1.27	60
33	A B	60	0.38	0.11	1	5.00	0.80	4	6.0	0.500	4.00	-	-	1.27	60
34	A B	60	0.38	0.11	1	6.00	0.66	6	3.0	0.500	3.00	-	-	1.27	60
35	A B	60	0.38	0.11	1	4.00	-	-	-	0.375	4.00	-	-	1.27	60
36	A B	60	0.38	0.11	1	4.00	-	-	-	0.375	4.00	-	-	1.27	60
37	A B	60	0.38	0.11	1	3.00	-	-	-	0.375	3.00	-	-	1.27	60
38	A B	60	0.38	0.11	1	3.00	-	-	-	0.375	3.00	-	-	1.27	60
39	A B	60	0.5	0.20	1	5.00	0.44	4	6.0	0.375	4.00	-	-	1.27	60
40	A B	60	0.5	0.20	1	5.00	0.44	4	6.0	0.375	4.00	-	-	1.27	60
41	A B	60	0.5	0.20	1	6.00	0.44	4	6.0	0.500	3.00	-	-	1.27	60
42	A B	60	0.5	0.20	1	6.00	0.44	4	6.0	0.500	3.00	-	-	1.27	60
43	A B	60	0.5	0.20	1	4.00	-	-	-	0.375	4.00	-	-	1.27	60
44	A B	60	0.5	0.20	1	4.00	-	-	-	0.375	4.00	-	-	1.27	60
45	A B	60	0.38	0.11	2	2.00	-	-	-	0.375	4.00	-	-	1.89	60
46	B	60	0.375	0.11	2	2.0	-	-	-	0.375	4.0	-	-	1.27	60
47	A B	60	0.38	0.11	2	2.00	-	-	-	0.375	4.00	-	-	1.89	60
48	A B	60	0.38	0.11	2	2.00	-	-	-	0.375	4.50	-	-	1.89	60
49	A B	60	0.38	0.11	2	4.00	-	-	-	0.375	4.00	-	-	1.27	60
50	A B	60	0.38	0.11	2	4.00	-	-	-	0.375	4.00	-	-	1.27	60
51	A B	60	0.38	0.11	2	4.00	-	-	-	0.500	4.00	-	-	1.27	60
52	A B	60	0.38	0.11	2	4.00	-	-	-	0.500	4.00	-	-	1.67	60

[1]Specimen had full stirrups around the longitudinal bars in the hook region but not around the hooked bars

Table A.1 Cont. Comprehensive test results and data for No. 5 specimens with two hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
53	5-12-90-2#3-i-2.5-2-5	A B	90°	Para	A1035	5.8 5.8	5.8	11090	83	0.625
54	5-15-90-2#3-i-2.5-2-6	A B	90°	Para	A1035	6.3 6.5	6.4	15800	61	0.625
55	5-15-90-2#3-i-2.5-2-4	A B	90°	Para	A1035	3.5 4.0	3.8	15800	61	0.625
56	5-5-90-2#3-i-3.5-2-6	A B	90°	Para	A1035	6.0 5.8	5.9	5230	6	0.625
57	5-5-90-2#3-i-3.5-2-8	A B	90°	Para	A1035	7.9 7.5	7.7	5190	7	0.625
58	5-8-90-2#3-i-3.5-2-6	A B	90°	Para	A1035	6.5 6.0	6.3	8580	15	0.625
59	5-8-90-2#3-i-3.5-2-8	A B	90°	Para	A1035	7.1 7.0	7.1	8710	16	0.625
60	5-12-90-2#3-i-3.5-2-5	A B	90°	Para	A1035	5.6 5.3	5.4	10410	15	0.625
61	5-12-90-2#3-i-3.5-2-10	A B	90°	Para	A1035	10.8 10.6	10.7	11090	83	0.625
62	5-5-180-2#3-i-2.5-2-8	A B	180°	Para	A1035	8.0 8.0	8.0	5670	7	0.625
63	5-5-180-2#3-i-2.5-2-6	A B	180°	Para	A615	5.8 5.5	5.6	5860	8	0.625
64	5-8-180-2#3-i-2.5-2-7	A B	180°	Para	A1035	7.0 7.3	7.1	9080	11	0.625
65	5-8-180-2#3-i-3.5-2-7	A B	180°	Para	A1035	6.8 6.9	6.8	9080	11	0.625
66	5-8-90-4#3-i-2.5-2-8	A B	90°	Para	A1035	7.9 7.5	7.7	8380	13	0.625
67	5-8-90-4#3-i-3.5-2-8	A B	90°	Para	A1035	8.6 8.3	8.4	8380	13	0.625
68	5-5-90-5#3-o-1.5-2-5	B	90°	Para	A615	5.0	5.0	5205	5	0.625
69	5-5-90-5#3-o-1.5-2-8	A B	90°	Para	A1035	8.0 7.8	7.9	5650	6	0.625
70	5-5-90-5#3-o-1.5-2-6.5	A B	90°	Para	A1035	6.5 6.5	6.5	5780	7	0.625
71	5-5-90-5#3-o-2.5-2-5	A B	90°	Para	A615	5.2 5.1	5.2	4903	4	0.625
72	5-5-90-5#3-o-2.5-2-8	A	90°	Para	A1035	7.5	7.5	5650	6	0.625
73	5-5-90-5#3-i-2.5-2-7	A B	90°	Para	A1035	5.6 7.0	6.3	5230	6	0.625
74	5-12-90-5#3-i-2.5-2-5	A B	90°	Para	A1035	5.1 5.8	5.4	10410	15	0.625
75	5-15-90-5#3-i-2.5-2-4	A B	90°	Para	A1035	3.8 4.1	4.0	15800	62	0.625
76	5-15-90-5#3-i-2.5-2-5	A B	90°	Para	A1035	5.0 5.1	5.1	15800	62	0.625
77	5-5-90-5#3-i-3.5-2-7	A B	90°	Para	A1035	7.5 6.8	7.1	5190	7	0.625
78	5-12-90-5#3-i-3.5-2-5	A B	90°	Para	A1035	5.3 4.8	5.0	11090	83	0.625
79	5-12-90-5#3-i-3.5-2-10	A B	90°	Para	A1035	11.0 11.3	11.1	11090	83	0.625

[1]Specimen had full stirrups around the longitudinal bars in the hook region but not around the hooked bars

Table A.1 Cont. Comprehensive test results and data for No. 5 specimens with two hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout°
53	A B	0.073	13.0	8.8	5.25	8.375	2.5 2.8	2.6	3.0 3.0	6.5	2	30	A1
54	A B	0.073	12.6	8.2	5.25	8.375	2.4 2.4	2.4	1.9 1.7	6.6	2	30	A2
55	A B	0.073	13.0	6.1	5.25	8.375	2.5 2.5	2.5	2.6 2.1	6.8	2	30	A9
56	A B	0.073	14.5	8.3	5.25	8.375	3.4 3.4	3.4	2.3 2.5	6.5	2	30	A1
57	A B	0.073	14.9	10.3	5.25	8.375	3.4 3.5	3.4	2.3 2.8	6.8	2	30	A1
58	A B	0.073	14.9	8.0	5.25	8.375	3.5 3.8	3.6	1.5 2.0	6.4	2	80	A1
59	A B	0.060	14.9	10.0	5.25	8.375	3.5 3.5	3.5	2.9 3.0	6.6	2	80	A5
60	A B	0.073	15.1	7.4	5.25	8.375	3.8 3.5	3.6	1.8 2.2	6.6	2	30	A1
61	A B	0.073	15.1	13.0	5.25	8.375	3.5 3.6	3.6	2.3 2.4	6.8	2	30	A4
62	A B	0.073	13.1	10.0	5.25	8.375	2.5 2.5	2.5	2.0 2.0	6.9	2	80	A1
63	A B	0.060	13.1	7.8	5.25	8.375	2.6 2.6	2.6	2.0 2.3	6.6	2	80	A1
64	A B	0.073	12.6	9.3	5.25	8.375	2.5 2.5	2.5	2.3 2.1	6.4	2	30	A1
65	A B	0.073	15.1	9.2	5.25	8.375	3.4 3.5	3.4	2.4 2.3	7.0	2	30	A1
66	A B	0.060	12.6	10.0	5.25	8.375	2.5 2.5	2.5	2.1 2.5	6.4	2	80	A5
67	A B	0.060	15.1	10.0	5.25	8.375	3.5 3.5	3.5	1.4 1.8	6.9	2	80	A5
68	B	0.077	10.8	7.1	5.25	8.375	1.5	1.5	2.0	6.5	2	80	A1
69	A B	0.077	10.7	10.3	5.25	8.375	1.6 1.5	1.5	2.3 2.6	6.4	2	80	A1
70	A B	0.073	10.9	8.5	5.25	8.375	1.6 1.6	1.6	2.0 2.0	6.5	2	80	A4
71	A B	0.077	13.1	7.0	5.38	8.375	2.6 2.6	2.6	1.9 1.9	6.6	2	80	A1
72	A	0.077	13.1	10.4	5.25	8.375	2.6	2.6	2.1	6.5	2	80	A1
73	A B	0.073	13.3	9.3	5.25	8.375	2.8 2.8	2.8	3.6 2.3	6.5	2	30	A1
74	A B	0.073	13.0	7.3	5.25	8.375	2.6 2.6	2.6	2.1 1.5	6.5	2	30	A1
75	A B	0.073	12.8	6.0	5.25	8.375	2.4 2.5	2.4	2.2 1.9	6.6	2	30	A9
76	A B	0.073	12.8	7.1	5.25	8.375	2.4 2.3	2.4	2.1 1.9	6.8	2	30	A2
77	A B	0.073	15.1	9.5	5.25	8.375	3.4 3.5	3.4	2.0 2.8	7.0	2	30	A1
78	A B	0.073	14.4	7.0	5.25	8.375	3.3 3.3	3.3	2.5 1.5	6.6	2	30	A1
79	A B	0.073	15.1	13.0	5.25	8.375	3.5 3.5	3.5	2.0 1.8	6.9	2	30	A4

[1]Specimen had full stirrups around the longitudinal bars in the hook region but not around the hooked bars
° Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.1 Cont. Comprehensive test results and data for No. 5 specimens with two hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{su,ACI}$ psi	Slip at Failure in.	Failure Type
53	A	25201	25120	48696	24348	81295	78542	69203	-	FP/SS
	B	29393	23576			94816			-	FP
54	A	42381	42381	85276	42638	136714	137542	91580	-	FP
	B	42895	42895			138371			-	FB
55	A	18652	18652	37334	18667	60167	60217	53871	-	FB
	B	21256	18683			68569			-	FP
56	A	21341	21146	42186	21093	68842	68042	48557	0.183	SS/FP
	B	21262	21040			68586			-	SS/FP
57	A	43675	43675	89329	44665	140887	144079	63551	-	FP
	B	45654	45654			147271			-	FP
58	A	29930	29930	60069	30035	96549	96886	66163	-	FP
	B	30139	30139			97223			-	FP/SS
59	A	38022	28716	57312	28656	122652	92439	75329	-	FP
	B	28596	28596			92246			-	FP
60	A	27860	27860	56728	28364	89871	91497	63404	-	FP
	B	28869	28869			93124			0.349	FP
61	A	46561	44490	90490	45245	150197	145952	128628	-	BY
	B	46006	46001			148406			-	BY
62	A	34036	33674	68157	34078	109795	109930	68845	-	FP/SS
	B	34483	34483			111236			-	FP/SS
63	A	26852	26782	53456	26728	86620	86220	49211	-	FP/SS
	B	26912	26674			86814			-	FP
64	A	34580	29762	58459	29230	111548	94289	77592	-	FP/SS
	B	28697	28697			92572			.369(.081)	FP/SS
65	A	29310	29285	61862	30931	94550	99777	74189	-	FP/SS
	B	32577	32577			105086			.329(.028)	FP
66	A	33367	25867	52823	26411	107636	85198	80426	-	FP/SS
	B	27016	26955			87150			-	FP/SS
67	A	42471	37810	76960	38480	137003	124130	88273	-	FP
	B	39278	39150			126704			-	SS/FP
68	B	22060	22060	22060	22060	71000	71000	51500	-	FP/SB
69	A	25173	25173	50221	25110	81202	81002	84562	-	FP/SB
	B	30446	25048			98211			-	FP/SB
70	A	26229	22736	43422	21711	84610	70035	70596	-	FP/SB
	B	20940	20686			67550			-	FP/SB
71	A	22279	22230	45058	22529	71868	72675	51578	-	FP/SB
	B	29466	22829			95050			-	FP/SB
72	A	28429	28429	28429	28429	91706	91706	80536	-	FP
73	A	32080	32080	63393	31696	103484	102246	65216	-	FP
	B	31340	31313			101095			-	FP/SS
74	A	33923	33923	68839	34420	109428	111031	79255	0.292	FP/SS
	B	34916	34916			112634			0.295	SS/FP
75	A	31312	31312	62637	31318	101006	101027	71266	0.603	FP
	B	31325	31325			101048			0.378	FP
76	A	38574	38574	78312	39156	124434	126309	90907	-	FP
	B	46165	39737			148921			-	BY
77	A	44301	36844	72050	36025	142906	116210	73328	-	FP
	B	35206	35206			113568			-	FP
78	A	31472	31396	60882	30441	101522	98196	75221	-	FP
	B	31302	29485			100973			-	FP
79	A	46464	46464	92102	46051	149882	148551	167366	-	BY
	B	45703	45638			148400			-	BY

[1]Specimen had full stirrups around the longitudinal bars in the hook region but not around the hooked bars

Table A.1 Cont. Comprehensive test results and data for No. 5 specimens with two hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.^{2}	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
53	A B	60	0.38	0.11	2	3.30	0.33	3	3.3	0.500	3.00	-	-	1.27	60
54	A B	60	0.38	0.11	2	3.00	-	-	-	0.375	2.75	-	-	3.16	60
55	A B	60	0.38	0.11	2	3.00	-	-	-	0.375	1.75	-	-	2.51	60
56	A B	60	0.38	0.11	2	3.50	0.11	1	3.5	0.375	3.50	-	-	1.27	60
57	A B	60	0.38	0.11	2	3.50	-	-	-	0.375	4.00	-	-	1.27	60
58	A B	60	0.38	0.11	2	4.00	-	-	-	0.500	4.00	-	-	1.27	60
59	A B	60	0.38	0.11	2	4.00	-	-	-	0.500	4.00	-	-	1.67	60
60	A B	60	0.38	0.11	2	3.33	0.33	3	3.3	0.500	3.00	-	-	1.27	60
61	A B	60	0.38	0.11	2	3.30	-	-	-	0.375	5.00	-	-	1.89	60
62	A B	60	0.38	0.11	2	2.50	-	-	-	0.375	4.00	-	-	1.27	60
63	A B	60	0.38	0.11	2	2.50	-	-	-	0.375	4.00	-	-	1.27	60
64	A B	60	0.38	0.11	2	2.00	-	-	-	0.375	3.00	-	-	1.27	60
65	A B	60	0.38	0.11	2	2.00	-	-	-	0.375	3.00	-	-	1.27	60
66	A B	60	0.38	0.11	4	2.00	-	-	-	0.500	4.00	-	-	1.67	60
67	A B	60	0.38	0.11	4	2.00	-	-	-	0.500	4.00	-	-	1.67	60
68	B	60	0.375	0.11	5	2.00	-	-	-	0.375	2.50	-	-	1.27	60
69	A B	60	0.38	0.11	5	2.50	-	-	-	0.375	2.50	-	-	1.27	60
70	A B	60	0.38	0.11	5	2.50	-	-	-	0.375	2.50	-	-	1.89	60
71	A B	60	0.38	0.11	5	2.00	-	-	-	0.375	2.50	-	-	1.27	60
72	A	60	0.375	0.11	5	2.50	-	-	-	0.375	2.50	-	-	1.27	60
73	A B	60	0.38	0.11	5	1.75	-	-	-	0.500	3.50	-	-	1.27	60
74	A B	60	0.38	0.11	5	1.67	-	-	-	0.500	3.00	-	-	1.27	60
75	A B	60	0.38	0.11	5	1.75	-	-	-	0.375	1.75	-	-	2.51	60
76	A B	60	0.38	0.11	5	1.75	-	-	-	0.375	2.25	-	-	3.16	60
77	A B	60	0.38	0.11	5	1.75	-	-	-	0.500	3.50	-	-	1.27	60
78	A B	60	0.38	0.11	5	1.70	-	-	-	0.500	3.00	-	-	1.27	60
79	A B	60	0.38	0.11	5	1.70	-	-	-	0.375	5.00	-	-	1.89	60

[1]Specimen had full stirrups around the longitudinal bars in the hook region but not around the hooked bars

Table A.1 Comprehensive test results and data for No. 8 specimens with two hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
80	8-5-90-0-o-2.5-2-10a	A B	90°	-	A1035[a]	10.3 10.5	10.4	5270	7	1
81	8-5-90-0-o-2.5-2-10b	A B	90°	-	A1035[a]	9.3 10.3	9.8	5440	8	1
82	8-5-90-0-o-2.5-2-10c	A B	90°	-	A1035[a]	10.8 10.5	10.6	5650	9	1
83	8-8-90-0-o-2.5-2-8	A B	90°	-	A1035[b]	8.6 8.3	8.4	8740	12	1
84	8-8-90-0-o-3.5-2-8	A B	90°	-	A1035[b]	7.6 8.0	7.8	8810	14	1
85	8-8-90-0-o-4-2-8	A B	90°	-	A1035[b]	8.1 8.3	8.2	8630	11	1
86	8-5-90-0-i-2.5-2-16	A B	90°	-	A1035[b]	16.0 16.8	16.4	4980	7	1
87	8-5-90-0-i-2.5-2-9.5	A B	90°	-	A615	9.0 10.3	9.6	5140	8	1
88	8-5-90-0-i-2.5-2-12.5	A B	90°	-	A615	13.3 13.3	13.3	5240	9	1
89	8-5-90-0-i-2.5-2-18	A B	90°	-	A1035[b]	19.5 17.9	18.7	5380	11	1
90	8-5-90-0-i-2.5-2-13	A B	90°	-	A1035[b]	13.3 13.5	13.4	5560	11	1
91	8-5-90-0-i-2.5-2-15(1)	A B	90°	-	A1035[b]	14.5 15.3	14.9	5910	14	1
92	8-5-90-0-i-2.5-2-15	A B	90°	-	A1035[b]	15.3 14.4	14.8	6210	8	1
93	(2@3) 8-5-90-0-i-2.5-2-10[‡]	A B	90°	-	A615	10.4 10.6	10.5	4490	10	1
94	(2@5) 8-5-90-0-i-2.5-2-10[‡]	A B	90°	-	A615	10.1 10.1	10.1	4490	10	1
95	8-8-90-0-i-2.5-2-8	A B	90°	-	A1035[b]	8.9 8.0	8.4	7910	15	1
96	8-8-90-0-i-2.5-2-10	A B	90°	-	A1035[b]	9.8 9.5	9.6	7700	14	1
97	8-8-90-0-i-2.5-2-8(1)	A B	90°	-	A1035[b]	8.0 8.0	8.0	8780	13	1
98	8-8-90-0-i-2.5sc-2tc-9[‡]	A B	90°	-	A615	9.5 9.5	9.5	7710	25	1
99	8-8-90-0-i-2.5sc-9tc-9	A B	90°	-	A615	9.3 9.0	9.1	7710	25	1
100	(2@3) 8-8-90-0-i-2.5-9-9	A B	90°	-	A615	9.3 9.0	9.1	7510	21	1
101	(2@4) 8-8-90-0-i-2.5-9-9	A B	90°	-	A615	9.9 10.0	9.9	7510	21	1
102	8-12-90-0-i-2.5-2-9	A B	90°	-	A1035[b]	9.0 9.0	9.0	11160	77	1
103	8-12-90-0-i-2.5-2-12.5	A B	90°	-	A1035[c]	12.9 12.8	12.8	11850	39	1
104	8-12-90-0-i-2.5-2-12	A B	90°	-	A1035[c]	12.1 12.1	12.1	11760	34	1
105	8-15-90-0-i-2.5-2-8.5	A B	90°	-	A1035[c]	8.8 8.9	8.8	15800	61	1

[‡] Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout[o]
80	A B	0.084	17.1	12.3	10.5	8.375	2.5 2.6	2.6	2.0 1.8	10.0	2	80	A2
81	A B	0.084	17.0	12.5	10.5	8.375	2.5 2.5	2.5	3.3 2.3	10.0	2	80	A2
82	A B	0.084	17.0	12.3	10.5	8.375	2.5 2.5	2.5	1.5 1.8	10.0	2	80	A2
83	A B	0.078	16.3	10.4	10.5	8.375	2.8 2.5	2.6	1.8 2.1	9.0	2	30	A2
84	A B	0.078	18.9	10.0	10.5	8.375	3.5 3.6	3.6	2.4 2.0	9.8	2	30	A2
85	A B	0.078	20.0	10.6	10.5	8.375	4.5 3.8	4.1	2.5 2.4	9.8	2	30	A2
86	A B	0.078	17.0	17.9	10.5	8.375	2.8 2.8	2.8	1.8 1.4	9.5	2	80	A2
87	A B	0.078	16.8	12.0	10.5	8.375	2.8 2.5	2.6	3.0 1.8	9.5	2	80	A2
88	A B	0.078	17.3	14.5	10.5	8.375	2.8 2.8	2.8	1.3 1.3	9.8	2	80	A2
89	A B	0.078	17.5	20.3	10.5	8.375	2.5 2.5	2.5	0.8 2.4	10.5	2	30	A6
90	A B	0.078	16.8	15.3	10.5	8.375	2.5 2.5	2.5	2.0 1.8	9.8	2	30	A2
91	A B	0.073	16.7	17.3	10.5	8.375	2.5 2.6	2.5	2.8 2.0	9.6	2	30	A2
92	A B	0.073	16.6	17.3	10.5	8.375	2.5 2.6	2.6	2.0 2.9	9.5	2	30	A2
93	A B	0.073	9.0	12.0	10.5	8.375	2.5 2.5	2.5	1.6 1.4	2.0	2	30	A2
94	A B	0.073	10.9	12.0	10.5	8.375	2.5 2.3	2.4	1.9 1.9	4.1	2	30	A2
95	A B	0.078	16.3	10.0	10.5	8.375	2.8 2.9	2.8	1.1 2.0	8.6	2	30	A2
96	A B	0.078	16.6	12.0	10.5	8.375	2.8 2.9	2.8	2.3 2.5	9.0	2	30	A2
97	A B	0.078	17.0	10.8	10.5	8.375	2.8 2.8	2.8	2.8 2.8	9.5	2	30	A2
98	A B	0.073	17.3	11.0	10.5	8.375	2.5 2.8	2.6	1.5 1.5	10.0	2	30	A2
99	A B	0.073	17.5	18.0	10.5	8.375	2.8 2.8	2.8	8.8 9.0	10.0	2	30	A7
100	A B	0.073	9.1	18.0	10.5	8.375	2.5 2.6	2.6	8.8 9.0	2.0	2	30	A7
101	A B	0.073	10.2	18.0	10.5	8.375	2.6 2.5	2.5	8.1 8.0	3.1	2	30	A7
102	A B	0.078	17.0	11.4	10.5	8.375	2.8 2.6	2.7	2.4 2.4	9.6	2	30	A2
103	A B	0.073	17.4	14.6	10.5	8.375	2.6 2.6	2.6	1.7 1.8	10.1	2	30	A2
104	A B	0.073	16.8	14.0	10.5	8.375	2.5 2.4	2.5	1.9 1.9	9.8	2	30	A2
105	A B	0.073	17.0	10.8	10.5	8.375	2.5 2.5	2.5	2.0 1.9	10.0	2	30	A6

[‡] Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3
[o] Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type
80	A	40645	38970	84628	42314	51449	53562	53798	-	FP/SS
	B	46612	45658			59003			0.186	SS/FP
81	A	47870	38190	67302	33651	60596	42596	51366	-	FP/SS
	B	30599	29112			38733			-	SS/FP
82	A	62682	57437	111949	55975	79345	70854	57046	-	FP/SS
	B	54558	54512			69061			0.132	SS/FP/TK
83	A	44396	32792	66029	33015	56198	41791	56343	0.153	SB/TK
	B	33238	33238			42073			0.113	SB/TK
84	A	35613	35613	71745	35872	45080	45408	52378	-	FP/SS
	B	44488	36132			56314			-	SS/FP
85	A	37130	35849	75022	37511	47000	47482	54329	0.362	SS/FP
	B	39173	39173			49586			.(0.017)	SS
86	A	83310	83310	166479	83239	105455	105366	82541	-	FP/SB
	B	86063	83169			108940			-	FB/TK
87	A	44627	44627	88971	44485	56489	56311	49289	-	FP
	B	65800	44344			83291			-	SS
88	A	65254	65254	131639	65819	82600	83316	68510	-	SS/B
	B	69872	66385			88446			-	SS
89	A	100169	82023	161763	80881	126796	102381	97907	-	FB/SS/TK
	B	79805	79740			101018			0.153	FB/SS/TK
90	A	73143	65881	131078	65539	92586	82960	71237	-	SS
	B	65197	65197			82527			-	FP/SS
91	A	64532	64532	127534	63767	81686	80718	81681	-	FB/SB
	B	87275	63002			110475			-	SB
92	A	76256	76162	150955	75478	96527	95541	83377		SS/FP
	B	80724	74793			102182				SB/FP
93	A	38900	38908	80626	40313	49241	51029	50256	0.2	FP
	B	41700	41718			52785			-	FP
94	A	41853	41853	80104	40052	52979	50699	48150	0.33	FP
	B	38251	38251			48419			0	FB/SS
95	A	54674	45317	90486	45243	69208	57269	53601	-	FP/TK
	B	45169	45169			57176			-	FP/SS
96	A	50000	49985	102911	51455	63291	65134	60328	0.195	FP
	B	52926	52926			66995			0.185	FP
97	A	38047	35988	73642	36821	48161	46609	53544	0.387	FP/SS
	B	37660	37654			47671			0.229	FP/SS
98	A	35543	35543	70199	35100	44991	44430	59583	0.104	FB
	B	34656	34656			43868			0	FB
99	A	38519	38519	75358	37679	48758	47695	57231	0.12	FB
	B	36839	36839			46632			0.29	FB
100	A	34015	33826	61345	30672	43057	38826	56484		FP
	B	27575	27518			34905			-	FP
101	A	32856	32856	68391	34195	41590	43285	61513	0.018	FP
	B	35534	35534			44980			0	FP
102	A	50809	50677	99845	49923	64315	63193	67912	0.219	FP/SS
	B	54796	49168			69362				SS/FP
103	A	66009	65995	133873	66937	83555	84730	99624	0.295	FB/SB
	B	77378	67878			97947			0.266	FB/SB
104	A	70689	65980	131758	65879	89479	83391	93920	-	SB/FP
	B	65778	65778			83263			0.0119	FB/SS
105	A	43063	43063	87150	43575	54510	55158	79122	-	FP
	B	44078	44087			55800			-	FP

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.^{2}	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
80	A B	60	-	-	-	-	3.10	5	3.5	0.63	3.50	-	-	3.16	60
81	A B	60	-	-	-	-	3.10	5	3.5	0.63	3.50	-	-	3.16	60
82	A B	60	-	-	-	-	3.10	5	3.5	0.63	3.50	-	-	3.16	60
83	A B	60	-	-	-	-	2.00	10	3.0	0.50	1.75	-	-	3.16	60
84	A B	60	-	-	-	-	2.00	10	3.0	0.50	1.75	-	-	3.16	60
85	A B	60	-	-	-	-	2.00	10	3.0	0.50	1.75	-	-	3.16	60
86	A B	60	-	-	-	-	2.00	10	3.0	0.50	3.00	-	-	3.16	60
87	A B	60	-	-	-	-	2.00	10	3.0	0.50	3.00	-	-	3.16	60
88	A B	60	-	-	-	-	2.00	10	3.0	0.50	3.00	-	-	3.16	60
89	A B	60	-	-	-	-	1.10	10	3.0	0.38	3.50	0.375	1	3.78	60
90	A B	60	-	-	-	-	1.00	5	3.0	0.50	3.00	0.375	1	3.16	60
91	A B	60	-	-	-	-	1.10	10	3.0	0.38	3.50	0.375	2	3.16	60
92	A B	60	-	-	-	-	1.10	10	3.0	0.38	3.50	0.375	2	3.16	60
93	A B	60	-	-	-	-	-	-	-	0.38	5.00	-	-	3.16	120
94	A B	60	-	-	-	-	-	-	-	0.38	5.00	-	-	3.16	120
95	A B	60	-	-	-	-	1.60	8	4.0	0.50	1.75	-	-	3.16	60
96	A B	60	-	-	-	-	1.60	8	4.0	0.63	3.50	-	-	3.16	60
97	A B	60	-	-	-	-	1.60	8	4.0	0.50	1.50	-	-	3.16	60
98	A B	60	-	-	-	-	-	-	-	0.38	4.00	-	-	3.16	60
99	A B	60	-	-	-	-	-	-	-	0.38	4.00	-	-	4.74	60
100	A B	60	-	-	-	-	-	-	-	0.38	4.00	-	-	4.74	60
101	A B	60	-	-	-	-	-	-	-	0.38	4.00	-	-	4.74	60
102	A B	60	-	-	-	-	0.88	8	4.0	0.50	4.00	0.375	2	3.16	60
103	A B	60	-	-	-	-	-	-	-	0.50	2.25	-	-	3.16	60
104	A B	60	-	-	-	-	-	-	-	0.38	4.00	-	-	3.16	60
105	A B	60	-	-	-	-	-	-	-	0.38	4.00	-	-	3.78	60

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
106	8-15-90-0-i-2.5-2-13	A B	90°	-	A1035[c]	12.8 12.8	12.8	15800	61	1
107	8-5-90-0-i-3.5-2-18	A B	90°	-	A1035[b]	19.0 18.0	18.5	5380	11	1
108	8-5-90-0-i-3.5-2-13	A B	90°	-	A1035[b]	13.4 13.4	13.4	5560	11	1
109	8-5-90-0-i-3.5-2-15(2)	A B	90°	-	A1035[c]	15.6 14.9	15.3	5180	8	1
110	8-5-90-0-i-3.5-2-15(1)	A B	90°	-	A1035[c]	15.4 15.1	15.3	6440	9	1
111	8-8-90-0-i-3.5-2-8(1)	A B	90°	-	A1035[b]	7.8 7.8	7.8	7910	15	1
112	8-8-90-0-i-3.5-2-10	A B	90°	-	A1035[b]	8.8 10.8	9.8	7700	14	1
113	8-8-90-0-i-3.5-2-8(2)	A B	90°	-	A1035[b]	8.5 8.0	8.3	8780	13	1
114	8-12-90-0-i-3.5-2-9	A B	90°	-	A1035[b]	9.0 9.0	9.0	11160	77	1
115	8-8-90-0-i-4-2-8	A B	90°	-	A1035[b]	7.6 8.0	7.8	8740	12	1
116	8-5-180-0-i-2.5-2-11	A B	180°	-	A615	11.0 11.0	11.0	4550	7	1
117	8-5-180-0-i-2.5-2-14	A B	180°	-	A1035[b]	14.0 14.0	14.0	4840	8	1
118	(2@3) 8-5-180-0-i-2.5-2-10‡	A B	180°	-	A615	10.3 10.0	10.2	5260	15	1
119	(2@5)8-5-180-0-i-2.5-2-10‡	A B	180°	-	A615	10.0 10.0	10.0	5260	15	1
120	8-8-180-0-i-2.5-2-11.5	A B	180°	-	A1035[b]	9.3 9.3	9.3	8630	11	1
121	8-12-180-0-i-2.5-2-12.5	A B	180°	-	A1035[c]	12.8 12.5	12.6	11850	39	1
122	8-5-180-0-i-3.5-2-11	A B	180°	-	A615	11.6 11.6	11.6	4550	7	1
123	8-5-180-0-i-3.5-2-14	A B	180°	-	A1035[b]	14.4 13.9	14.1	4840	8	1
124	8-15-180-0-i-2.5-2-13.5	A B	180°	-	A1035[c]	13.8 13.5	13.6	16510	88	1
125	8-5-90-1#3-i-2.5-2-16	A B	90°	Para	A1035[b]	15.6 15.6	15.6	4810	6	1
126	8-5-90-1#3-i-2.5-2-12.5	A B	90°	Para	A1035[b]	12.5 12.5	12.5	5140	8	1
127	8-5-90-1#3-i-2.5-2-9.5	A B	90°	Para	A615	9.0 9.0	9.0	5240	9	1
128	8-5-180-1#3-i-2.5-2-11	A B	180°	Para	A615	11.5 11.5	11.5	4300	6	1
129	8-5-180-1#3-i-2.5-2-14	A B	180°	Para	A1035[b]	14.8 15.0	14.9	4870	9	1
130	8-5-180-1#3-i-3.5-2-11	A B	180°	Para	A615	11.6 10.6	11.1	4550	7	1
131	8-5-180-1#3-i-3.5-2-14	A B	180°	Para	A1035[b]	15.6 14.5	15.1	4840	8	1

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout[o]
106	A B	0.073	16.8	14.8	10.5	8.375	2.4 2.5	2.4	2.1 2.0	9.9	2	30	A7
107	A B	0.078	18.5	20.4	10.5	8.375	3.8 3.4	3.6	1.4 2.4	9.4	2	30	A6
108	A B	0.078	18.4	15.3	10.5	8.375	3.6 3.4	3.5	1.9 1.9	9.4	2	30	A2
109	A B	0.073	18.5	17.3	10.5	8.375	3.5 3.5	3.5	1.6 2.4	9.5	2	30	A2
110	A B	0.073	18.8	17.1	10.5	8.375	3.3 3.4	3.3	1.8 2.0	10.1	2	30	A2
111	A B	0.078	18.3	10.0	10.5	8.375	3.5 3.8	3.6	2.3 2.3	9.0	2	30	A2
112	A B	0.078	18.5	12.0	10.5	8.375	3.8 3.8	3.8	3.3 1.3	9.0	2	30	A2
113	A B	0.078	19.4	10.6	10.5	8.375	3.6 3.8	3.7	2.1 2.6	10.0	2	30	A2
114	A B	0.078	19.0	11.3	10.5	8.375	3.5 3.8	3.6	2.4 2.1	9.8	2	30	A2
115	A B	0.078	19.9	10.5	10.5	8.375	4.5 3.9	4.2	2.9 2.5	9.5	2	30	A2
116	A B	0.078	17.5	13.0	10.5	8.375	3.0 2.8	2.9	2.0 2.0	9.8	2	80	A2
117	A B	0.078	17.1	16.0	10.5	8.375	2.8 2.6	2.7	2.0 2.0	9.8	2	80	A2
118	A B	0.073	8.9	12.0	10.5	8.375	2.5 2.4	2.4	1.7 2.0	2.0	2	30	A10
119	A B	0.073	11.0	12.0	10.5	8.375	2.4 2.5	2.4	2.0 2.0	4.1	2	30	A10
120	A B	0.078	17.5	13.8	10.5	8.375	3.0 3.0	3.0	4.5 4.5	9.5	2	30	A2
121	A B	0.073	17.1	14.9	10.5	8.375	3.0 2.5	2.8	2.1 2.4	9.6	2	30	A2
122	A B	0.078	19.5	13.0	10.5	8.375	3.8 3.8	3.8	1.4 1.4	10.0	2	80	A2
123	A B	0.078	19.4	16.0	10.5	8.375	3.9 3.8	3.8	1.6 2.1	9.8	2	80	A2
124	A B	0.073	17.0	15.8	10.5	8.375	2.5 2.5	2.5	2.0 2.3	10.0	2	30	A7
125	A B	0.078	17.3	17.9	10.5	8.375	2.8 3.0	2.9	2.3 2.3	9.5	2	80	A2
126	A B	0.078	17.1	14.6	10.5	8.375	2.6 2.8	2.7	2.1 2.1	9.8	2	80	A2
127	A B	0.078	17.1	11.5	10.5	8.375	2.6 2.8	2.7	2.5 2.5	9.8	2	80	A2
128	A B	0.078	17.0	13.0	10.5	8.375	2.5 2.5	2.5	1.5 1.5	10.0	2	80	A2
129	A B	0.078	17.5	16.0	10.5	8.375	2.8 2.9	2.8	1.3 1.0	9.9	2	80	A2
130	A B	0.078	19.3	13.0	10.5	8.375	3.8 3.5	3.6	1.4 2.4	10.0	2	80	A2
131	A B	0.078	19.3	16.5	10.5	8.375	3.6 3.6	3.6	0.9 2.0	10.0	2	80	A2

[‡] Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3
[o] Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type
106	A B	77232 79007	77232 79007	156239	78120	97762 100009	98885	114756	- -	FB/SB FB
107	A B	96026 105140	96026 94717	190743	95372	121552 133089	120724	96925	0.181 -	FP/SS/TK FB/SS
108	A B	69449 68307	67892 68307	136199	68099	87910 86464	86202	71237	- -	FP/SS SS/FP
109	A B	106184 85459	89959 85459	175417	87709	134410 108176	111024	78398	- -	SS SS/FP
110	A B	71216 79405	70412 70890	141302	70651	90146 100512	89432	87415		SS/FP SB
111	A B	43697 43993	43697 43993	87690	43845	55313 55687	55500	49234	0.144 0.156	SS/FP SS/FP
112	A B	55230 71880	55088 56046	111134	55567	69911 90987	70338	61111	0.195 0.242	FP/SS SS/FP
113	A B	41170 42930	41170 42899	84069	42034	52114 54341	53208	55217	0.133 0.201	FP FP
114	A B	61380 68385	61380 59097	120477	60238	77696 86563	76251	67912	 0.434	FP FP/SS
115	A B	37554 48708	37554 37309	74863	37431	47537 61656	47381	52170	- -	FP/SS FP
116	A B	45587 50511	45587 46699	92286	46143	57705 63938	58409	52999	0.275 -	SS/FP SS
117	A B	49439 69415	49439 48866	98305	49152	62581 87867	62218	69570	0.088 0.096	SS SS
118	A B	47587 56064	47587 56064	103651	51825	60236 70967	65602	52614	0 0.9	FP FP
119	A B	52300 54030	52300 54030	106330	53165	66202 68392	67297	51804		FP FP
120	A B	62777 80190	62777 80190	142967	71484	79465 101506	90485	61379	- -	FP/SB FP/SS
121	A B	74782 92250	74782 75635	150417	75208	94661 116772	95201	98166	0.193 0.242	FB/SB FP
122	A B	58575 60519	58145 60439	118584	59292	74145 76606	75053	56011	0.372 0.239	FP/SS SS
123	A B	63745 78050	63689 63320	127009	63504	80690 98797	80385	70191	- -	SS FB/SS
124	A B	90688 89145	90688 89145	179833	89916	114795 112841	113818	125050	- -	- FB/SB
125	A B	94588 73936	75682 73936	149617	74809	119731 93589	94694	77429	- -	FP/SS FP/SS
126	A B	73919 64783	64891 64783	129674	64837	93569 82004	82072	64012	- -	FP/SS SS/FP
127	A B	62525 65289	59716 64750	124467	62233	79145 82645	78776	46535	- -	SB FP/SS
128	A B	57294 68950	48342 51122	99464	49732	72524 87278	62952	53865	0.088 0.341	SS/FP SS/FP
129	A B	67269 70909	67183 70860	138043	69021	85150 89758	87369	74147	- 0.123	SS/FP FP/SS
130	A B	62945 56154	54681 56100	110781	55390	79678 71082	70114	53602	0.434 0.216	SS SS
131	A B	78657 76919	75069 76919	151988	75994	99565 97300	96195	74850	0.232 0.227	SS/FP SS/FP

[‡] Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.^{2}	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
106	A B	60	-	-	-	-	-	-	-	0.38	5.00	-	-	4.74	60
107	A B	60	-	-	-	-	1.10	10	3.0	0.38	3.50	0.375	1	3.78	60
108	A B	60	-	-	-	-	1.00	5	3.0	0.50	3.00	0.375	1	3.16	60
109	A B	60	-	-	-	-	1.10	10	3.0	0.38	3.50	0.375	2	3.16	60
110	A B	60	-	-	-	-	1.10	10	3.0	0.38	3.50	0.375	2	3.16	60
111	A B	60	-	-	-	-	1.60	8	4.0	0.50	1.75	-	-	3.16	60
112	A B	60	-	-	-	-	1.60	8	4.0	0.63	3.50	-	-	3.16	60
113	A B	60	-	-	-	-	1.60	8	4.0	0.50	1.50	-	-	3.16	60
114	A B	60	-	-	-	-	0.88	8	4.0	0.50	4.00	0.375	2	3.16	60
115	A B	60	-	-	-	-	1.60	8	4.0	0.50	1.75	-	-	3.16	60
116	A B	60	-	-	-	-	0.44	4	3.5	0.50	3.50	-	-	3.16	60
117	A B	60	-	-	-	-	0.44	4	3.5	0.50	3.50	-	-	3.16	60
118	A B	60	-	-	-	-	-	-	-	0.50	4.00	-	-	6.32	120
119	A B	60	-	-	-	-	-	-	-	0.50	4.00	-	-	6.32	120
120	A B	60	-	-	-	-	0.44	4	3.0	0.50	3.00	-	-	3.16	60
121	A B	60	-	-	-	-	-	-	-	0.50	2.25	-	-	3.16	60
122	A B	60	-	-	-	-	0.44	4	3.5	0.50	3.50	-	-	3.16	60
123	A B	60	-	-	-	-	0.44	4	3.5	0.50	3.50	-	-	3.16	60
124	A B	60	-	-	-	-	-	-	-	0.50	4.00	-	-	4.74	60
125	A B	60	0.38	0.11	1	9.00	2.00	10	3.0	0.50	3.00	-	-	3.16	60
126	A B	60	0.38	0.11	1	9.00	2.00	10	3.0	0.50	3.00	-	-	3.16	60
127	A B	60	0.38	0.11	1	9.00	2.00	10	3.0	0.50	3.00	-	-	3.16	60
128	A B	60	0.38	0.11	1	3.50	0.44	4	4.5	0.50	3.50	-	-	3.16	60
129	A B	60	0.38	0.11	1	3.50	0.44	4	4.5	0.50	3.50	-	-	3.16	60
130	A B	60	0.38	0.11	1	3.50	0.44	4	4.5	0.50	3.50	-	-	3.16	60
131	A B	60	0.38	0.11	1	3.50	0.44	4	4.5	0.50	3.50	-	-	3.16	60

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
132	8-8-180-1#4-i-2.5-2-11.5	A B	180°	Para	A1035[b]	12.0 12.3	12.1	8740	12	1
133	8-5-90-2#3-i-2.5-2-16	A B	90°	Para	A1035[b]	15.0 15.8	15.4	4810	6	1
134	8-5-90-2#3-i-2.5-2-9.5	A B	90°	Para	A615	9.0 9.3	9.1	5140	8	1
135	8-5-90-2#3-i-2.5-2-12.5	A B	90°	Para	A615	12.0 12.0	12.0	5240	9	1
136	8-5-90-2#3-i-2.5-2-8.5	A B	90°	Para	A1035[c]	8.9 9.6	9.3	5240	6	1
137	8-5-90-2#3-i-2.5-2-14	A B	90°	Para	A1035[c]	13.5 14.0	13.8	5450	7	1
138	(2@3) 8-5-90-2#3-i-2.5-2-10‡	A B	90°	Para	A615	10.0 10.5	10.3	4760	11	1
139	(2@5) 8-5-90-2#3-i-2.5-2-10‡	A B	90°	Para	A615	9.6 10.0	9.8	4760	11	1
140	8-8-90-2#3-i-2.5-2-8	A B	90°	Para	A1035[b]	8.0 8.5	8.3	7700	14	1
141	8-8-90-2#3-i-2.5-2-10	A B	90°	Para	A1035[b]	9.9 9.5	9.7	8990	17	1
142	8-12-90-2#3-i-2.5-2-9	A B	90°	Para	A1035[b]	9.0 9.0	9.0	11160	77	1
143	8-12-90-2#3-i-2.5-2-11	A B	90°	Para	A1035[c]	10.5 11.3	10.9	12010	42	1
144	8-12-90-2#3vr-i-2.5-2-11	A B	90°	Perp	A1035[c]	10.9 10.4	10.6	12010	42	1
145	8-15-90-2#3-i-2.5-2-6	A B	90°	Para	A1035[c]	5.8 6.4	6.1	15800	61	1
146	8-15-90-2#3-i-2.5-2-11	A B	90°	Para	A1035[c]	11.3 10.8	11.0	15800	61	1
147	8-5-90-2#3-i-3.5-2-17	A B	90°	Para	A1035[b]	17.5 17.0	17.3	5570	12	1
148	8-5-90-2#3-i-3.5-2-13	A B	90°	Para	A1035[b]	13.8 13.5	13.6	5560	11	1
149	8-8-90-2#3-i-3.5-2-8	A B	90°	Para	A1035[b]	8.0 8.1	8.1	8290	16	1
150	8-8-90-2#3-i-3.5-2-10	A B	90°	Para	A1035[b]	8.8 8.8	8.8	8990	17	1
151	8-12-90-2#3-i-3.5-2-9	A B	90°	Para	A1035[b]	9.0 9.0	9.0	11160	77	1
152	8-5-180-2#3-i-2.5-2-11	A B	180°	Para	A615	10.8 10.5	10.6	4550	7	1
153	8-5-180-2#3-i-2.5-2-14	A B	180°	Para	A1035[b]	13.5 14.0	13.8	4870	9	1
154	(2@3) 8-5-180-2#3-i-2.5-2-10‡	A B	180°	Para	A615	10.3 10.3	10.3	5400	16	1
155	(2@5) 8-5-180-2#3-i-2.5-2-10‡	A B	180°	Para	A615	10.3 9.8	10.0	5400	16	1
156	8-8-180-2#3-i-2.5-2-11.5	A B	180°	Para	A1035[b]	10.5 10.3	10.4	8810	14	1

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout[o]
132	A B	0.078	17.1	14.0	10.5	8.375	2.9 2.8	2.8	2.0 1.8	9.5	2	30	A2
133	A B	0.078	17.1	17.9	10.5	8.375	2.8 2.9	2.8	2.9 2.1	9.5	2	80	A2
134	A B	0.078	17.0	11.6	10.5	8.375	2.5 2.5	2.5	2.6 2.3	10.0	2	80	A2
135	A B	0.078	17.0	14.6	10.5	8.375	2.8 2.8	2.8	2.6 2.6	9.5	2	80	A2
136	A B	0.073	17.1	10.7	10.5	8.375	3.0 3.0	3.0	1.8 1.1	9.1	2	30	A2
137	A B	0.073	17.0	16.1	10.5	8.375	2.8 3.0	2.9	2.6 2.1	9.3	2	30	A2
138	A B	0.073	9.3	12.0	10.5	8.375	2.5 2.5	2.5	2.0 1.5	2.3	2	30	A2
139	A B	0.073	10.9	12.0	10.5	8.375	2.5 2.5	2.5	2.4 2.0	3.9	2	30	A2
140	A B	0.078	16.9	10.0	10.5	8.375	3.0 2.9	2.9	2.0 1.5	9.0	2	30	A2
141	A B	0.078	16.0	12.0	10.5	8.375	2.8 2.8	2.8	2.1 2.5	8.5	2	30	A2
142	A B	0.078	17.0	11.3	10.5	8.375	2.9 2.6	2.8	2.3 2.3	9.5	2	30	A2
143	A B	0.073	17.0	12.9	10.5	8.375	2.8 2.8	2.8	2.4 1.6	9.5	2	30	A2
144	A B	0.073	16.5	13.0	10.5	8.375	2.5 2.3	2.4	2.1 2.6	9.8	2	30	A2
145	A B	0.073	16.8	8.1	10.5	8.375	2.5 2.4	2.4	2.3 1.8	9.9	2	30	A11
146	A B	0.073	17.0	13.1	10.5	8.375	2.5 2.5	2.5	1.9 2.4	10.0	2	30	A11
147	A B	0.078	18.9	19.3	10.5	8.375	3.3 3.5	3.4	1.8 2.3	10.1	2	30	A2
148	A B	0.078	19.0	15.3	10.5	8.375	3.1 3.6	3.4	1.5 1.8	10.3	2	30	A2
149	A B	0.078	17.9	10.0	10.5	8.375	3.6 3.8	3.7	2.0 1.9	8.5	2	30	A2
150	A B	0.078	17.9	12.0	10.5	8.375	3.6 3.8	3.7	3.3 3.3	8.5	2	30	A2
151	A B	0.078	19.3	11.3	10.5	8.375	3.6 4.0	3.8	2.3 2.4	9.6	2	30	A2
152	A B	0.078	16.8	13.0	10.5	8.375	2.8 2.5	2.6	2.3 2.5	9.5	2	80	A2
153	A B	0.078	17.3	16.0	10.5	8.375	2.8 2.8	2.8	2.5 2.0	9.8	2	80	A2
154	A B	0.073	9.0	12.0	10.5	8.375	2.5 2.5	2.5	1.8 1.8	2.0	2	30	A10
155	A B	0.073	11.0	12.0	10.5	8.375	2.5 2.5	2.5	1.8 2.3	4.0	2	30	A10
156	A B	0.078	17.5	12.8	10.5	8.375	2.8 2.8	2.8	2.3 2.5	10.0	2	30	A2

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3
[o] Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type
132	A B	72047 72506	71987 72475	144462	72231	91199 91780	91432	80967	- .(0.013)	FP/SS FP/SS
133	A B	80014 92780	79629 79629	159258	79629	101284 117443	100796	76166	- -	SS/FP FP
134	A B	54916 53621	53621 53621	107242	53621	69513 67874	67874	46729	- -	FP FP
135	A B	74108 76334	67801 76334	144135	72067	93808 96625	91225	62047	- -	FP FP/SS
136	A B	52863 48439	52862 48260	101122	50561	66915 61315	64001	47828		FP/SS SS
137	A B	76959 77540	76388 77540	153927	76964	97416 98151	97422	72506		SS/FP FP/SS
138	A B	58584 47051	58435 35184	93619	46810	74157 59558	59253	50513	0.21 -	FP FP
139	A B	48430 48617	48412 48617	97029	48515	61303 61541	61411	48357	0.23 0.108	FB FB
140	A B	46211 55377	46211 49540	95751	47876	58495 70098	60602	51710	- -	FP/SS FP/SS
141	A B	60670 67001	60670 61378	122047	61024	76797 84812	77245	65609	0.186 0.152	FP FB
142	A B	61813 60251	61813 60213	122026	61013	78244 76267	77232	67912	0.345 0.361	FP/SS SS/FP
143	A B	68128 79794	68101 69264	137365	68683	86237 101004	86940	85128	0.181 0.165	FP FP
144	A B	50709 66830	50709 54637	105346	52673	64188 84595	66674	83171	- 0.13	FP/SS FP
145	A B	37450 37689	37450 37689	75138	37569	47405 47707	47556	54712	- -	FP FP
146	A B	99011 83603	83072 83567	166640	83320	125330 105827	105468	98763	- 0.123	FB FB
147	A B	102613 88572	91402 88426	179829	89914	129889 112117	113816	91958	- -	SS SS/FP
148	A B	81199 86858	81199 79522	160720	80360	102783 109946	101722	72568	- -	SS/FP SS/FP
149	A B	48324 49258	48324 49222	97545	48773	61169 62352	61738	52435	0.31 .340(.147)	FP FP
150	A B	53960 53810	53960 53810	107770	53885	68304 68113	68209	59260	- -	SS FP
151	A B	50266 49289	50266 49289	99555	49777	63628 62391	63009	67912	0.15 	FP/SS FP/SS
152	A B	64232 61892	58650 61819	120469	60235	81306 78345	76246	51193	0.26 0.087	SS/FP SS/FP
153	A B	87080 76851	75744 76814	152558	76279	110228 97279	96556	68539	0.774 0.199	FP FP/SS
154	A B	57472 58835	57188 58114	115302	57651	72749 74474	72976	53801	 0.288	FP FP
155	A B	63698 60130	63640 60130	123770	61885	80630 76114	78335	52489	 0.263	FB FB
156	A B	70102 59494	56934 59408	116343	58171	88737 75300	73635	69558	0.261 .25(.027)	FB/SS FP/SS

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.^{2}	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
132	A B	60	0.5	0.20	1	3.00	0.44	4	3.0	0.50	3.00	-	-	3.16	60
133	A B	60	0.38	0.11	2	3.00	2.00	10	3.0	0.50	3.00	-	-	3.16	60
134	A B	60	0.38	0.11	2	3.00	2.00	10	3.0	0.50	3.00	-	-	3.16	60
135	A B	60	0.38	0.11	2	3.00	2.00	10	3.0	0.50	3.00	-	-	3.16	60
136	A B	60	0.38	0.11	2	7.50	2.00	10	2.5	0.50	3.25	0.5	1	3.16	60
137	A B	60	0.38	0.11	2	6.00	0.88	8	3.0	0.50	3.50	0.5	1	3.16	60
138	A B	60	0.38	0.11	2	3.00	-	-	-	0.38	4.00	-	-	3.16	120
139	A B	60	0.38	0.11	2	3.00	-	-	-	0.38	5.00	-	-	3.16	120
140	A B	60	0.38	0.11	2	7.13	1.20	6	4.0	0.50	1.50	-	-	3.16	60
141	A B	60	0.38	0.11	2	7.13	1.20	6	4.0	0.63	3.50	-	-	3.16	60
142	A B	60	0.38	0.11	2	8.00	0.88	8	4.0	0.50	4.00	0.375	2	3.16	60
143	A B	60	0.38	0.11	2	8.00	-	-	-	0.50	2.00	-	-	3.16	60
144	A B	60	0.38	0.11	2	2.67	-	-	-	0.50	2.00	-	-	3.16	60
145	A B	60	0.38	0.11	2	6.00	-	-	-	0.38	2.75	-	-	6.32	60
146	A B	60	0.38	0.11	2	5.50	-	-	-	0.38	4.00	-	-	6.32	60
147	A B	60	0.38	0.11	2	8.00	0.80	4	4.0	0.50	4.00	0.375	1	3.16	60
148	A B	60	0.38	0.11	2	8.00	0.44	4	4.0	0.50	3.00	-	-	3.16	60
149	A B	60	0.38	0.11	2	7.13	1.20	6	4.0	0.50	1.50	-	-	3.16	60
150	A B	60	0.38	0.11	2	7.13	1.20	6	4.0	0.63	3.50	-	-	3.16	60
151	A B	60	0.38	0.11	2	8.00	0.88	8	4.0	0.50	4.00	0.375	2	3.16	60
152	A B	60	0.38	0.11	2	3.50	-	-	-	0.50	3.50	-	-	3.16	60
153	A B	60	0.38	0.11	2	3.50	-	-	-	0.50	3.50	-	-	3.16	60
154	A B	60	0.38	0.11	2	3.00	-	-	-	0.50	4.00	-	-	6.32	120
155	A B	60	0.38	0.11	2	3.00	-	-	-	0.50	4.00	-	-	6.32	120
156	A B	60	0.38	0.11	2	3.00	-	-	-	0.50	3.00	-	-	3.16	60

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
157	8-12-180-2#3-i-2.5-2-11	A B	180°	Para	A1035[c]	11.1 10.4	10.8	12010	42	1
158	8-12-180-2#3vr-i-2.5-2-11	A B	180°	Perp	A1035[b]	10.9 10.9	10.9	12010	42	1
159	8-5-180-2#3-i-3.5-2-11	A B	180°	Para	A1035[b]	10.1 10.6	10.4	4300	6	1
160	8-5-180-2#3-i-3.5-2-14	A B	180°	Para	A1035[b]	13.5 13.6	13.6	4870	9	1
161	8-15-180-2#3-i-2.5-2-11	A B	180°	Para	A1035[b]	11.1 11.1	11.1	15550	87	1
162	8-8-90-2#4-i-2.5-2-10	A B	90°	Para	A1035[b]	8.5 9.3	8.9	8290	16	1
163	8-8-90-2#4-i-3.5-2-10	A B	90°	Para	A1035[b]	9.0 9.8	9.4	8290	16	1
164	8-5-90-4#3-i-2.5-2-16	B A	90°	Para	A1035[b]	16.0 16.3	16.1	4810	6	1
165	8-5-90-4#3-i-2.5-2-12.5	A B	90°	Para	A1035[b]	11.9 11.9	11.9	4980	7	1
166	8-5-90-4#3-i-2.5-2-9.5	A B	90°	Para	A615	9.5 9.5	9.5	5140	8	1
167	8-5-90-5#3-o-2.5-2-10a	A B	90°	Para	A1035[a]	10.3 10.5	10.4	5270	7	1
168	8-5-90-5#3-o-2.5-2-10b	A B	90°	Para	A1035[a]	10.5 10.5	10.5	5440	8	1
169	8-5-90-5#3-o-2.5-2-10c	A B	90°	Para	A1035[a]	11.3 10.5	10.9	5650	9	1
170	8-8-90-5#3-o-2.5-2-8	A B	90°	Para	A1035[b]	8.3 8.8	8.5	8630	11	1
171	8-8-90-5#3-o-3.5-2-8	A B	90°	Para	A1035[b]	7.8 8.0	7.9	8810	14	1
172	8-8-90-5#3-o-4-2-8	A B	90°	Para	A1035[b]	8.5 8.0	8.3	8740	12	1
173	8-5-90-5#3-i-2.5-2-10b	A B	90°	Para	A1035[a]	10.3 10.5	10.4	5440	8	1
174	8-5-90-5#3-i-2.5-2-10c	A B	90°	Para	A1035[a]	10.5 10.5	10.5	5650	9	1
175	8-5-90-5#3-i-2.5-2-15	A B	90°	Para	A1035[b]	15.3 15.8	15.5	4850	7	1
176	8-5-90-5#3-i-2.5-2-13	A B	90°	Para	A1035[b]	13.8 13.5	13.6	5560	11	1
177	8-5-90-5#3-i-2.5-2-12(1)	A B	90°	Para	A1035[c]	11.5 11.1	11.3	5090	7	1
178	8-5-90-5#3-i-2.5-2-12	A B	90°	Para	A1035[c]	11.3 12.3	11.8	5960	7	1
179	8-5-90-5#3-i-2.5-2-12(2)	A B	90°	Para	A1035[c]	12.4 12.0	12.2	5240	6	1
180	8-5-90-5#3-i-2.5-2-8	A B	90°	Para	A1035[c]	7.8 7.4	7.6	5240	6	1
181	8-5-90-5#3-i-2.5-2-10a	B	90°	Para	A1035[a]	10.5	10.5	5270	7	1
182	(2@3) 8-5-90-5#3-i-2.5-2-10[‡]	A B	90°	Para	A615	10.0 10.5	10.3	4805	12	1

[‡] Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout[o]
157	A B	0.073	16.8	13.2	10.5	8.375	2.5 2.6	2.6	2.1 2.8	9.6	2	30	A2
158	A B	0.073	17.1	13.3	10.5	8.375	2.8 2.6	2.7	2.4 2.4	9.8	2	30	A2
159	A B	0.078	18.6	13.0	10.5	8.375	3.4 3.5	3.4	2.9 2.4	9.8	2	80	A2
160	A B	0.078	19.1	16.0	10.5	8.375	3.6 3.8	3.7	2.5 2.4	9.8	2	80	A2
161	A B	0.073	17.3	13.1	10.5	8.375	2.8 2.8	2.8	2.1 2.0	9.8	2	30	A7
162	A B	0.078	17.3	12.0	10.5	8.375	3.0 3.0	3.0	3.5 2.8	9.3	2	30	A2
163	A B	0.078	18.8	12.0	10.5	8.375	3.8 3.9	3.8	3.0 2.3	9.1	2	30	A2
164	B A	0.078	17.3	17.9	10.5	8.375	2.8 3.0	2.9	1.9 1.6	9.5	2	80	A2
165	A B	0.078	17.0	13.9	10.5	8.375	2.5 2.5	2.5	2.0 2.0	10.0	2	80	A2
166	A B	0.078	17.1	11.5	10.5	8.375	2.8 2.9	2.8	2.0 2.0	9.5	2	80	A2
167	A B	0.084	17.1	12.3	10.5	8.375	2.6 2.6	2.6	1.8 2.0	9.9	2	80	A2
168	A B	0.084	17.0	12.5	10.5	8.375	2.5 2.6	2.6	2.0 2.0	9.9	2	80	A2
169	A B	0.084	17.0	12.5	10.5	8.375	2.6 2.5	2.6	1.3 2.0	9.9	2	80	A2
170	A B	0.078	16.8	10.0	10.5	8.375	2.8 2.8	2.8	1.8 1.3	9.3	2	30	A2
171	A B	0.078	18.5	10.0	10.5	8.375	3.5 3.5	3.5	2.3 2.0	9.5	2	30	A2
172	A B	0.078	20.4	10.0	10.5	8.375	3.9 4.5	4.2	1.5 2.0	10.0	2	30	A2
173	A B	0.084	17.3	12.3	10.5	8.375	2.8 2.6	2.7	2.0 1.8	9.9	2	80	A2
174	A B	0.084	17.0	12.5	10.5	8.375	2.5 2.5	2.5	2.0 2.0	10.0	2	80	A2
175	A B	0.078	17.1	17.2	10.5	8.375	2.8 2.5	2.6	1.9 1.4	9.9	2	30	A2
176	A B	0.078	17.1	15.3	10.5	8.375	2.5 2.4	2.4	1.5 1.8	10.3	2	30	A2
177	A B	0.073	16.8	14.1	10.5	8.375	2.5 2.5	2.5	2.6 3.0	9.8	2	30	A2
178	A B	0.073	16.6	14.3	10.5	8.375	2.5 2.4	2.4	3.0 2.0	9.8	2	30	A2
179	A B	0.073	16.1	14.1	10.5	8.375	2.5 2.6	2.6	1.8 2.1	9.0	2	30	A2
180	A B	0.073	16.6	10.3	10.5	8.375	2.8 2.9	2.8	2.6 2.9	9.0	2	30	A2
181	B	0.08	17	12.3	10.5	8.375	2.5	2.5	1.8	9.8	2	80	A2
182	A B	0.073	9.2	12.0	10.5	8.375	2.4 2.8	2.6	2.0 1.5	2.0	2	30	A2

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

[o] Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type
157	A B	73700 66200	63140 66170	129310	64655	93291 83797	81842	84150	- -	FP FB
158	A B	67136 87053	67136 64423	131559	65780	84983 110194	83265	85128	- 0.369	SS/FP FB/SB
159	A B	57158 54943	56965 54772	111737	55869	72352 69548	70720	48595	0.167 0.212	SS/FP SS/FP
160	A B	68293 90408	68293 58642	126934	63467	86446 114441	80338	67605	- -	FP/SS FP/SS
161	A B	79626 78291	79553 78291	157845	78922	100792 99103	99902	98813	- -	FB/SS FP
162	A B	61367 71322	61286 61434	122721	61360	77680 90281	77671	57719	0.171 .285(.129)	FP/SS FP/SS
163	A B	69451 69474	69451 69474	138925	69463	87913 87942	87927	60971	0.26 .181(.104)	SS/FP FP/SS
164	B A	91801 97200	91801 89056	180857	90429	116204 123038	114467	79881	- -	FP/SS FP/SS
165	A B	83079 68634	68532 68634	137165	68583	105164 86878	86814	59883	- -	FP FP
166	A B	63275 54846	55094 54733	109827	54914	80094 69425	69511	48649	- -	FP FP/SS
167	A B	55700 55774	53308 55206	108513	54257	70507 70601	68679	67247	- 0.213	SS SB
168	A B	66444 69470	61714 69470	131183	65592	84107 87936	83027	69147	0.203 0.235	FP/SB SB/FP
169	A B	80648 58800	80648 58340	138988	69494	102086 74430	87967	72985	- -	SS/FP SS/FP
170	A B	56092 66796	56092 59870	115962	57981	71002 84551	73394	70503	0.253 .237(.033)	FP/SS FB/SS
171	A B	53926 56134	53865 56048	109914	54957	68261 71055	69566	65996	- .251(.249)	FP FP/SS
172	A B	39553 41461	39553 38589	78142	39071	50067 52483	49457	68864	0.388 0.754	SS/FP FP
173	A B	78824 66728	75418 64012	139430	69715	99777 84466	88247	68323	0.129 -	FP/SS FP
174	A B	68947 69633	68071 69604	137674	68837	87275 88143	87136	70469	- -	FP/SS FP/SS
175	A B	77125 72603	74150 72603	146753	73377	97627 91903	92882	96574	0.196 -	FP/SS FP/SS
176	A B	93116 81340	83412 81340	164752	82376	117868 102962	104273	90710	- -	SS/FP FP/SS
177	A B	66726 75878	66726 66001	132727	66363	84463 96048	84004	72061	- -	SS/FP SS/FP
178	A B	84900 72000	* 72000	72000	72000	107468 91139	91139	80992		SS SS
179	A B	72359 77425	72321 70619	142939	71470	91593 98006	90468	78770		FP/SS FP/SS
180	A B	48024 47008	47948 47008	94956	47478	60790 59503	60099	48878	0.321	FP FP
181	B	82800	82800	82800	82800	104800	104800	68100	0.164	FP/SS
182	A B	61451 58224	57620 58224	115845	57922	77787 73671	73319	63438	0.05 0.37	FB/SS FB/SS

*Data not available

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.^{2}	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
157	A B	60	0.38	0.11	2	8.00	-	-	-	0.50	2.00	-	-	3.16	60
158	A B	60	0.38	0.11	2	2.67	-	-	-	0.50	2.00	-	-	3.16	60
159	A B	60	0.38	0.11	2	3.50	-	-	-	0.50	3.50	-	-	3.16	60
160	A B	60	0.38	0.11	2	3.50	-	-	-	0.50	3.50	-	-	3.16	60
161	A B	60	0.38	0.11	2	5.00	-	-	-	0.50	4.00	-	-	4.74	60
162	A B	60	0.5	0.20	2	7.13	1.20	6	4.0	0.50	2.00	-	-	3.16	60
163	A B	60	0.5	0.20	2	7.13	1.20	6	4.0	0.50	2.00	-	-	3.16	60
164	B A	60	0.38	0.11	4	3.00	2.00	10	3.0	0.50	3.00	-	-	3.16	60
165	A B	60	0.38	0.11	4	3.00	2.00	10	3.0	0.50	3.00	-	-	3.16	60
166	A B	60	0.38	0.11	4	3.00	2.00	10	3.0	0.50	3.00	-	-	3.16	60
167	A B	60	0.38	0.11	5	3.00	1.10	10	3.0	0.63	5.00	-	-	3.16	60
168	A B	60	0.38	0.11	5	3.00	1.10	10	3.0	0.63	5.00	-	-	3.16	60
169	A B	60	0.38	0.11	5	3.00	1.10	10	3.0	0.63	5.00	-	-	3.16	60
170	A B	60	0.38	0.11	5	3.00	2.00	10	3.0	0.50	1.75	-	-	3.16	60
171	A B	60	0.38	0.11	5	3.00	2.00	10	3.0	0.50	1.75	-	-	3.16	60
172	A B	60	0.38	0.11	5	3.00	2.00	10	3.0	0.50	1.75	-	-	3.16	60
173	A B	60	0.38	0.11	5	3.00	1.10	10	3.0	0.63	5.00	-	-	3.16	60
174	A B	60	0.38	0.11	5	3.00	1.10	10	3.0	0.63	5.00	-	-	3.16	60
175	A B	60	0.38	0.11	5	3.00	0.55	5	3.0	0.38	3.50	0.375	2	3.16	60
176	A B	60	0.38	0.11	5	3.00	1.00	5	3.0	0.50	3.00	0.375	1	3.16	60
177	A B	60	0.38	0.11	5	3.00	0.55	5	3.0	0.38	3.50	0.5	2	3.16	60
178	A B	60	0.38	0.11	5	3.00	0.55	5	3.0	0.38	3.50	0.5	2	3.16	60
179	A B	60	0.38	0.11	5	3.00	0.55	5	3.0	0.38	3.50	0.375	1	3.16	60
180	A B	60	0.38	0.11	5	3.00	1.55	5	3.0	0.50	3.00	0.5	1	3.16	60
181	B	60	0.375	0.11	5	3.0	1.10	10	3.0	0.63	3.50	-	-	3.16	60
182	A B	60	0.38	0.11	5	3.00	-	-	-	0.38	4.00	-	-	3.16	120

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
183	(2@5) 8-5-90-5#3-i-2.5-2-10‡	A B	90°	Para	A615	9.9 9.5	9.7	4805	12	1
184	8-8-90-5#3-i-2.5-2-8	A B	90°	Para	A1035[b]	7.3 7.3	7.3	8290	16	1
185	8-8-90-5#3-i-2.5-2-9‡	A B	90°	Para	A615	8.6 9.0	8.8	7710	25	1
186	8-8-90-5#3-i-2.5-9-9‡	A B	90°	Para	A615	9.0 9.3	9.1	7710	25	1
187	(2@3) 8-8-90-5#3-i-2.5-9-9	A B	90°	Para	A615	9.3 9.5	9.4	7440	22	1
188	(2@4) 8-8-90-5#3-i-2.5-9-9	A B	90°	Para	A615	8.9 9.1	9.0	7440	22	1
189	8-12-90-5#3-i-2.5-2-9	A B	90°	Para	A1035[b]	9.0 9.0	9.0	11160	77	1
190	8-12-90-5#3-i-2.5-2-10	A B	90°	Para	A1035[c]	9.0 9.9	9.4	11800	38	1
191	8-12-90-5#3-i-2.5-2-12‡	A B	90°	Para	A1035[c]	12.2 12.3	12.2	11760	34	1
192	8-12-90-5#3vr-i-2.5-2-10	A B	90°	Perp	A1035[c]	10.3 10.2	10.2	11800	38	1
193	8-12-90-4#3vr-i-2.5-2-10	A B	90°	Perp	A1035[c]	10.6 10.3	10.4	11850	39	1
194	8-15-90-5#3-i-2.5-2-6	A B	90°	Para	A1035[c]	6.5 6.1	6.3	15800	60	1
195	8-15-90-5#3-i-2.5-2-10	A B	90°	Para	A1035[c]	10.6 9.7	10.1	15800	60	1
196	8-5-90-5#3-i-3.5-2-15	A B	90°	Para	A1035[b]	15.8 15.8	15.8	4850	7	1
197	8-5-90-5#3-i-3.5-2-13	A B	90°	Para	A1035[b]	13.3 13.0	13.1	5570	12	1
198	8-5-90-5#3-i-3.5-2-12(1)	A B	90°	Para	A1035[c]	12.8 12.3	12.5	5090	7	1
199	8-5-90-5#3-i-3.5-2-12	A B	90°	Para	A1035[c]	12.5 11.8	12.1	6440	9	1
200	8-8-90-5#3-i-3.5-2-8	A B	90°	Para	A1035[b]	8.0 8.0	8.0	7910	15	1
201	8-12-90-5#3-i-3.5-2-9	A B	90°	Para	A1035[b]	9.0 9.0	9.0	11160	77	1
202	(2@5) 8-5-180-5#3-i-2.5-2-10‡	A B	180°	Para	A615	10.0 10.3	10.1	5540	17	1
203	8-12-180-5#3-i-2.5-2-10	A B	180°	Para	A1035[c]	9.9 9.6	9.8	11800	38	1
204	8-12-180-5#3vr-i-2.5-2-10	A B	180°	Perp	A1035[c]	11.1 10.5	10.8	11800	38	1
205	8-12-180-4#3vr-i-2.5-2-10	A B	180°	Perp	A1035[c]	10.5 10.0	10.3	11850	39	1
206	8-15-180-5#3-i-2.5-2-9.5	A B	180°	Para	A1035[c]	9.6 9.8	9.7	15550	87	1
207	8-5-90-4#4s-i-2.5-2-15	A B	90°	Para	A1035[b]	15.6 15.6	15.6	4810	6	1

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout[o]
183	A B	0.073	10.9	12.0	10.5	8.375	2.3 2.4	2.3	2.1 2.5	4.3	2	30	A2
184	A B	0.078	16.1	10.0	10.5	8.375	2.9 2.8	2.8	2.8 2.8	8.5	2	30	A2
185	A B	0.073	17.8	11.0	10.5	8.375	2.8 3.3	3.0	2.4 2.0	9.8	2	30	A2
186	A B	0.073	17.3	18.0	10.5	8.375	2.5 2.8	2.6	9.0 8.8	10.0	2	30	A7
187	A B	0.073	9.0	18.0	10.5	8.375	2.5 2.5	2.5	8.8 8.5	2.0	2	30	A7
188	A B	0.073	10.3	18.0	10.5	8.375	2.5 2.5	2.5	9.1 8.9	3.3	2	30	A7
189	A B	0.078	16.6	11.5	10.5	8.375	2.5 2.6	2.6	2.5 2.5	9.5	2	30	A2
190	A B	0.073	16.8	12.2	10.5	8.375	2.6 2.3	2.4	3.2 2.3	9.9	2	30	A2
191	A B	0.073	16.9	14.2	10.5	8.375	2.4 2.5	2.4	2.0 1.9	10.0	2	30	A2
192	A B	0.073	16.6	11.9	10.5	8.375	2.5 2.4	2.4	1.7 1.7	9.8	2	30	A2
193	A B	0.073	16.0	12.4	10.5	8.375	2.5 2.5	2.5	1.8 2.1	9.0	2	30	A2
194	A B	0.073	17.0	8.3	10.5	8.375	2.6 2.6	2.6	1.8 2.2	9.8	2	30	A11
195	A B	0.073	16.7	12.1	10.5	8.375	2.4 2.4	2.4	1.6 2.4	9.9	2	30	A11
196	A B	0.078	19.3	17.0	10.5	8.375	3.6 3.5	3.5	1.3 1.3	10.3	2	30	A2
197	A B	0.078	19.3	15.4	10.5	8.375	3.4 3.5	3.4	2.1 2.4	10.4	2	30	A2
198	A B	0.073	18.7	14.3	10.5	8.375	3.5 3.4	3.5	1.6 2.1	9.8	2	30	A2
199	A B	0.073	18.6	14.2	10.5	8.375	3.4 3.5	3.4	1.7 2.4	9.8	2	30	A2
200	A B	0.078	18.0	10.0	10.5	8.375	3.5 3.6	3.6	2.0 2.0	8.9	2	30	A2
201	A B	0.078	18.1	11.5	10.5	8.375	3.3 3.4	3.3	2.5 2.5	9.5	2	30	A2
202	A B	0.073	11.0	12.0	10.5	8.375	2.5 2.5	2.5	2.0 1.8	4.0	2	30	A10
203	A B	0.073	16.9	12.2	10.5	8.375	2.3 2.8	2.5	2.3 2.6	9.9	2	30	A2
204	A B	0.073	16.8	12.4	10.5	8.375	2.5 2.5	2.5	1.3 1.9	9.8	2	30	A2
205	A B	0.073	17.0	12.3	10.5	8.375	2.8 2.5	2.6	1.8 2.3	9.8	2	30	A2
206	A B	0.073	17.3	11.7	10.5	8.375	2.5 2.8	2.6	2.1 1.9	10.0	2	30	A10
207	A B	0.078	17.0	17.3	10.5	8.375	3.0 2.9	2.9	1.6 1.6	9.1	2	30	A2

[‡] Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3
[o] Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type
183	A	59715	59715	111921	55960	75589	70836	59957	0.12	FB
	B	52232	52205			66116			0.29	FB
184	A	56006	49326	100532	50266	70893	63628	58938	0.3	FP
	B	51206	51206			64818			.375 (.092)	FP
185	A	64834	64834	128795	64397	82068	81516	69089	0.047	FB
	B	64027	63961			81047			0	FB
186	A	61960	61894	126597	63298	78431	80125	71539	0.05	FB
	B	65209	64703			82543			0	FB
187	A	56456	56420	117585	58792	71463	74421	72200	0.082	FP
	B	61169	61165			77430			-	FP
188	A	55664	55603	114911	57455	70461	72728	69312	0.117	FB
	B	59345	59307			75120			0	FB
189	A	66512	66512	129507	64753	84193	81966	84890	0.224	FP/SS
	B	63119	62994			79897			0.252	FP/SS
190	A	66000	64479	129061	64530	83544	81684	91533	0.44	FB/SS
	B	64599	64582			81771			0.547	SS/FP
191	A	90544	88954	175422	87711	114613	111027	118308	-	FB/SS
	B	86469	86469			109454			-	SS/FP
192	A	59428	59428	120439	60219	75225	76227	99111	0.236	FP
	B	64145	61011			81196			0.246	FP
193	A	80288	59214	118481	59241	101630	74988	81157	0.123	FP/SS
	B	59267	59267			75021			0.101	FP
194	A	48315	48315	96998	48499	61158	61391	70845	-	FP
	B	48683	48683			61624			-	FP
195	A	111610	89783	180007	90003	141278	113928	113633	-	FB/SS
	B	90223	90223			114207			0.407	FB/SS
196	A	81187	81187	160681	80341	102768	101697	97934	.214(.026)	SS/FP
	B	87144	79494			110309			-	SS/FP
197	A	89620	78290	154137	77069	113443	97555	87460	-	SS
	B	75971	75847			96166			-	SS/FP
198	A	78862	78813	152863	76431	99825	96749	79625	-	SS/FP
	B	75869	74050			96037			-	SS
199	A	79156	79156	158301	79150	100198	100190	86877		FP
	B	79258	79145			100327			0.162	FP/SS
200	A	55391	55391	111619	55810	70116	70645	63527	-	FP
	B	56240	56228			71190			-	FP
201	A	68822	68822	135663	67831	87116	85863	84890		FP/SS
	B	82227	66841			104084			0.415	FP/SS
202	A	58132	58132	133288	66644	73585	84359	67287		FB
	B	75155	75155			95134			0.111	FB
203	A	63041	63041	128214	64107	79798	81148	94564	-	FP/SS
	B	81419	65173			103062			0.339	FP
204	A	67538	67538	135560	67780	85491	85798	104869	-	FP
	B	68023	68023			86105			0.321	FB
205	A	69654	69654	138377	69188	88170	87580	79699	-	FP
	B	68753	68723			87030			-	FP
206	A	85951	85951	171901	85951	108798	108798	107512	-	SS
	B	85951	85951			108798			-	FP/SS
207	A	93337	93337	187306	93653	118148	118548	77404	0.21	SS/FP
	B	107709	93969			136300			-	FP/SS

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.^{2}	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
183	A B	60	0.38	0.11	5	3.00	-	-	-	0.38	4.00	-	-	3.16	120
184	A B	60	0.38	0.11	5	3.00	1.20	6	3.0	0.50	1.50	-	-	3.16	60
185	A B	60	0.38	0.11	5	3.00	-	-	-	0.38	4.00	-	-	3.16	120
186	A B	60	0.38	0.11	5	3.00	-	-	-	0.38	4.00	-	-	4.74	120
187	A B	60	0.38	0.11	5	3.00	-	-	-	0.38	4.00	-	-	4.74	60
188	A B	60	0.38	0.11	5	3.00	-	-	-	0.38	4.00	-	-	4.74	60
189	A B	60	0.38	0.11	5	3.00	0.88	8	4.0	0.50	4.00	0.375	2	3.16	60
190	A B	60	0.38	0.11	5	3.00	-	-	-	0.50	1.75	-	-	3.16	60
191	A B	60	0.38	0.11	5	3.00	-	-	-	0.38	4.00	-	-	3.16	120
192	A B	60	0.38	0.11	5	1.75	-	-	-	0.50	1.75	-	-	3.16	60
193	A B	60	0.38	0.11	4	2.25	-	-	-	0.50	1.75	-	-	3.16	60
194	A B	60	0.38	0.11	5	3.00	-	-	-	0.38	2.75	-	-	6.32	60
195	A B	60	0.38	0.11	5	3.00	-	-	-	0.38	3.00	-	-	6.32	60
196	A B	60	0.38	0.11	5	3.00	0.55	5	3.0	0.38	3.50	0.375	2	3.16	60
197	A B	60	0.38	0.11	5	3.00	1.00	5	3.0	0.50	3.00	0.375	1	3.16	60
198	A B	60	0.38	0.11	5	3.00	0.55	5	3.0	0.38	3.50	0.5	2	3.16	60
199	A B	60	0.38	0.11	5	3.00	0.55	5	3.0	0.38	3.50	0.5	2	3.16	60
200	A B	60	0.38	0.11	5	3.00	1.20	6	3.0	0.50	1.50	-	-	3.16	60
201	A B	60	0.38	0.11	5	3.00	0.88	8	4.0	0.50	4.00	0.375	2	3.16	60
202	A B	60	0.38	0.11	5	3.00	-	-	-	0.50	4.00	-	-	6.32	120
203	A B	60	0.38	0.11	5	3.00	-	-	-	0.50	1.75	-	-	3.16	60
204	A B	60	0.38	0.11	5	1.75	-	-	-	0.50	1.75	-	-	3.16	60
205	A B	60	0.38	0.11	4	2.25	-	-	-	0.50	1.75	-	-	3.16	60
206	A B	60	0.38	0.11	5	3.00	-	-	-	0.50	4.00	-	-	6.32	60
207	A B	60	0.5	0.20	4	4.00	0.88	8	4.0	0.38	3.50	0.375	2	3.16	60

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
208	8-5-90-4#4s-i-2.5-2-12(1)	A B	90°	Para	A1035[c]	12.3 12.5	12.4	5180	8	1
209	8-5-90-4#4s-i-2.5-2-12	A B	90°	Para	A1035[c]	12.0 12.6	12.3	6210	8	1
210	8-5-90-4#4s-i-3.5-2-15	A B	90°	Para	A1035[b]	15.5 15.1	15.3	4810	6	1
211	8-5-90-4#4s-i-3.5-2-12(1)	A B	90°	Para	A1035[c]	12.0 11.9	11.9	5910	14	1
212	8-5-90-4#4s-i-3.5-2-12	A B	90°	Para	A1035[c]	12.0 12.5	12.3	5960	7	1

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout[o]
208	A B	0.073	17.1	14.4	10.5	8.375	2.5 2.6	2.6	2.1 1.9	10.0	2	30	A2
209	A B	0.073	16.6	14.3	10.5	8.375	2.6 2.5	2.6	2.3 1.6	9.5	2	30	A2
210	A B	0.078	19.6	17.3	10.5	8.375	4.1 4.0	4.1	1.8 2.1	9.5	2	30	A2
211	A B	0.073	19.0	14.3	10.5	8.375	3.8 3.5	3.6	2.3 2.4	9.8	2	30	A2
212	A B	0.073	18.3	14.4	10.5	8.375	3.8 3.5	3.6	2.4 1.9	9.0	2	30	A2

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3
[o] Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type
208	A B	100177 90092	91540 90092	181632	90816	126806 114041	114957	63618	- -	FP/SS FP/SS
209	A B	116352 99672	99838 99672	199509	99755	147281 126167	126272	69305		FP/SS SS/FP
210	A B	105974 90156	91613 90118	181730	90865	134144 114121	115019	75856	- -	FP/SS SS/FP
211	A B	115165 92876	113609 77301	190910	95455	145779 117565	120829	65551	- -	SS FP/SS
212	A B	103861 96919	99392 96919	196312	98156	131470 122700	124248	67551		SS/FP FP/SS

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.2 Cont. Comprehensive test results and data for No. 8 specimens with two hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.^{2}	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
208	A B	60	0.5	0.20	4	4.00	1.60	8	4.0	0.50	3.50	0.5	1	3.16	60
209	A B	60	0.5	0.20	4	4.00	1.60	8	4.0	0.50	3.50	0.5	1	3.16	60
210	A B	60	0.5	0.20	4	4.00	0.88	8	4.0	0.38	3.50	0.375	2	3.16	60
211	A B	60	0.5	0.20	4	4.00	1.60	8	4.0	0.50	3.50	0.5	1	3.16	60
212	A B	60	0.5	0.20	4	4.00	1.60	8	4.0	0.50	3.50	0.5	1	3.16	60

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.3 Comprehensive test results and data for No. 11 specimens with two hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
213	11-8-90-0-o-2.5-2-25	A B	90°	-	A1035	25.3 25.1	25.2	9460	9	1.41
214	11-8-90-0-o-2.5-2-17	A B	90°	-	A1035	16.8 16.4	16.6	9460	9	1.41
215	11-12-90-0-o-2.5-2-17	A B	90°	-	A1035	17.1 16.6	16.9	11800	36	1.41
216	11-12-180-0-o-2.5-2-17	A B	180°	-	A1035	16.9 17.3	17.1	11800	36	1.41
217	11-5-90-0-i-2.5-2-14	A B	90°	-	A615	13.5 15.3	14.4	4910	13	1.41
218	11-5-90-0-i-2.5-2-26	A B	90°	-	A1035	26.0 26.0	26.0	5360	6	1.41
219	(2@5.35) 11-5-90-0-i-2.5-13-13	A B	90°	-	A615	14.0 13.9	13.9	5330	11	1.41
220	11-8-90-0-i-2.5-2-17	A B	90°	-	A1035	17.3 18.0	17.6	9460	9	1.41
221	11-8-90-0-i-2.5-2-21	A B	90°	-	A1035	20.0 21.1	20.6	7870	6	1.41
222	11-8-90-0-i-2.5-2-17	A B	90°	-	A1035	16.3 18.1	17.2	8520	7	1.41
223	11-12-90-0-i-2.5-2-17	A B	90°	-	A1035	16.1 16.9	16.5	11880	35	1.41
224	11-12-90-0-i-2.5-2-17.5	A B	90°	-	A1035	17.6 17.8	17.7	13330	31	1.41
225	11-12-90-0-i-2.5-2-25	A B	90°	-	A1035	24.9 24.4	24.6	13330	34	1.41
226	11-15-90-0-i-2.5-2-24	A B	90°	-	A1035	24.0 24.8	24.4	16180	62	1.41
227	11-15-90-0-i-2.5-2-11	A B	90°	-	A1035	12.1 11.5	11.8	16180	63	1.41
228	11-15-90-0-i-2.5-2-10‡	A B	90°	-	A615	9.5 9.5	9.5	14050	76	1.41
229	11-15-90-0-i-2.5-2-15‡	A B	90°	-	A1035	14.0 14.0	14.0	14050	77	1.41
230	11-5-90-0-i-3.5-2-17	A B	90°	-	A1035	18.1 17.6	17.9	5600	24	1.41
231	11-5-90-0-i-3.5-2-14	A B	90°	-	A615	14.8 15.3	15.0	4910	13	1.41
232	11-5-90-0-i-3.5-2-26	A B	90°	-	A1035	26.3 25.8	26.0	5960	8	1.41
233	11-8-180-0-i-2.5-2-21	A B	180°	-	A1035	21.3 20.9	21.1	7870	6	1.41
234	11-8-180-0-i-2.5-2-17	A B	180°	-	A1035	17.8 18.0	17.9	8520	7	1.41
235	11-12-180-0-i-2.5-2-17	A B	180°	-	A1035	16.6 16.6	16.6	11880	35	1.41
236	11-5-90-1#4-i-2.5-2-17	A B	90°	Para	A1035	17.8 17.6	17.7	5790	25	1.41
237	11-5-90-1#4-i-3.5-2-17	A B	90°	Para	A1035	17.8 17.8	17.8	5790	25	1.41
238	11-5-90-2#3-i-2.5-2-17	A B	90°	Para	A1035	17.4 17.8	17.6	5600	24	1.41

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

Table A.3 Cont. Comprehensive test results and data for No. 11 specimens with two hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout°
213	A B	0.085	21.9	27.4	19.5	8.375	2.6 2.9	2.8	2.2 2.3	13.6	2	169	A16
214	A B	0.085	21.4	19.3	19.5	8.375	2.5 2.4	2.4	2.6 2.9	13.8	2	116	A16
215	A B	0.085	21.6	19.3	19.5	8.375	2.5 2.5	2.5	2.2 2.7	13.8	2	117	A7
216	A B	0.085	21.3	19.2	19.5	8.375	2.5 2.6	2.5	2.3 1.9	13.4	2	114	A7
217	A B	0.069	21.6	16.0	19.5	8.375	2.8 2.8	2.8	2.5 0.8	13.3	2	97	A7
218	A B	0.085	21.5	28.1	19.5	8.375	2.5 2.9	2.7	2.1 2.1	13.3	2	169	A12
219	A B	0.085	14.1	26.0	19.5	8.375	2.6 2.6	2.6	12.0 12.1	6.2	2	103	A14
220	A B	0.085	21.2	19.3	19.5	8.375	2.5 2.5	2.5	2.0 1.3	13.4	2	114	A16
221	A B	0.085	21.1	23.4	19.5	8.375	2.5 2.8	2.6	3.4 2.3	13.0	2	138	A13
222	A B	0.085	21.3	19.3	19.5	8.375	2.5 2.5	2.5	3.0 1.1	13.5	2	115	A8
223	A B	0.085	21.2	19.3	19.5	8.375	2.5 2.6	2.6	3.1 2.4	13.3	2	114	A13
224	A B	0.085	22.8	19.8	19.5	8.375	3.8 2.5	3.1	2.1 2.0	13.8	2	126	A7
225	A B	0.085	20.9	27.3	19.5	8.375	2.5 2.5	2.5	2.4 2.9	13.1	2	160	A12
226	A B	0.085	21.3	26.0	19.5	8.375	2.5 2.5	2.5	2.0 1.3	13.5	2	155	A11
227	A B	0.085	20.9	13.1	19.5	8.375	2.4 2.8	2.6	1.0 1.6	13.0	2	77	A2
228	A B	0.085	21.9	12.0	19.5	8.375	2.8 2.7	2.7	2.5 2.5	13.6	2	74	A15
229	A B	0.085	21.4	17.0	19.5	8.375	2.8 2.8	2.8	3.0 3.0	13.0	2	102	A15
230	A B	0.085	23.8	20.0	19.5	8.375	4.0 3.9	3.9	1.8 2.5	13.1	2	133	A7
231	A B	0.069	23.7	16.3	19.5	8.375	3.8 3.9	3.8	1.5 1.0	13.3	2	108	A7
232	A B	0.085	23.8	28.4	19.5	8.375	3.8 3.8	3.8	2.1 2.6	13.5	2	189	A12
233	A B	0.085	21.1	23.1	19.5	8.375	2.9 2.4	2.7	1.8 2.2	13.0	2	137	A13
234	A B	0.085	21.4	19.1	19.5	8.375	2.4 2.5	2.4	1.4 1.1	13.8	2	115	A8
235	A B	0.085	21.6	19.2	19.5	8.375	3.0 2.5	2.8	2.5 2.5	13.3	2	116	A13
236	A B	0.085	21.4	19.6	19.5	8.375	2.8 2.8	2.8	1.8 2.0	13.1	2	117	A7
237	A B	0.085	23.6	19.5	19.5	8.375	3.8 3.9	3.8	1.8 1.8	13.1	2	129	A7
238	A B	0.085	21.3	19.6	19.5	8.375	2.5 2.6	2.6	2.3 1.8	13.4	2	117	A7

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

° Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.3 Cont. Comprehensive test results and data for No. 11 specimens with two hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type
213	A B	194500 170700	178670 170860	349530	174765	124679 109423	112029	124103	- -	SB SB
214	A B	121403 105721	108779 105638	214417	107209	77822 67770	68723	81606	- -	SB/FB SB/TK
215	A B	123725 105794	105010 105794	210804	105402	79311 67817	67565	92862	0.143 -	FB/TK FP/TK
216	A B	83343 90122	83343 83644	166986	83493	53425 57770	53521	93894	- -	SS/FP SB
217	A B	67249 81430	67249 65931	133180	66590	43108 52199	42686	51027	0.139 -	FP/SS SS
218	A B	165682 146801	150653 146801	297454	148727	106206 94103	95338	96429	- -	FB/SS FB/SS/TK
219	A B	58206 63035	58206 62981	121186	60593	37311 40407	38842	51547	0.2 -	FP FP
220	A B	131998 141233	131969 132141	264111	132055	84614 90534	84651	86842	- -	FP/TK FB/TK
221	A B	127061 147904	127061 123191	250252	125126	81449 94810	80209	92409	- -	FP/TK FB
222	A B	105626 115172	105537 104020	209557	104779	67709 73828	67166	80368	- -	SS FP
223	A B	148361 120380	148361 120380	268741	134371	95103 77167	86135	91106	- -	SB SB/FP
224	A B	125648 123622	125648 123597	249245	124622	80544 79245	79886	103451	- 0.25	SS/TK SS
225	A B	205050 198110	201395 198091	399486	199743	131443 126994	128040	144027	- -	SB SB
226	A B	212601 231323	212601 213928	426530	213265	136283 148284	136708	157068	- -	SB/TK SB/TK
227	A B	48563 47717	48563 47689	96252	48126	31130 30588	30850	76117	- 0.252	FL FL
228	A B	52097 50882	52097 50866	102962	51481	33395 32617	33001	57045	- -	FP FP
229	A B	93327 91008	93327 91008	184335	92168	59825 58339	59082	84066	- -	SB SB
230	A B	105772 117570	105772 110472	216244	108122	67803 75366	69309	67763	0.187 -	SS/TK SS
231	A B	82601 68982	70046 68982	139027	69514	52949 44219	44560	53246	- -	FP/SS FP/SS/TK
232	A B	198346 181661	183026 181481	364508	182254	127145 116449	116829	101683	- -	SB/FB FB/SB
233	A B	137773 126839	129406 126839	256246	128123	88316 81307	82130	94656	- -	FB FB/SB
234	A B	101710 121269	101710 99197	200907	100453	65199 77737	64393	83583	- -	FP FB
235	A B	106726 108195	106726 108195	214921	107461	68414 69356	68885	91796	0.156 -	SB/FP SS
236	A B	99443 119681	99403 103592	202995	101498	63746 76718	65063	68180	- -	SS/FP FP/SS
237	A B	105692 108846	103693 108846	212540	106270	67751 69773	68122	68421	- -	SS SS/FP/TK
238	A B	108406 103234	98172 103218	201390	100695	69491 66200	64548	66578	- -	SS/FP SS/FP

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

Table A.3 Cont. Comprehensive test results and data for No. 11 specimens with two hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.^{2}	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
213	A B	60	-	-	-	-	-	-	-	0.50	6.0	-	-	9.48	60
214	A B	60	-	-	-	-	-	-	-	0.50	6.0	-	-	9.48	60
215	A B	60	-	-	-	-	-	-	-	0.50	3.5	-	-	4.74	60
216	A B	60	-	-	-	-	-	-	-	0.50	3.5	-	-	4.74	60
217	A B	60	-	-	-	-	2.4	12	4.0	0.50	4.0	0.375	2	4.74	60
218	A B	60	-	-	-	-	1.86	6	4.0	0.50	4.0	0.375	1	6.32	60
219	A B	60	-	-	-	-	-	-	-	0.50	7.0	-	-	7.90	60
220	A B	60	-	-	-	-	-	-	-	0.50	6.0	-	-	9.48	60
221	A B	60	-	-	-	-	-	-	-	0.50	6.0	-	-	9.40	60
222	A B	60	-	-	-	-	-	-	-	0.50	8.0	-	-	6.28	60
223	A B	60	-	-	-	-	-	-	-	0.50	6.0	-	-	9.40	60
224	A B	60	-	-	-	-	2.4	12	4.0	0.50	4.0	-	-	4.74	60
225	A B	60	-	-	-	-	3.6	18	4.0	0.50	4.0	0.5	1	6.32	60
226	A B	60	-	-	-	-	-	-	-	0.50	3.5	-	-	6.32	60
227	A B	60	-	-	-	-	-	-	-	0.50	3.0	-	-	3.16	60
228	A B	60	-	-	-	-	-	-	-	0.50	4.5	-	-	6.94	120
229	A B	60	-	-	-	-	-	-	-	0.50	4.5	-	-	6.94	120
230	A B	60	-	-	-	-	2.4	12	4.0	0.50	4.0	0.375	2	4.74	60
231	A B	60	-	-	-	-	2.4	12	4.0	0.50	4.0	0.375	2	4.74	60
232	A B	60	-	-	-	-	1.86	6	4.0	0.50	4.0	0.375	1	6.32	60
233	A B	60	-	-	-	-	-	-	-	0.50	6.0	-	-	9.40	60
234	A B	60	-	-	-	-	-	-	-	0.50	8.0	-	-	6.28	60
235	A B	60	-	-	-	-	-	-	-	0.50	6.0	-	-	9.40	60
236	A B	60	0.5	0.20	1	8.75	2.2	11	4.0	0.50	4.0	0.375	2	4.74	60
237	A B	60	0.5	0.20	1	8.75	2.2	11	4.0	0.50	4.0	0.375	2	4.74	60
238	A B	60	0.38	0.11	2	8.00	2	10	4.0	0.50	4.0	0.375	2	4.74	60

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

Table A.3 Cont. Comprehensive test results and data for No. 11 specimens with two hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
239	11-5-90-2#3-i-2.5-2-14	A B	90°	Para	A615	13.5 13.8	13.6	4910	13	1.41
240	(2@5.35) 11-5-90-2#3-i-2.5-13-13	A B	90°	Para	A615	13.9 13.8	13.8	5330	11	1.41
241	11-12-90-2#3-i-2.5-2-17.5	A B	90°	Para	A1035	18.0 17.5	17.8	13710	30	1.41
242	11-12-90-2#3-i-2.5-2-25	A B	90°	Para	A1035	25.0 24.5	24.8	13710	30	1.41
243	11-15-90-2#3-i-2.5-2-23	A B	90°	Para	A1035	23.5 23.5	23.5	16180	62	1.41
244	11-15-90-2#3-i-2.5-2-10.5	A B	90°	Para	A1035	11.8 10.5	11.1	16180	63	1.41
245	11-15-90-2#3-i-2.5-2-10‡	A B	90°	Para	A615	10.0 10.0	10.0	14045	76	1.41
246	11-15-90-2#3-i-2.5-2-15‡	A B	90°	Para	A1035	14.0 14.3	14.1	14045	80	1.41
247	11-5-90-2#3-i-3.5-2-17	A B	90°	Para	A1035	17.5 17.8	17.6	7070	28	1.41
248	11-5-90-2#3-i-3.5-2-14	A B	90°	Para	A615	14.5 13.4	13.9	4910	12	1.41
249	11-5-90-5#3-i-2.5-2-14	A B	90°	Para	A615	14.3 13.5	13.9	4910	12	1.41
250	11-5-90-5#3-i-3.5-2-14	A B	90°	Para	A615	14.6 14.5	14.6	4910	14	1.41
251	11-8-90-6#3-o-2.5-2-16	A B	90°	Para	A1035	15.9 16.5	16.2	9420	8	1.41
252	11-8-90-6#3-o-2.5-2-22	A B	90°	Para	A1035	21.5 22.3	21.9	9120	7	1.41
253	11-12-90-6#3-o-2.5-2-17	A B	90°	Para	A1035	15.6 17.3	16.4	11800	36	1.41
254	11-12-180-6#3-o-2.5-2-17	A B	180°	Para	A1035	16.6 16.4	16.5	11800	36	1.41
255	11-5-90-6#3-i-2.5-2-20	A B	90°	Para	A1035	19.5 19.0	19.3	5420	7	1.41
256	(2@5.35) 11-5-90-6#3-i-2.5-13-13	A B	90°	Para	A615	14.0 13.8	13.9	5280	12	1.41
257	(2@5.35) 11-5-90-6#3-i-2.5-18-18	A B	90°	Para	A1035	19.3 19.5	19.4	5280	12	1.41
258	11-8-90-6#3-i-2.5-2-16	A B	90°	Para	A1035	15.5 16.4	15.9	9120	7	1.41
259	11-8-90-6#3-i-2.5-2-22	A B	90°	Para	A1035	21.3 21.5	21.4	9420	8	1.41
260	11-8-90-6#3-i-2.5-2-22	A B	90°	Para	A1035	21.9 22.0	21.9	9420	8	1.41
261	11-8-90-6#3-i-2.5-2-15	A B	90°	Para	A1035	15.8 15.3	15.5	7500	5	1.41
262	11-8-90-6#3-i-2.5-2-19	A B	90°	Para	A1035	19.1 19.4	19.2	7500	5	1.41
263	11-12-90-6#3-i-2.5-2-17	A B	90°	Para	A1035	17.1 16.5	16.8	12370	37	1.41
264	11-12-90-6#3-i-2.5-2-16	A B	90°	Para	A1035	14.8 16.0	15.4	13710	31	1.41

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

Table A.3 Cont. Comprehensive test results and data for No. 11 specimens with two hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout°
239	A B	0.069	21.7	16.0	19.5	8.375	2.8 2.9	2.8	2.5 2.3	13.3	2	97	A7
240	A B	0.085	14.3	26.0	19.5	8.375	2.7 2.6	2.6	12.1 12.3	6.2	2	104	A14
241	A B	0.085	21.1	19.5	19.5	8.375	2.5 2.5	2.5	1.5 2.0	13.3	2	115	A7
242	A B	0.085	21.4	27.3	19.5	8.375	2.6 3.0	2.8	2.3 2.8	13.0	2	164	A12
243	A B	0.085	21.3	25.0	19.5	8.375	2.8 2.8	2.8	1.5 1.5	13.0	2	149	A11
244	A B	0.085	21.8	12.8	19.5	8.375	2.5 2.8	2.6	1.0 2.3	13.8	2	78	A2
245	A B	0.085	22.0	12.0	19.5	8.375	2.8 3.0	2.9	2.0 2.0	13.4	2	74	A15
246	A B	0.085	21.5	17.0	19.5	8.375	2.6 2.6	2.6	3.0 2.8	13.6	2	102	A15
247	A B	0.085	23.4	19.7	19.5	8.375	3.6 3.6	3.6	2.1 2.0	13.4	2	129	A7
248	A B	0.069	23.7	16.1	19.5	8.375	3.8 3.9	3.8	1.6 2.8	13.3	2	107	A7
249	A B	0.069	21.8	16.0	19.5	8.375	2.8 2.9	2.8	1.8 2.5	13.4	2	98	A7
250	A B	0.069	23.7	16.0	19.5	8.375	3.9 3.9	3.9	1.4 1.5	13.1	2	106	A7
251	A B	0.085	21.6	18.1	19.5	8.375	2.5 2.6	2.6	2.3 1.6	13.6	2	109	A16
252	A B	0.085	21.4	24.4	19.5	8.375	2.5 2.6	2.6	2.9 2.1	13.5	2	146	A16
253	A B	0.085	21.4	19.3	19.5	8.375	2.5 2.4	2.4	3.6 2.0	13.8	2	116	A7
254	A B	0.085	21.6	19.5	19.5	8.375	2.5 2.8	2.6	2.9 3.1	13.5	2	118	A7
255	A B	0.085	20.9	22.3	19.5	8.375	2.6 2.6	2.6	2.8 3.3	12.9	2	130	A7
256	A B	0.085	14.2	26.0	19.5	8.375	2.4 2.8	2.6	12.0 12.3	6.2	2	103	A14
257	A B	0.085	14.3	36.0	19.5	8.375	2.7 2.6	2.6	16.8 16.5	6.2	2	144	A14
258	A B	0.085	21.2	18.3	19.5	8.375	2.5 2.5	2.5	2.8 1.9	13.4	2	108	A16
259	A B	0.085	21.4	24.1	19.5	8.375	2.5 2.6	2.6	2.8 2.6	13.5	2	145	A11
260	A B	0.085	21.7	24.2	19.5	8.375	2.6 2.9	2.8	2.3 2.2	13.4	2	147	A16
261	A B	0.085	21.6	17.3	19.5	8.375	2.8 2.5	2.6	1.5 2.0	13.5	2	104	A13
262	A B	0.085	21.4	21.0	19.5	8.375	2.5 2.6	2.6	2.0 1.7	13.5	2	126	A13
263	A B	0.085	21.4	19.1	19.5	8.375	2.6 3.0	2.8	1.9 2.6	13.0	2	114	A13
264	A B	0.085	20.8	18.0	19.5	8.375	2.5 2.5	2.5	3.3 2.0	13.0	2	105	A7

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
° Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.3 Cont. Comprehensive test results and data for No. 11 specimens with two hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type
239	A B	77718 77214	77718 77127	154845	77422	49819 49496	49630	48365	0.206 -	FP/SS SS
240	A B	68288 70143	68250 69997	138247	69123	43774 44963	44310	51084	-	FP FP
241	A B	133178 129868	132555 128223	260779	130389	85371 83249	83583	105286	- -	SS SS
242	A B	210112 205996	210112 205996	416108	208054	134687 132049	133368	146807	- -	BY BY
243	A B	232100 206900	212550 206600	419150	209575	148782 132628	134343	151429	- -	SB SB/FB
244	A B	50558 49575	50558 49547	100105	50053	32409 31779	32085	71687	0.249 -	FL FL
245	A B	64250 63631	64250 63631	127881	63940	41186 40789	40987	60036	-	FP FP
246	A B	115577 114801	115577 114801	230377	115189	74088 73590	73839	84801	- -	FP/SB FP/SB
247	A B	107807 111480	107807 111480	219287	109644	69107 71462	70284	75074	- -	SS/FP/TK SS
248	A B	92719 81848	82732 81817	164549	82275	59435 52467	52740	49474	- -	FP/SS SS/FP/TK
249	A B	105597 94115	96267 94072	190339	95170	67690 60330	61006	49252	0.397 0.375	SS/FP SS/FP
250	A B	101315 94663	101315 94663	195979	97989	64946 60682	62814	51693	- -	FP/SS SS/FP
251	A B	138900 134714	138793 134714	273507	136753	89038 86355	87662	99487	- -	SB/FB SB/FB
252	A B	186100 170498	170000 170498	340498	170249	119295 109294	109134	132284	- -	SB SB/FB
253	A B	116430 147268	116390 115367	231757	115878	74635 94403	74281	113068	- -	FB/SS SB/FB
254	A B	130005 113819	112424 113819	226243	113121	83337 72961	72514	113498	- 0.112	SB FB/SS
255	A B	153119 134977	137617 134927	272543	136272	98153 86524	87354	89741	0.274 -	FP/SS FP/SS
256	A B	83757 95951	83556 95940	179496	89748	53691 61507	57531	63843	- -	FP FP
257	A B	118507 128624	116107 127103	243210	121605	75966 82451	77952	89150	 -	FP FP
258	A B	147508 129692	136385 129586	265971	132986	94556 83136	85247	96379	- -	FP/SS FP/SS
259	A B	204260 183175	186246 182892	369138	184569	130936 117420	118314	131369	- -	* SS
260	A B	197739 191344	190740 191344	382084	191042	126756 122656	122463	134827	- -	* SB/FB
261	A B	142278 108021	108602 108021	216623	108312	91204 69245	69431	85001	- -	SS SS/FP
262	A B	182735 146093	144766 146093	290860	145430	117138 93650	93224	105395	- -	FB/SS FB/SS
263	A B	179693 162285	161019 162277	323295	161648	115188 104029	103620	118408	0.334 -	FB/SB SP/SS
264	A B	115139 127542	115089 115306	230394	115197	73807 81700	73844	113998	- 0.952	SS/FP SB/FB

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
*Test terminated prior to failure of second hooked bar

Table A.3 Cont. Comprehensive test results and data for No. 11 specimens with two hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.^{2}	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
239	A B	60	0.38	0.11	2	8.00	2.4	12	4.0	0.50	4.0	0.375	2	4.74	60
240	A B	60	0.38	0.11	2	8.00	-	-	-	0.50	7.0	-	-	7.90	60
241	A B	60	0.38	0.11	2	12.00	2.4	12	4.0	0.50	4.0	-	-	4.74	60
242	A B	60	0.38	0.11	2	12.00	3.2	16	4.0	0.50	4.0	0.5	1	6.32	60
243	A B	60	0.38	0.11	2	8.00	-	-	-	0.50	3.0	-	-	6.32	60
244	A B	60	0.38	0.11	2	8.00	-	-	-	0.50	2.8	-	-	3.16	60
245	A B	60	0.38	0.11	2	8.00	-	-	-	0.50	4.5	-	-	6.94	120
246	A B	60	0.38	0.11	2	8.00	-	-	-	0.50	4.5	-	-	6.94	120
247	A B	60	0.38	0.11	2	8.00	2	10	4.0	0.50	4.0	0.375	2	4.74	60
248	A B	60	0.38	0.11	2	8.00	2.4	12	4.0	0.50	4.0	0.375	2	4.74	60
249	A B	60	0.38	0.11	5	4.38	2.4	12	4.0	0.50	4.0	0.375	2	4.74	60
250	A B	60	0.38	0.11	5	4.38	2.4	12	4.0	0.50	4.0	0.375	2	4.74	60
251	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	6.0	-	-	9.48	60
252	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	6.0	-	-	9.48	60
253	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	3.5	-	-	4.74	60
254	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	3.5	-	-	4.74	60
255	A B	60	0.38	0.11	6	4.00	1.2	6	4.0	0.50	4.0	0.375	2	4.74	60
256	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	7.0	-	-	7.90	60
257	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	7.0	-	-	7.90	60
258	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	6.0	-	-	9.48	60
259	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	2.5	-	-	6.32	60
260	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	6.0	-	-	9.48	60
261	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	6.0	-	-	9.40	60
262	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	6.0	-	-	9.40	60
263	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	6.0	-	-	9.40	60
264	A B	60	0.38	0.11	6	4.00	2.4	12	4.0	0.50	4.0	0.375	1	4.74	60

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

Table A.3 Cont. Comprehensive test results and data for No. 11 specimens with two hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
265	11-12-90-6#3-i-2.5-2-22	A B	90°	Para	A1035	21.9 21.5	21.7	13710	31	1.41
266	11-15-90-6#3-i-2.5-2-22	A B	90°	Para	A1035	22.3 22.4	22.3	16180	62	1.41
267	11-15-90-6#3-i-2.5-2-9.5	A B	90°	Para	A1035	9.0 10.3	9.6	16180	63	1.41
268	11-15-90-6#3-i-2.5-2-10a‡	A B	90°	Para	A615	9.5 10.0	9.8	14045	76	1.41
269	11-15-90-6#3-i-2.5-2-10b‡	A B	90°	Para	A615	9.5 9.8	9.6	14050	77	1.41
270	11-15-90-6#3-i-2.5-2-15‡	A B	90°	Para	A1035	14.5 15.0	14.8	14045	80	1.41
271	11-5-90-6#3-i-3.5-2-20	A B	90°	Para	A1035	20.5 20.3	20.4	5420	7	1.41
272	11-8-180-6#3-i-2.5-2-15	A B	180°	Para	A1035	15.1 15.5	15.3	7500	5	1.41
273	11-8-180-6#3-i-2.5-2-19	A B	180°	Para	A1035	19.6 19.9	19.8	7870	6	1.41
274	11-12-180-6#3-i-2.5-2-17	A B	180°	Para	A1035	16.9 16.5	16.7	12370	37	1.41
275	11-12-180-6#3-i-2.5-2-17	A B	180°	Para	A1035	16.8 16.8	16.8	12370	37	1.41
276	11-5-90-5#4s-i-2.5-2-20	A B	90°	Para	A1035	20.0 20.3	20.1	5420	7	1.41
277	11-5-90-5#4s-i-3.5-2-20	A B	90°	Para	A1035	19.8 19.3	19.5	5960	8	1.41

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

Table A.3 Cont. Comprehensive test results and data for No. 11 specimens with two hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout[o]
265	A B	0.085	22.1	24.3	19.5	8.375	2.9 3.1	3.0	2.4 2.8	13.3	2	150	A12
266	A B	0.085	21.8	24.0	19.5	8.375	3.0 2.5	2.8	1.8 1.6	13.5	2	147	A10
267	A B	0.085	21.6	11.5	19.5	8.375	2.5 3.0	2.8	2.5 1.3	13.3	2	69	A2
268	A B	0.085	21.5	12.0	19.5	8.375	2.6 2.8	2.7	2.5 2.0	13.4	2	72	A15
269	A B	0.085	21.4	12.0	19.5	8.375	2.8 2.8	2.8	2.5 2.3	13.0	2	72	A10
270	A B	0.085	21.5	17.0	19.5	8.375	2.6 2.6	2.6	2.5 2.0	13.6	2	102	A15
271	A B	0.085	23.6	22.3	19.5	8.375	3.8 3.9	3.8	1.8 2.0	13.1	2	147	A7
272	A B	0.085	21.8	17.1	19.5	8.375	2.9 3.1	3.0	2.0 1.6	13.0	2	104	A13
273	A B	0.085	21.8	21.2	19.5	8.375	2.9 2.9	2.9	1.5 1.3	13.3	2	129	A13
274	A B	0.085	21.7	19.8	19.5	8.375	2.6 2.8	2.7	2.9 3.3	13.5	2	120	A7
275	A B	0.085	21.4	19.4	19.5	8.375	2.5 2.8	2.6	2.7 2.6	13.4	2	117	A13
276	A B	0.085	21.4	22.3	19.5	8.375	2.5 2.8	2.6	2.3 2.0	13.4	2	134	A7
277	A B	0.085	23.4	22.0	19.5	8.375	3.8 3.8	3.8	2.3 2.8	13.1	2	144	A7

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

º Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.3 Cont. Comprehensive test results and data for No. 11 specimens with two hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type
265	A	206283	203983	402379	201189	132233	128967	160802	-	SS/FB
	B	199234	198395			127714			-	FB
266	A	204557	200084	395618	197809	131126	126801	179722	-	FB/SS
	B	195710	195534			125455			-	SB/FB
267	A	58154	58154	114765	57383	37278	36784	77527	0.358	FL
	B	56612	56612			36290			-	FL
268	A	83558	83558	165362	82681	53563	53001	73169	-	FP
	B	81804	81804			52438			-	FP
269	A	76605	76605	151158	75579	49106	48448	72244		FP
	B	74596	74553			47818			-	FP
270	A	145670	145664	290534	145267	93378	93120	110692	-	FP
	B	144870	144870			92866			-	FP
271	A	150216	136607	271643	135821	96293	87065	94986	-	SS/FP
	B	135259	135036			86704			-	SS
272	A	112423	112423	223356	111678	72066	71588	83973	-	SS
	B	110981	110933			71142			-	SS
273	A	170000	149000	298000	149000	108974	95513	110947	-	FB/SS
	B	149000	149000			95513			-	FB/SS
274	A	123150	115105	232743	116371	78942	74597	117527	-	FP
	B	117638	117638			75409			0.379	FP/SB
275	A	148872	148872	297356	148678	95431	95306	118188	-	FP/SS
	B	173034	148484			110919			-	SB/FB
276	A	141399	141399	282090	141045	90640	90414	75057	-	FP/SS
	B	161640	140691			103615			-	FP/SS
277	A	186703	152402	305934	152967	119681	98056	76262	-	SS/FP
	B	153546	153532			98400			-	FP/SS

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

Table A.3 Cont. Comprehensive test results and data for No. 11 specimens with two hooks

	Hook	**f_{yt} ksi**	**d_{tr} in.**	**$A_{tr,l}$ in.^{2}**	**N_{tr}**	**s_{tr} in.**	**A_{cti} in.^{2}**	**N_{cti}**	**s_{cti} in.**	**d_s in.**	**s_s in.**	**d_{cto} in.**	**N_{cto}**	**A_s in.^{2}**	**f_{ys} ksi**
265	A B	60	0.38	0.11	6	4.00	3.06	12	4.0	0.50	4.0	0.375	2	6.32	60
266	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	3.0	-	-	6.32	60
267	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	2.3	-	-	3.16	60
268	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	4.5	-	-	6.94	120
269	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	4.5	-	-	6.32	120
270	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	4.5	-	-	6.94	120
271	A B	60	0.38	0.11	6	4.00	1.2	6	4.0	0.50	4.0	0.375	2	4.74	60
272	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	6.0	-	-	9.40	60
273	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	6.0	-	-	9.40	60
274	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	3.0	-	-	4.74	60
275	A B	60	0.38	0.11	6	4.00	-	-	-	0.50	6.0	-	-	9.40	60
276	A B	60	0.5	0.20	5	5.00	4	10	5.0	0.50	5.0	0.375	2	4.74	60
277	A B	60	0.5	0.20	5	5.00	4	10	5.0	0.50	5.0	0.375	2	4.74	60

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

Table A.4 Cont. Comprehensive test results and data for No. 5 specimens with multiple hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
278	(4@4) 5-5-90-0-i-2.5-2-6	A B C D	90°	-	A1035	5.4 5.3 4.8 5.3	5.2	6430	11	0.625
279	(4@4) 5-5-90-0-i-2.5-2-10	A B C D	90°	-	A1035	9.0 8.0 9.3 9.9	9.0	6470	12	0.625
280	(4@4) 5-8-90-0-i-2.5-2-6	A B C D	90°	-	A1035	6.3 5.8 5.8 6.0	5.9	6950	18	0.625
281	(4@6) 5-8-90-0-i-2.5-2-6	A B C D	90°	-	A1035	6.0 6.0 5.8 6.0	5.9	6693	21	0.625
282	(4@6) 5-8-90-0-i-2.5-6-6	A B C D	90°	-	A1035	6.3 6.3 6.3 6.3	6.3	6693	21	0.625
283	(3@4) 5-8-90-0-i-2.5-2-6	A B C	90°	-	A1035	6.0 5.6 6.0	5.9	6950	18	0.625
284	(3@6) 5-8-90-0-i-2.5-2-6	A B C	90°	-	A1035	6.4 5.9 5.8	6.0	6950	18	0.625
285	(4@4) 5-5-90-2#3-i-2.5-2-6	A B C D	90°	Para	A1035	6.3 6.1 6.3 6.4	6.3	6430	11	0.625
286	(4@4) 5-5-90-2#3-i-2.5-2-8	A B C D	90°	Para	A1035	8.4 7.8 8.0 7.8	8.0	6430	11	0.625
287	(3@6) 5-8-90-5#3-i-2.5-2-6.25	A B C	90°	Para	A1035	5.0 6.3 5.3	5.5	10110	196	0.625
288	(3@4) 5-8-90-5#3-i-2.5-2-6‡	A B C	90°	Para	A1035	6.0 6.3 6.0	6.1	6703	22	0.625
289	(3@6) 5-8-90-5#3-i-2.5-2-6‡	A B C	90°	Para	A1035	6.0 6.0 6.0	6.0	6703	22	0.625
290	(4@4) 5-5-90-5#3-i-2.5-2-7	A B C D	90°	Para	A1035	6.6 7.9 7.5 6.5	7.1	6430	11	0.625
291	(4@4) 5-5-90-5#3-i-2.5-2-6	A B C D	90°	Para	A1035	6.0 6.5 6.6 6.3	6.3	6430	11	0.625

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

Table A.4 Cont. Comprehensive test results and data for No. 5 specimens with multiple hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout°
278	A B C D	0.073	13.2	8.2	5.3	8.375	2.4 4.9 5.1 2.8	2.6	2.8 2.9 3.4 2.9	1.9 1.9 1.8	4	30	A1
279	A B C D	0.073	13.2	12.3	5.3	8.375	2.6 5.0 5.0 2.8	2.7	3.3 4.3 3.0 2.4	1.8 1.9 1.6 -	4	30	A1
280	A B C D	0.073	12.9	8.0	5.3	8.375	2.5 5.0 5.0 2.5	2.5	1.8 2.3 2.3 2.0	1.9 1.6 1.9 -	4	30	A2
281	A B C D	0.073	17.3	8.0	5.3	8.375	2.7 6.5 6.5 2.7	2.7	2.0 2.0 2.3 2.0	3.1 3.1 3.1 -	4	30	A2
282	A B C D	0.073	17.1	12.0	5.3	8.375	2.5 6.3 6.5 2.7	2.6	5.8 5.8 5.8 5.8	3.1 3.1 3.1 -	4	30	A7
283	A B C	0.073	10.75	8.0	5.3	8.375	2.6 5.6 2.7	2.6	2.0 2.4 2.0	1.8 1.9 -	3	30	A2
284	A B C	0.073	13.25	8.0	5.3	8.375	2.6 6.2 2.7	2.6	1.6 2.1 2.3	3.0 3.1 -	3	30	A2
285	A B C D	0.073	12.9	8.1	5.3	8.375	2.5 5.0 4.8 2.5	2.5	1.9 2.0 1.9 1.8	1.9 1.9 1.6 -	4	30	A1
286	A B C D	0.073	13.0	10.1	5.3	8.375	2.5 5.0 4.9 2.5	2.5	1.8 2.4 2.1 2.4	1.9 1.9 1.8 -	4	30	A1
287	A B C	0.073	12.75	8.8	5.3	8.375	2.5 5.4 2.5	2.5	3.8 2.6 3.6	2.9 3.0 -	3	30	A1
287	A B C	0.073	10.85	8.0	5.3	8.375	2.5 5.0 2.5	2.5	2.0 1.8 2.0	2.1 1.9 -	3	30	A2
288	A B C	0.073	13.38	8.0	5.3	8.375	2.5 5.0 2.5	2.5	2.0 2.0 2.0	3.4 3.1 -	3	30	A2
290	A B C D	0.073	12.5	9.1	5.3	8.375	2.5 4.6 4.6 2.4	2.4	2.5 1.3 1.6 2.6	1.5 2.0 1.6 -	4	30	A1
291	A B C D	0.073	13.1	8.5	5.3	8.375	2.5 5.1 5.0 2.6	2.6	2.5 2.0 1.9 2.3	2.0 1.8 1.8 -	4	30	A1

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
° Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.4 Cont. Comprehensive test results and data for No. 5 specimens with multiple hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type†
278	A	12150	12150	58167	14542	39194	46909	47396	-	FP
	B	16822	16822			54265			-	FP
	C	15517	15510			50055			-	FP
	D	13684	13684			44142			-	FP
279	A	27937	27938	113608	28402	90119	91619	83022	-	FP
	B	28572	28455			92168			0.358	FP
	C	44806	31762			144535			-	FP
	D	27649	25453			89190			-	FP
280	A	17307	17307	61916	15479	55829	49932	56570	-	FP/SS
	B	17615	17430			56823			-	FP/SS
	C	14066	13684			45374			-	FP/SS
	D	14082	13495			45426			-	FP/SS
281	A	20647	17356	77211	19303	66603	62267	55514	-	FP
	B	22459	22123			72448			-	FP
	C	22914	22649			73916			-	FP
	D	15140	15082			48839			-	FP
282	A	16185	16185	64205	16051	52210	51778	58436	-	FP/SS
	B	14727	14728			47506			-	FP/SS
	C	16472	16472			53135			-	FP/SS
	D	16819	16819			54255			-	FP/SS
283	A	18497	18326	50416	16805	59668	54211	55975	-	FP
	B	17550	17370			56613			-	FP
	C	14720	14720			47484			-	FP
284	A	25526	25526	74657	24886	82342	80277	57166	-	FP
	B	34858	25964			112445			-	FP
	C	23167	23167			74732			-	FP
285	A	22446	21831	85621	21405	72406	69049	57277	-	FP
	B	22211	18818			71648			0.23	FP
	C	24049	23273			77577			-	FP
	D	21725	21699			70081			0.484	FP
286	A	23977	23111	104069	26017	77345	83926	73028	-	FP
	B	31206	28774			100665			0.365	FP
	C	35987	28714			116087			-	FP
	D	23712	23469			76490			0.398	FP
287	A	27125	27035	77489	25830	87498	83321	79002	-	FP
	B	32375	24934			104436			-	FP
	C	27035	25519			87210			-	FP
288	A	35751	35751	104667	34889	115326	112545	71151	-	FP
	B	34693	34518			111913			-	FP
	C	34397	34397			110958			-	FP
289	A	37827	37754	109345	36448	122023	117576	70176	-	FP
	B	34172	34152			110232			-	FP
	C	37469	37439			120868			-	FP
290	A	27259	26864	108458	27114	87932	87466	65295	-	FP
	B	37030	32039			119452			-	FP
	C	29522	29523			95232			-	FP
	D	22950	20032			74032			-	FP
291	A	24862	24863	103591	25898	80200	83541	58136	-	FP
	B	27208	27018			87700			-	FP
	C	26773	26774			86500			0.333	FP
	D	26616	24937			85800			-	FP

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

Table A.4 Cont. Comprehensive test results and data for No. 5 specimens with multiple hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
278	A B C D	60	-	-	-	-	1.10	10	2.0	0.375	2.5	0.375	1	1.27	60
279	A B C D	60	-	-	-	-	1.10	10	2.0	0.375	3.0	0.500	1	1.27	60
280	A B C D	60	-	-	-	-	-	-	-	0.375	3.0	-	-	3.16	60
281	A B C D	60	-	-	-	-	-	-	-	0.375	3.0	-	-	3.16	60
282	A B C D	60	-	-	-	-	-	-	-	0.375	3.0	-	-	4.74	60
283	A B C	60	-	-	-	-	-	-	-	0.375	3.0	-	-	3.16	60
284	A B C	60	-	-	-	-	-	-	-	0.375	3.0	-	-	3.16	60
285	A B C D	60	0.38	0.11	2	4.0	0.66	6	4.0	0.375	3.0	0.375	2	1.27	60
286	A B C D	60	0.38	0.11	2	5.0	1.20	6	2.5	0.375	3.0	0.500	2	1.27	60
287	A B C	60	0.38	0.11	5	2	-	-	-	0.50	3.0	0.375	1	1.27	60
288	A B C	60	0.38	0.11	5	2	-	-	-	0.38	3.0	-	-	3.16	120
289	A B C	60	0.38	0.11	5	2	-	-	-	0.38	3.0	-	-	3.16	120
290	A B C D	60	0.38	0.11	5	1.8	0.55	5	1.8	0.375	2.8	0.500	2	1.27	60
291	A B C D	60	0.38	0.11	5	2.0	0.55	5	2.0	0.375	3.0	0.375	2	1.27	60

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

Table A.4 Cont. Comprehensive test results and data for No. 5 specimens with multiple hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
292	(4@6) 5-8-90-5#3-i-2.5-2-6‡	A B C D	90°	Para	A1035	6.0 6.0 6.0 6.0	6.0	6693	21	0.625
293	(4@6) 5-8-90-5#3-i-2.5-6-6‡	A B C D	90°	Para	A1035	6.8 6.0 6.5 6.3	6.4	6693	21	0.625
294	(4@4) 5-8-90-5#3-i-2.5-2-6‡	A B C D	90°	Para	A1035	5.8 5.5 6.3 6.5	6.0	6703	22	0.625
295	(3@6) 5-8-90-5#3-i-3.5-2-6.25	A B C	90°	Para	A1035	6.3 6.3 6.3	6.3	10110	196	0.625

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

Table A.4 Cont. Comprehensive test results and data for No. 5 specimens with multiple hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout°
292	A B C D	0.073	17.8	8.0	5.3	8.375	2.7 6.5 6.5 2.7	2.7	2.0 2.0 2.0 2.0	3.4 3.4 3.1 -	4	30	A2
293	A B C D	0.073	16.8	8.0	5.3	8.375	2.5 6.5 6.5 2.7	2.6	1.3 2.0 1.5 1.8	3.1 3.1 2.9 -	4	30	A7
294	A B C D	0.073	13.1	8.0	5.3	8.375	2.5 5.0 5.0 2.5	2.5	2.3 2.5 1.8 1.5	1.9 1.9 1.9 -	4	30	A2
295	A B C	0.073	15	8.3	5.3	8.375	3.5 6.6 3.8	3.6	2.1 2.1 2.1	2.6 3.3 -	3	30	A1

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
° Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.4 Cont. Comprehensive test results and data for No. 5 specimens with multiple hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type†
292	A	30306	30282	113284	28321	97761	91358	56099	-	FP
	B	30095	30085			97081			-	FP
	C	27572	27573			88942			-	FP
	D	25343	25344			81752			-	FP
293	A	3210	32083	124607	31152	10354	100489	59605	-	FP
	B	29935	29930			96565			-	FP
	C	30839	30839			99481			-	FP
	D	31800	31755			102581			-	FP
294	A	27967	27968	109970	27493	90216	88686	56141	-	FP
	B	27348	27348			88219			-	FP
	C	28550	28551			92097			-	FP
	D	26208	26103			84542			-	FP
295	A	36112	36112	105803	35268	116491	113766	89775	-	FP
	B	33789	33344			109000			-	FP
	C	40826	36347			131600			0.454	FP

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

Table A.4 Cont. Comprehensive test results and data for No. 5 specimens with multiple hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
292	A B C D	60	0.38	0.11	5	1.7	-	-	-	0.375	3.0	-	-	3.16	120
293	A B C D	60	0.38	0.11	5	1.7	-	-	-	0.375	3.0	-	-	4.74	120
294	A B C D	60	0.38	0.11	5	1.7	-	-	-	0.375	3.0	-	-	3.16	120
295	A B C	60	0.38	0.11	5	2	-	-	-	0.50	3.0	0.375	1	1.27	60

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

Table A.5 Comprehensive test results and data for No. 8 specimens with multiple hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
296	(3@5.5) 8-5-90-0-i-2.5-2-16	A B C	90°	-	A1035^b	16.5 15.8 16.0	16.1	6255	13	1
297	(3@5.5) 8-5-90-0-i-2.5-2-10	A B C	90°	-	A1035^b	9.0 9.4 9.8	9.4	6461	14	1
298	(3@5.5) 8-5-90-0-i-2.5-2-8‡	A B C	90°	-	A615	7.5 8.0 8.0	7.8	5730	18	1
299	(3@3) 8-5-90-0-i-2.5-2-10‡	A B C	90°	-	A615	10.0 10.3 10.0	10.1	4490	10	1
300	(3@5) 8-5-90-0-i-2.5-2-10‡	A B C	90°	-	A615	10.3 10.1 10.0	10.1	4490	10	1
301	(3@5.5) 8-8-90-0-i-2.5-2-8	A B C	90°	-	A1035^b	7.8 8.8 7.3	7.9	8700	24	1
302	(3@3) 8-8-90-0-i-2.5-9-9	A B C	90°	-	A615	9.5 9.5 9.3	9.4	7510	21	1
303	(3@4) 8-8-90-0-i-2.5-9-9	A B C	90°	-	A615	9.3 9.3 9.3	9.3	7510	21	1
304	(3@3) 8-12-90-0-i-2.5-2-12‡	A B C	90°	-	A1035^c	12.1 12.1 12.2	12.1	11040	31	1
305	(3@4) 8-12-90-0-i-2.5-2-12‡	A B C	90°	-	A1035^c	12.9 12.5 12.5	12.6	11440	32	1
306	(3@5) 8-12-90-0-i-2.5-2-12‡	A B C	90°	-	A1035^c	12.3 12.0 12.3	12.2	11460	33	1
307	(4@3) 8-8-90-0-i-2.5-9-9	A B C D	90°	-	A615	9.4 9.3 9.3 9.6	9.4	7510	21	1
308	(4@4) 8-8-90-0-i-2.5-9-9	A B C D	90°	-	A615	9.4 9.1 9.0 9.1	9.2	7510	21	1
309	(3@3) 8-5-180-0-i-2.5-2-10‡	A B C	180°	-	A615	9.8 10.0 9.8	9.8	5260	15	1
310	(3@5) 8-5-180-0-i-2.5-2-10‡	A B C	180°	-	A615	10.0 10.0 10.0	10.0	5260	15	1
311	(3@5.5) 8-5-90-2#3-i-2.5-2-14	A B C	90°	Para	A1035^b	14.6 13.9 14.8	14.4	6460	14	1
312	(3@5.5) 8-5-90-2#3-i-2.5-2-8.5	A B C	90°	Para	A1035^b	9.8 8.8 8.9	9.1	6460	14	1

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.5 Cont. Comprehensive test results and data for No. 8 specimens with multiple hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout[o]
296	A B C	0.078	17.3	18.1	10.5	8.375	2.6 8.0 2.8	2.7	1.6 2.4 2.1	4.4 4.5 -	3	30	A2
297	A B C	0.078	16.9	12.2	10.5	8.375	2.6 7.9 2.5	2.6	3.2 2.8 2.4	4.4 4.4 -	3	30	A2
298	A B C	0.073	17	10.0	10.5	8.375	2.5 8.0 2.5	2.5	2.5 2.0 2.0	4.5 4.5 -	3	30	A10
299	A B C	0.073	12.8	12.0	10.5	8.375	2.6 5.5 2.5	2.6	2.0 1.8 2.0	2.4 2.3 -	3	30	A2
300	A B C	0.073	16	12.0	10.5	8.375	2.3 7.3 2.5	2.4	1.8 1.9 2.0	4.0 4.3 -	3	30	A2
301	A B C	0.078	16.4	10.1	10.5	8.375	3.0 8.2 2.8	2.9	2.4 1.4 2.9	4.3 3.4 -	3	30	A2
302	A B C	0.073	12.3	18.0	10.5	8.375	2.5 5.6 2.5	2.5	8.5 8.5 8.8	2.1 2.1 -	3	30	A7
303	A B C	0.073	14.1	18.0	10.5	8.375	2.5 6.5 2.5	2.5	8.8 8.8 8.8	3.0 3.1 -	3	30	A7
304	A B C	0.073	12.1	14.0	10.5	8.375	2.5 5.4 2.4	2.5	1.8 1.9 1.8	2.1 2.0 -	3	30	A2
305	A B C	0.073	13.9	14.1	10.5	8.375	2.5 6.4 2.5	2.5	1.3 1.6 1.6	2.9 3.0 -	3	30	A2
306	A B C	0.073	15.9	14.0	10.5	8.375	2.4 7.4 2.5	2.4	1.8 2.0 1.8	4.0 4.0 -	3	30	A2
307	A B C D	0.073	15.0	18.0	10.5	8.375	2.5 5.5 5.5 2.5	2.5	8.6 8.8 8.8 8.4	2.0 2.0 2.0 -	4	30	A12
308	A B C D	0.073	18.3	18.0	10.5	8.375	2.5 6.6 6.5 2.5	2.5	8.6 8.9 9.0 8.9	3.1 3.1 3.0 -	4	30	A12
309	A B C	0.073	11.6	12.0	10.5	8.375	2.4 5.4 2.3	2.3	2.3 2.0 2.3	2.0 2.0 -	3	30	A10
310	A B C	0.073	16.5	12.0	10.5	8.375	2.5 7.8 2.5	2.5	2.0 2.0 2.0	4.3 4.3 -	3	30	A10
311	A B C	0.078	17.1	16.1	10.5	8.375	2.8 8.0 2.5	2.6	1.5 2.2 1.3	4.4 4.5 -	3	30	A2
312	A B C	0.078	16.5	10.7	10.5	8.375	2.5 7.8 2.5	2.5	0.9 1.9 1.8	4.3 4.3 -	3	30	A4

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3; [o] Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.5 Cont. Comprehensive test results and data for No. 8 specimens with multiple hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type
	A	65266	65265			82615			-	FP
296	B	103741	76608	188393	62798	131318	79491	90858	0.191	FP
	C	46521	46520			58887			-	FP
	A	26783	26683			33903			-	FP
297	B	57434	55164	108161	36054	72701	45637	53826	-	FP
	C	26314	26314			33309			-	FP
	A	30459	30459			38556				FP
298	B	23292	23292	73234	24411	29484	30900	42354		FP
	C	19482	19482			24661			0.15	FP
	A	30671	30671			38824			0.09	FP
299	B	43708	33363	85439	28480	55327	36050	48261	0.12	FP
	C	21404	21405			27094			0	FP
	A	30145	30145			38158			0.015	FP
300	B	38965	34709	96899	32300	49323	40886	48357	-	FP
	C	3259	32045			4126			-	FP
	A	41000	37670			51899			-	FP
301	B	41000	37670	113010	37670	51899	47684	52744	-	FP
	C	41000	37670			51899			-	FP
	A	24580	24580			31114				FP
302	B	25019	25019	64314	21438	31670	27137	58289		FP
	C	14714	14714			18625				FP
	A	29402	29403			37218			0.026	FP
303	B	27244	27226	79058	26353	34486	33358	57258		FP
	C	22429	22429			28391				FP
	A	56490	56461			71506			0.194	SB
304	B	46273	38034	144116	48039	58573	60808	90999	-	FP
	C	55048	49621			69681			-	FP
	A	56769	56681			71859			0.255	FP/SS
305	B	76126	57568	167466	55822	96362	70661	96453	-	FP
	C	57723	53216			73067			-	FP/SS
	A	53307	53307			67477			-	FP
306	B	66123	42900	157056	52352	83700	66268	93033	-	FP
	C	60849	60849			77024			-	FP
	A	22186	22181			28083				FP
307	B	21191	21153	74637	18659	26824	23619	58031		FP
	C	18263	18251			23117				FP
	D	13052	13052			16521				FP
	A	20362	20362			25775				FP
308	B	19012	19012	72146	18036	24066	22831	56677		FP
	C	18477	18449			23389				FP
	D	14323	14323			18130				FP
	A	37063	37064			46915				FP
309	B	59803	59799	141746	47249	75700	59809	50941		FP
	C	44883	44884			56814				FP
	A	41465	40204			52487				FP
310	B	60400	59739	137789	45930	76456	58139	51804		FP
	C	37920	37846			48000			0.123	FP
	A	66835	66811			84601			-	FP
311	B	65764	42778	171782	57261	83246	72482	82766	-	FP
	C	62311	62193			78875			-	FP
	A	25157	24718			31844			0.215	FP
312	B	68732	58920	122656	40885	87000	51754	52387	0.285	FP
	C	39164	39019			49600			-	FP

‡ Specimen contained A1035 Grade 120 for column longitudinal steel

[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.5 Cont. Comprehensive test results and data for No. 8 specimens with multiple hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
296	A B C	60	-	-	-	-	2.0	10	3	0.50	3.0	0.375	1	3.16	60
297	A B C	60	-	-	-	-	2.0	10	3	0.50	3.0	0.500	1	3.16	60
298	A B C	60	-	-	-	-	-	-	-	0.50	4.0	-	-	6.32	120
299	A B C	60	-	-	-	-	-	-	-	0.38	3.0	-	-	3.16	120
300	A B C	60	-	-	-	-	-	-	-	0.38	4.0	-	-	3.16	120
301	A B C	60	-	-	0	-	2.2	20	3	0.50	1.8	-	-	3.16	60
302	A B C	60	-	-	-	-	-	-	-	0.38	4.0	-	-	4.74	60
303	A B C	60	-	-	-	-	-	-	-	0.38	4.0	-	-	4.74	60
304	A B C	60	0.38	0.11	0	-	-	-	-	0.38	3.0	-	-	3.16	120
305	A B C	60	0.38	0.11	0	-	-	-	-	0.38	3.0	-	-	3.16	120
306	A B C	60	0.38	0.11	0	-	-	-	-	0.38	3.0	-	-	3.16	120
307	A B C D	60	0.38	0.11	0	3.0	-	-	-	0.375	4.0	-	-	6.32	60
308	A B C D	60	0.38	0.11	0	0.0	-	-	-	0.375	4.0	-	-	6.32	60
309	A B C	60	-	0.11	-	-	-	-	-	0.50	4.0	-	-	6.32	120
310	A B C	60	-	0.11	-	-	-	-	-	0.50	3.0	-	-	6.32	120
311	A B C	60	0.38	0.11	2	8	2.0	10	2.5	0.38	3.0	0.500	2	3.16	60
312	A B C	60	0.38	0.11	2	8	2.0	10	2.5	0.38	2.5	0.500	2	1.89	60

[‡] Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.5 Cont. Comprehensive test results and data for No. 8 specimens with multiple hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
313	(3@5.5) 8-5-90-2#3-i-2.5-2-14(1)	A B C	90°	Para	A1035[c]	14.7 15.2 14.8	14.9	5450	7	1
314	(3@5.5) 8-5-90-2#3-i-2.5-2-8.5(1)	A B C	90°	Para	A1035[c]	7.3 8.9 8.4	8.2	5450	7	1
315	(3@3) 8-5-90-2#3-i-2.5-2-10[‡]	A B C	90°	Para	A615	9.9 10.1 10.0	10.0	4760	11	1
316	(3@5) 8-5-90-2#3-i-2.5-2-10[‡]	A B C	90°	Para	A615	10.5 10.6 10.4	10.5	4760	11	1
317	(3@3) 8-5-180-2#3-i-2.5-2-10[‡]	A B C	180°	Para	A615	10.5 10.3 10.0	9.4	5400	16	1
318	(3@5) 8-5-180-2#3-i-2.5-2-10[‡]	A B C	180°	Para	A615	9.6 9.8 9.8	9.4	5400	16	1
319	(3@5.5) 8-5-90-5#3-i-2.5-2-8	A B C	90°	Para	A1035[b]	8.0 8.1 7.8	8.0	6620	15	1
320	(3@5.5) 8-5-90-5#3-i-2.5-2-12	A B C	90°	Para	A1035[b]	12.4 12.1 12.1	12.2	6620	15	1
321	(3@5.5) 8-5-90-5#3-i-2.5-2-8(1)	A B C	90°	Para	A1035[c]	7.3 8.4 7.3	7.6	5660	8	1
322	(3@5.5) 8-5-90-5#3-i-2.5-2-12(1)	A B C	90°	Para	A1035[c]	11.4 12.5 12.0	12.0	5660	8	1
323	(3@5.5) 8-5-90-5#3-i-2.5-2-8(2)[‡]	A B C	90°	Para	A615	8.0 8.0 8.5	8.2	5730	18	1
324	(3@3) 8-5-90-5#3-i-2.5-2-10[‡]	A B C	90°	Para	A615	10.0 9.8 9.9	9.9	4810	12	1
325	(3@5) 8-5-90-5#3-i-2.5-2-10[‡]	A B C	90°	Para	A615	10.0 10.0 9.8	9.9	4850	13	1
326	(3@3) 8-8-90-5#3-i-2.5-9-9	A B C	90°	Para	A615	9.5 9.0 9.5	9.3	7440	22	1
327	(3@4) 8-8-90-5#3-i-2.5-9-9	A B C	90°	Para	A615	8.9 9.1 9.3	9.1	7440	22	1
328	(3@3) 8-12-90-5#3-i-2.5-2-12[‡]	A B C	90°	Para	A1035[c]	11.9 11.9 11.6	11.8	11040	31	1
329	(3@4) 8-12-90-5#3-i-2.5-2-12[‡]	A B C	90°	Para	A1035[c]	12.5 12.0 12.5	12.3	11440	32	1

[‡] Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.5 Cont. Comprehensive test results and data for No. 8 specimens with multiple hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout[o]
	A						2.8		1.7	4.2			
313	B	0.073	16.8	16.4	10.5	8.375	7.9	2.7	1.2	4.3	3	30	A2
	C						2.6		1.6	-			
	A						2.3		3.5	4.5			
314	B	0.073	16.8	10.8	10.5	8.375	7.9	2.5	1.8	4.3	3	30	A2
	C						2.6		2.3	-			
	A						2.6		2.1	2.0			
315	B	0.073	12.1	12.0	10.5	8.375	5.6	2.6	1.9	2.0	3	30	A7
	C						2.5		2.0	-			
	A						2.5		1.5	4.5			
316	B	0.073	16.6	12.0	10.5	8.375	8.0	2.6	1.4	3.9	3	30	A2
	C						2.8		1.6	-			
	A						2.5		1.5	2.0			
317	B	0.073	12.3	11.1	10.5	8.375	5.5	2.6	1.8	2.0	3	30	A10
	C						2.8		2.0	-			
	A						2.5		2.4	4.2			
318	B	0.073	16.1	11.7	10.5	8.375	7.8	2.4	2.3	4.2	3	30	A10
	C						2.3		2.3	-			
	A						2.5		2.2	4.1			
319	B	0.078	16.6	10.2	10.5	8.375	7.6	2.5	2.1	4.5	3	30	A10
	C						2.5		2.4	-			
	A						2.5		1.8	4.3			
320	B	0.078	16.8	14.2	10.5	8.375	7.8	2.5	2.1	4.5	3	30	A1
	C						2.5		2.1	-			
	A						2.9		2.9	3.8			
321	B	0.073	16.6	10.1	10.5	8.375	7.6	2.9	1.8	4.1	3	30	A2
	C						2.9		2.9	-			
	A						2.5		2.8	4.3			
322	B	0.073	16.9	14.2	10.5	8.375	7.8	2.6	1.7	4.5	3	30	A2
	C						2.6		2.2	-			
	A						2.8		2.0	4.5			
323	B	0.073	17	10.0	10.5	8.375	8.0	2.5	2.0	4.5	3	30	A10
	C						2.3		1.5	-			
	A						2.8		2.0	2.1			
324	B	0.073	12.3	12.0	10.5	8.375	5.9	2.5	2.3	2.1	3	30	A7
	C						2.3		2.1	-			
	A						2.5		2.0	4.0			
325	B	0.073	16.3	12.0	10.5	8.375	7.5	2.6	2.0	4.0	3	30	A3
	C						2.8		2.3	-			
	A						2.5		8.5	2.0			
326	B	0.073	12	18.0	10.5	8.375	5.5	2.5	9.0	2.0	3	30	A7
	C						2.5		8.5	-			
	A						2.5		9.1	3.0			
327	B	0.073	14	18.0	10.5	8.375	6.5	2.5	8.9	3.0	3	30	A7
	C						2.5		8.8	-			
	A						2.5		2.3	2.0			
328	B	0.073	12	14.1	10.5	8.375	5.5	2.5	2.3	2.0	3	30	A2
	C						2.5		2.5	-			
	A						2.5		1.8	2.8			
329	B	0.073	13.8	14.3	10.5	8.375	6.3	2.5	2.3	3.0	3	30	A2
	C						2.5		1.8	-			

[‡] Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3
[o] Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.5 Cont. Comprehensive test results and data for No. 8 specimens with multiple hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type
	A	58682	58531			74281			-	FP/TK
313	B	97141	67310	196009	65336	122963	82704	78438	-	FP/TK
	C	70217	70168			88882			-	FP/TK
	A	36593	35595			46320			-	FP
314	B	43607	30047	97104	32368	55199	40972	43284	-	FP
	C	35210	31462			44570			-	FP
	A	42191	42191			53406			0.26	FP
315	B	4159	41586	122162	40721	5264	51545	49174	0.18	FP
	C	38385	38385			48589			-	FP
	A	43315	43030			54829			0.26	FP
316	B	54636	48236	134004	44668	69159	56542	51745	0.26	FP
	C	42769	42739			54138			-	FP
	A	59807	59807			75705				FP
317	B	56145	56145	163728	54576	71070	69083	49208		FP
	C	47776	47776			60476			0.32	FP
	A	59312	59313			75078				FP
318	B	4934	49344	154502	51501	6246	65191	49208		FP
	C	45845	45845			58032			0.14	FP
	A	30586	30530			38716			0.388	FP
319	B	46989	46919	111379	37126	59480	46995	57814	0.477	FP
	C	34069	33930			43125			-	FP
	A	60325	60281			76361			0.198	FP
320	B	110823	80058	198283	66094	140282	83664	88689	-	FP
	C	59279	57944			75037			-	FP
	A	29839	29789			37771			-	FP
321	B	30241	29643	94108	31369	38280	39708	51219	0.297	FP
	C	34714	34676			43942			0.381	FP
	A	55543	44226			70308			-	FP
322	B	74581	74581	143554	47851	94406	60571	80327	0.435	FP
	C	44410	24747			56215			0.927	FP
	A	57652	57652			72977				FP
323	B	43308	43309	143982	47994	54820	60752	55196		FP
	C	43030	43021			54468			0.54	FP
	A	48766	48766			61729			-	FP
324	B	44849	44503	141829	47276	56771	59843	61149	0.13	FP
	C	48560	48560			61468			0	FP
	A	58896	58896			74552			-	FP
325	B	63376	55612	183916	61305	80223	77602	61662	-	FP
	C	69408	69408			87858			-	FP
	A	43346	43346			54868				FP
326	B	49666	38730	119286	39762	62868	50332	71880		FP
	C	37210	37211			47101				FP
	A	48534	48534			61435			0.1	FP
327	B	38602	30171	109678	36559	48863	46278	70115		FP
	C	31956	30973			40451				FP
	A	70368	68183			89073			0.302	FP
328	B	84954	56310	186619	62206	107537	78742	110622	0.256	FP
	C	62126	62127			78641			0.251	FP
	A	70706	69965			89501			0.262	FP
329	B	100028	68745	194819	64940	126600	82202	117781	-	FP
	C	63666	56110			80600			0.205	FP

[‡] Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.5 Cont. Comprehensive test results and data for No. 8 specimens with multiple hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
313	A B C	60	0.38	0.11	2	6	1.6	8	3	0.38	2.5	0.375	2	3.16	60
314	A B C	60	0.38	0.11	2	6	2.0	10	3	0.50	2.5	0.375	1	3.16	60
315	A B C	60	0.38	0.11	2	3	-	-	-	0.50	5.0	-	-	4.74	120
316	A B C	60	0.38	0.11	2	3	-	-	-	0.38	3.0	-	-	3.16	120
317	A B C	60	0.38	0.11	2	3	-	-	-	0.50	4.0	-	-	6.32	120
318	A B C	60	0.38	0.11	2	3	-	-	-	0.50	3.0	-	-	6.32	120
319	A B C	60	0.38	0.11	5	3	2.0	10	3.3	0.38	2.5	0.500	2	1.89	60
320	A B C	60	0.38	0.11	5	3	2.0	10	3.2	0.38	2.5	0.500	2	1.27	60
321	A B C	60	0.38	0.11	5	3	2.0	10	3	0.50	2.5	0.375	1	3.16	60
322	A B C	60	0.38	0.11	5	3	1.0	5	2.8	0.50	3.5	0.500	1	3.16	60
323	A B C	60	0.38	0.11	5	3	-	-	-	0.50	4.0	-	-	6.32	120
324	A B C	60	0.38	0.11	5	3	-	-	-	0.50	4.0	-	-	4.74	120
325	A B C	60	0.38	0.11	5	3	-	-	-	0.38	3.0	-	-	3.95	120
326	A B C	60	0.38	0.11	5	3	-	-	-	0.38	4.0	-	-	4.74	60
327	A B C	60	0.38	0.11	5	3	-	-	-	0.38	4.0	-	-	4.74	60
328	A B C	60	0.38	0.11	5	3	-	-	-	0.38	3.0	-	-	3.16	120
329	A B C	60	0.38	0.11	5	3	-	-	-	0.38	3.0	-	-	3.16	120

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.5 Cont. Comprehensive test results and data for No. 8 specimens with multiple hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
330	(3@5) 8-12-90-5#3-i-2.5-2-12‡	A B C	90°	Para	A1035[c]	11.9 12.4 12.3	12.2	11460	33	1
331	(4@3)8-8-90-5#3-i-2.5-9-9	A B C D	90°	Para	A615	9.3 9.3 9.3 9.3	9.3	7440	22	1
332	(4@4) 8-8-90-5#3-i-2.5-9-9	A B C D	90°	Para	A615	9.5 9.5 9.3 9.6	9.5	7440	22	1
333	(3@3) 8-5-180-5#3-i-2.5-2-10‡	A B C	180°	Para	A615	10.1 9.9 9.8	9.9	5540	17	1
334	(3@5) 8-5-180-5#3-i-2.5-2-10‡	A B C	180°	Para	A615	9.9 9.8 9.5	9.7	5540	17	1

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.5 Cont. Comprehensive test results and data for No. 8 specimens with multiple hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout[o]
330	A B C	0.073	16	14.1	10.5	8.375	2.5 7.5 2.5	2.5	2.2 1.7 1.8	4.0 4.0 -	3	30	A2
331	A B C D	0.073	15.3	18.0	10.5	8.375	2.5 5.5 5.5 2.5	2.5	8.8 8.8 8.8 8.8	2.0 2.3 2.0 -	4	30	A7
332	A B C D	0.073	18.0	18.0	10.5	8.375	2.5 6.5 6.5 2.5	2.5	8.5 8.5 8.8 8.4	3.0 3.0 3.0 -	4	30	A7
333	A B C	0.073	12.5	12.0	10.5	8.375	2.8 5.8 2.8	2.8	1.9 2.1 2.3	2.0 2.0 -	3	30	A10
334	A B C	0.073	15.8	12.0	10.5	8.375	2.3 7.0 2.8	2.5	2.1 2.3 2.5	3.8 4.0 -	3	30	A10

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3
[o] Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.5 Cont. Comprehensive test results and data for No. 8 specimens with multiple hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type
330	A	59447	59447	194282	64761	75249	81976	116689	-	FP
	B	85455	65587			108171			-	FP
	C	69248	69248			87656			0.18	FP
331	A	32930	32930	125763	31441	41683	39798	56990		FP
	B	38749	38749			49049				FP
	C	27318	27290			34580				FP
	D	26809	26794			33936				FP
332	A	33657	33657	117937	29484	42604	37322	58338		FP
	B	30733	30723			38902				FP
	C	27886	27886			35299				FP
	D	25671	25671			32495				FP
333	A	50346	46175	176632	58877	63729	74528	65903		FP
	B	67397	65274			85313				FP
	C	66969	65183			84771			0.269	FP
334	A	55363	55236	176006	58669	70080	74264	64518		FP
	B	60892	60892			77089				FP
	C	59877	59877			75823			0.382	FP

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.5 Cont. Comprehensive test results and data for No. 8 specimens with multiple hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
330	A B C	60	0.38	0.11	5	3	-	-	-	0.38	3.0	-	-	3.16	120
331	A B C D	60	0.38	0.11	5	3.0	-	-	-	0.375	4.0	-	-	4.74	60
332	A B C D	60	0.38	0.11	5	3.0	-	-	-	0.375	4.0	-	-	4.74	60
333	A B C	60	0.38	0.11	5	3	-	-	-	0.50	4.0	-	-	6.32	120
334	A B C	60	0.38		5	3	-	-	-	0.50	3.0	-	-	6.32	120

‡ Specimen contained A1035 Grade 120 for column longitudinal steel
[a] Heat 1, [b] Heat 2, [c] Heat 3 as described in Table 3

Table A.6 Comprehensive test results and data for No. 11 specimens with multiple hooks

	Specimen	Hook	Bend Angle	Trans. Reinf. Orient.	Hook Bar Type	ℓ_{eh} in.	$\ell_{eh,avg}$ in.	f'_c psi	Age days	d_b in.
335	(3@5.35) 11-5-90-0-i-2.5-13-13	A B C	90°	-	A615	13.8 14.3 13.5	13.8	5330	11	1.41
336	(3@5.35) 11-5-90-2#3-i-2.5-13-13	A B C	90°	Para	A615	14.0 14.0 13.8	13.9	5330	11	1.41
337	(3@5.35) 11-5-90-6#3-i-2.5-13-13	A B C	90°	Para	A615	13.5 13.5 13.8	13.6	5280	12	1.41
338	(3@5.35) 11-5-90-6#3-i-2.5-18-18	A B C	90°	Para	A1035	18.6 18.6 18.6	18.6	5280	12	1.41

Table A.6 Cont. Comprehensive test results and data for No. 11 specimens with multiple hooks

	Hook	R_r	b in.	h in.	h_{cl} in.	h_c in.	c_{so} in.	$c_{so,avg}$ in.	c_{th} in.	c_h in.	N_h	Axial Load kips	Long. Reinf. Layout°
335	A B C	0.085	22.3	26.0	19.5	8.375	2.6 10.0 2.6	2.6	12.3 11.8 12.5	6.6 6.3 -	3	162	A14
336	A B C	0.085	21.5	26.0	19.5	8.375	2.6 10.0 2.6	2.6	12.0 12.0 12.3	6.1 6.1 -	3	157	A14
337	A B C	0.085	21.3	26.0	19.5	8.375	2.6 10.0 2.7	2.6	12.5 12.5 12.3	6.0 5.8 -	3	155	A14
338	A B C	0.085	21.2	36.0	19.5	8.375	2.5 10.0 2.8	2.7	17.4 17.4 17.4	6.1 5.6 -	3	214	A14

° Longitudinal column configurations shown in Appendix A, Layouts A1 – A16

Table A.6 Cont. Comprehensive test results and data for No. 11 specimens with multiple hooks

	Hook	T_{max} lb	T_{ind} lb	T_{total} lb	T lb	$f_{su,max}$ psi	f_{su} psi	$f_{s,ACI}$ psi	Slip at Failure in.	Failure Type
335	A B C	45416 49897 59323	45405 49897 59215	154517	51506	29113 31985 38028	33016	51162	0.113 - -	FP FP FP
336	A B C	50926 58487 64473	50926 58487 64349	173762	57921	32645 37492 41329	37129	51470	- - -	FP FP FP
337	A B C	59664 66536 72350	59647 66536 72350	198533	66178	38246 42651 46378	42422	50001	- - -	FP FP FP
338	A B C	103312 147805 113923	100804 121063 113733	335601	111867	66226 94744 73013	71710	68559	- - -	FP FP FP

Table A.6 Cont. Comprehensive test results and data for No. 11 specimens with multiple hooks

	Hook	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	A_{cti} in.	N_{cti}	s_{cti} in.	d_s in.	s_s in.	d_{cto} in.	N_{cto}	A_s in.^{2}	f_{ys} ksi
335	A B C	60	-	-	-	-	-	-	-	0.50	7.0	-	-	7.90	60
336	A B C	60	0.38	0.11	2	8	-	-	-	0.50	7.0	-	-	7.90	60
337	A B C	60	0.38	0.11	6	4	-	-	-	0.50	7.0	-	-	7.90	60
338	A B C	60	0.38	0.11	6	4	-	-	-	0.50	7.0	-	-	7.90	60

Table A.2 Test results for other researchers referenced in this study

		Specimen	Bend Angle	ℓ_{eh} in.	f'_c psi	f_y psi	d_b in.	b in.	h_{cl} in.	h_c in.
Marques and Jirsa (1975)	339	J7-180-12-1-H	180°	10.0	4350	64000	0.88	12	11.6	6
	340	J7-180-15-1-H	180°	13.0	4000	64000	0.88	12	11.6	6
	341	J 7- 90 -12 -1 - H	90°	10.0	4150	64000	0.88	12	11.6	6
	342	J 7- 90 -15 -1 - H	90°	13.0	4600	64000	0.88	12	11.6	6
	343	J 7- 90 -15 -1 - L	90°	13.0	4800	64000	0.88	12	11.6	6
	344	J 7- 90 -15 -1 - M	90°	13.0	5050	64000	0.88	12	11.6	6
	345	J 11 - 180 -15 -1 - H	180°	13.1	4400	68000	1.41	12	11.3	6
	346	J 11- 90 -12 -1 - H	90°	10.1	4600	68000	1.41	12	11.3	6
	347	J 11- 90 -15 -1 - H	90°	13.1	4900	68000	1.41	12	11.3	6
	348	J 11- 90 -15 -1 - L	90°	13.1	4750	68000	1.41	12	11.3	6
Pinc et al. (1977)	349	9-12	90°	10.0	4700	65000	1.13	12	*	*
	350	9-18	90°	16.0	4700	65000	1.13	12	*	*
	351	11-24	90°	22.1	4200	60000	1.41	12	*	*
	352	11-15	90°	13.1	5400	60000	1.41	12	*	*
	353	11-18	90°	16.1	4700	60000	1.41	12	*	*
	354	11-21	90°	19.1	5200	60000	1.41	12	*	*
Hamad et al. (1993)	355	7-90-U	90°	10.0	2570	60000[a]	0.88	12	11	6
	356	7-90-U'	90°	10.0	5400	60000[a]	0.88	12	11	6
	357	11-90-U	90°	13.0	2570	60000[a]	1.41	12	11	6
	358	11-90-U'	90°	13.0	5400	60000[a]	1.41	12	11	6
	359	11-180-U-HS	180°	13.0	7200	60000[a]	1.41	12	11	6
	360	11-90-U-HS	90°	13.0	7200	60000[a]	1.41	12	11	6
	361	11-90-U-T6	90°	13.0	3700	60000[a]	1.41	12	11	6
Ramirez & Russell (2008)	362	I-1	90°	6.5	8910	81900	0.75	15	12	6
	363	I-3	90°	6.5	12460	81900	0.75	15	12	6
	364	I-5	90°	6.5	12850	81900	0.75	15	12	6
	365	I-2	90°	12.5	8910	63100	1.41	15	12	6
	366	I-2'	90°	15.5	9540	63100	1.41	15	12	6
	367	I-4	90°	12.5	12460	63100	1.41	15	12	6
	368	I-6	90°	12.5	12850	63100	1.41	15	12	6
	369	III-13	90°	6.5	13980	81900	0.75	15	12	6
	370	III-15	90°	6.5	16350	81900	0.75	15	12	6
	371	III-14	90°	12.5	13980	63100	1.41	15	12	6
	372	III-16	90°	12.5	16500	63100	1.41	15	12	6
Lee & Park (2010)	373	H1	90°	18.7	4450	87000	0.88	14.6	*	*
	374	H2	90°	11.9	8270	87000	0.88	14.6	*	*
	375	H3	90°	15.0	4450	87000	0.88	14.6	*	*

[†]60,000 psi nominal yield strength for all transverse reinforcement
*Information not provided
[a] Nominal value

		Specimen	c_{so} in.	c_{th} in.	c_h in.	N_h	A_h in.^{2}	f_{yt} ksi	d_{tr} in.	$A_{tr,l}$ in.^{2}	N_{tr}	s_{tr} in.	T lb
Marques and Jirsa (1975)	339	J7-180-12-1-H	2.88	2.0	4.5	2	0.60	-	-	-	-	-	36600
	340	J7-180-15-1-H	2.88	2.0	4.5	2	0.60	-	-	-	-	-	52200
	341	J 7- 90 -12 -1 - H	2.88	2.0	4.5	2	0.60	-	-	-	-	-	37200
	342	J 7- 90 -15 -1 - H	2.88	2.0	4.5	2	0.60	-	-	-	-	-	54600
	343	J 7- 90 -15 -1 - L	2.88	2.0	4.5	2	0.60	-	-	-	-	-	58200
	344	J 7- 90 -15 -1 - M	2.88	2.0	4.5	2	0.60	-	-	-	-	-	60000
	345	J 11 - 180 -15 -1 -	2.88	1.5	3.4	2	1.56	-	-	-	-	-	70200
	346	J 11- 90 -12 -1 - H	2.88	1.5	3.4	2	1.56	-	-	-	-	-	65520
	347	J 11- 90 -15 -1 - H	2.88	1.5	3.4	2	1.56	-	-	-	-	-	74880
	348	J 11- 90 -15 -1 - L	2.88	1.5	3.4	2	1.56	-	-	-	-	-	81120
Pinc et al. (1977)	349	9-12	2.88	1.99	4.0	2	1.00	-	-	-	-		47000
	350	9-18	2.88	1.99	4.0	2	1.00	-	-	-	-		74000
	351	11-24	2.88	1.95	3.4	2	1.56	-	-	-	-		12012
	352	11-15	2.88	1.95	3.4	2	1.56	-	-	-	-		78000
	353	11-18	2.88	1.95	3.4	2	1.56	-	-	-	-		90480
	354	11-21	2.88	1.95	3.4	2	1.56	-	-	-	-		11388
Hamad et al. (1993)	355	7-90-U	3	2	4.25	2	0.60	-	-	-	-	-	25998
	356	7-90-U'	3	2	4.25	2	0.60	-	-	-	-	-	36732
	357	11-90-U	3	2	3.18	2	1.56	-	-	-	-	-	48048
	358	11-90-U'	3	2	3.18	2	1.56	-	-	-	-	-	75005
	359	11-180-U-HS	3	2	3.18	2	1.56	-	-	-	-	-	58843
	360	11-90-U-HS	3	2	3.18	2	1.56	-	-	-	-	-	73788
	361	11-90-U-T6	3	2	3.18	2	1.56	60	0.375	0.11	4	6	71807
Ramirez & Russell (2008)	362	I-1	2.5	2.5	8.5	2	0.44	-	-	-	-		30000
	363	I-3	2.5	2.5	8.5	2	0.44	-	-	-	-		30000
	364	I-5	2.5	2.5	8.5	2	0.44	-	-	-	-		30500
	365	I-2	2.5	2.5	7.18	2	1.56	-	-	-	-		88000
	366	I-2'	2.5	2.5	7.18	2	1.56	-	-	-	-		10500
	367	I-4	2.5	2.5	7.18	2	1.56	-	-	-	-		99100
	368	I-6	2.5	2.5	7.18	2	1.56	-	-	-	-		11400
	369	III-13	2.5	2.5	8.5	2	0.44	60	0.375	0.11	4	7.5	41300
	370	III-15	2.5	2.5	8.5	2	0.44	60	0.375	0.11	4	7.5	38500
	371	III-14	2.5	2.5	7.18	2	1.56	60	0.375	0.11	6	7.5	10500
	372	III-16	2.5	2.5	7.18	2	1.56	60	0.375	0.11	6	7.5	12000
Lee & Park (2010)	373	H1	3	2	7	2	0.6	-	-	-	-	-	86345
	374	H2	3	2	7	2	0.6	-	-	-	-	-	76992
	375	H3	3	2	7	2	0.6	60	0.375	0.11	4	2.625	53761

[†]60,000 psi nominal yield strength for all transverse reinforcement
*Information not provided
[a] Nominal value