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# Anchoring to Concrete

## UPDATE FOR '08 CODE

Several substantive and some editorial changes are made in this third edition of Appendix D (2008 Code.) Substantive changes include:

- Ductility requirements for the seismic design of anchors are revised (D.3.3.3-.4.)
- Design of non-ductile anchors, controlled by concrete failure modes, is permitted. Such designs are penalized by applying an additional strength reduction factor (D.3.3.6.)
- A definition for **Anchor Reinforcement** is introduced, and is contrasted with that of **Supplementary Reinforcement** (D.1.)
- Strength of Anchor Reinforcement used to preclude concrete breakout in tension and in shear is codified (D.5.2.9, D.6.2.9.) Guidance for detailing the anchor reinforcement is given in RD.5.2.9 and RD.6.2.9.)
- A modification factor is introduced for concrete breakout shear capacity in thin members (2.2, D.6.2.1, new D.6.2.8)

Editorial changes include:

- The effective cross-sectional area of an anchor in shear and in tension is clarified (2.1, D.5.1.2, D.6.1.2.)
- The definition of Anchor Group in tension and in shear is clarified for connections with multiple anchors. Only anchors that contribute to the failure mode being investigated shall be considered (D.1, D.5.4.2).
- The resistance mechanism of Hooked Bolt is clarified (D.1, RD.5.3.4).
- Notations in several commentary figures are improved to reflect the intended application.
- A consistent notation for anchor diameter is provided (2.1, D.1, D.5.3.5, D.6.2.2, D.6.2.3, D.8.1-.4)
- Definition of deep embedment relative to edge distance is clearly expressed (D.5.4.1.-2).

## BACKGROUND

Appendix D, Anchoring to Concrete, was introduced in ACI 318-02. It provides requirements for the design of anchorages to concrete using both cast-in-place and post-installed mechanical anchors. The following presents an overview regarding the development and publication of ACI 318 Appendix D. As of the late 1990's, ACI 318 and the American Institute of Steel Construction LRFD and ASD Specifications were silent regarding the design of anchorage to concrete. ACI 349-85 Appendix B and the Fifth Edition of PCI Design Handbook provided the primary sources of design information for connections to concrete using cast-in-place anchors. The design of connections to concrete using post-installed anchors has typically been based on information provided by individual anchor manufacturers.

During the 1990's. ACI Committee 318 took the lead in developing building code provisions for the design of anchorages to concrete using both cast-in-place and post-installed mechanical anchors. Committee 318 received support from ACI Committee 355 (ACI 355). Anchorage to Concrete, and ACI Committee 349, Concrete Nuclear Structures. Concurrent with the ACI 318 effort to develop design provisions, ACI 355 was involved with developing a test method for evaluating the performance of post-installed mechanical anchors in concrete. During the code cycle leading to ACI 318-99, a proposed Appendix D to ACI 318 dealing with the design of anchorages to concrete using both cast-in-place and post-installed mechanical anchors was approved by ACI 318. Final adoption of the proposed appendix awaited ACI 355 approval of a test method for evaluating the performance of post-installed mechanical anchors in concrete under the ACI consensus process.

Since ACI 355 was not able to complete the test method for evaluating post-installed mechanical anchors on time to meet the publication deadlines for the ACI 318-99 code, an attempt was made to process an ACI 318 Appendix D reduced in scope to only cast-in-place anchors (i.e., without post-installed mechanical anchors). However, there was not sufficient time to meet the deadlines established by the International Code Council for submittal of the published ACI 318-99 standard to be referenced in the International Building Code (IBC 2000). As a result, the anchorage to concrete provisions originally intended for ACI 318-99 Appendix D (excluding provisions for post-installed mechanical anchors) were submitted and approved for incorporation into Section 1913 of IBC 2000.

At the end of 2001, ACI Committee 355 completed ACI 355.2-01 titled "Evaluating the Performance of Post-Installed Mechanical Anchors." Availability of ACI 355.2 led the way to incorporating into ACI 318-02 a new Appendix D, Anchoring to Concrete, which provided design requirements for both cast-in-place and post-installed mechanical anchors. As a result, Section 1913 of IBC 2003 references ACI 318 Appendix D. Subsequently, IBC 2006 Section 1913 referenced ACI 318-05 Appendix D, which in turn adopted ACI 355.2-04 "Qualification of Post-Installed Mechanical Anchors in Concrete" by reference. It is anticipated that IBC 2009 will adopt ACI 318-08 Appendix D by reference. Note, the 2008 Code adopts an updated protocol for "Qualification of Post-Installed Mechanical Anchors in Concrete" (ACI 355.2-07.)

It should be noted that ACI 318-05 Appendix D does not address adhesive and grouted anchors. Like post-installed mechanical anchors, adhesive and grouted anchors are sensitive to installation. In addition to potential failure modes outlined in ACI 318 Appendix D, tests on adhesive and grouted anchors reveal other failure modes. As this document goes to press, ACI Committee 355 is developing a protocol for "Qualification of Post-Installed Adhesive Anchors in Concrete", and new design equations to safeguard against failure modes not currently identified in Appendix D. A protocol for grouted anchors will follow.

## EARLY DESIGN METHODS

The 45-degree cone method used in ACI 349-85 Appendix B and the PCI Design Handbook, Fifth Edition, was developed in the mid 1970's. In the 1980's, comprehensive tests of different types of anchors with various embedment lengths, edge distances, and group effects were performed at the University of Stuttgart on both uncracked and cracked concrete. The Stuttgart test results led to the development of the Kappa (K) method that was introduced in ACI 349 and ACI 355 in the late 1980's. In the early 1990's, the K method was improved, and made user-friendlier at the University of Texas at Austin. This effort resulted in the Concrete Capacity Design (CCD) method. During this same period, an international database was assembled. During the mid 1990's, the majority of the work of ACI Committees 349 and 355 was to evaluate both the CCD method and the 45-degree cone method using the international database of test results. As a result of this evaluation, ACI Committees 318, 349, and 355 proceeded with implementation of the CCD method. The design provisions of ACI 318 Appendix D and ACI 349-06 Appendix D are based on the CCD method. Differences between the CCD method and the 45-degree cone method are discussed below.

## GENERAL CONSIDERATIONS

The design of anchorages to concrete must address both strength of the anchor steel and that associated with the embedded portion of the anchors. The lesser of these two strengths will control the design.

The strength of the anchor steel depends on the steel properties and size of the anchor. The strength of the embedded portion of the anchorage depends on its embedment length, strength of the concrete, proximity to other anchors, distance to free edges, and the characteristics of the embedded end of the anchor (headed, hooked, expansion, undercut, etc.).

The primary difference between the ACI 318 Appendix D provisions and those of the 45-degree cone method lies in the calculation of the embedment capacity for concrete breakout (i.e., a concrete cone failure). In the 45-degree cone method, the calculation of breakout capacity is based on a 45-degree concrete cone failure model that results in an equation based on the embedment length squared ($h_{ef}^2$). The ACI 318 Appendix D provisions account for fracture mechanics and result in an equation for concrete breakout that is based on the embedment length to the 1.5 power ($h_{ef}^{1.5}$). Although the 45-degree concrete cone failure model gives conservative results for anchors with $h_{ef} \leq 6$ in., the ACI 318 Appendix D provisions have been shown to give a better prediction of embedment strength for both single anchors and for anchors influenced by edge and group effects.

In addition to better prediction of concrete breakout strength, the ACI 318 Appendix D provisions simplify the calculation of the effects of anchor groups and edges by using a rectangular area bounded by $1.5h_{ef}$ from each anchor and free edges rather than the overlapping circular cone areas typically used in the 45-degree cone method.

## DISCUSSION OF DESIGN PROVISIONS

The following provides a section-by-section discussion of the design provisions of ACI 318-05 Appendix D. Section, equation, and figure numbers in the following discussion and examples refer to those used in ACI 318-08 Appendix D. Note that notation for Appendix D is presented in 2.1 of ACI 318.

## D.1 DEFINITIONS

The definitions presented are generally self-explanatory and are further explained in the text and figures of Appendix D.

Noteworthy improvements introduced in the 2008 Code are the addition of new definitions for "Anchor reinforcement" and "Supplementary reinforcement", and the clarification of the definition of "Anchor group."

**Anchor reinforcement** can be used to preclude a concrete breakout failure in tension or in shear. It must be oriented in the direction of the load, or have a component in the direction of the load so as to transfer the full design load. Anchor reinforcement must be developed on both side of the breakout surface. See Figs. RD.5.2.9 and RD.6.2.9. A strength reduction factor equal to 0.75 must be used in the design of anchor reinforcement (D.5.2.9 and D.6.2.9.)

**Supplementary reinforcement** is similar to anchor reinforcement in that it acts to restrain the potential concrete breakout. However, supplementary reinforcement is not designed to transfer the full design load from the anchor into the structural member.

In 2008, the definition of **Anchor group** was revised to reflect the difference between anchors in tension and those in shear. Moreover, it flags that only anchors susceptible to the particular failure mode under consideration should be included in the group capacity.

The following tables are provided as an aid to the designer in determining values for many of the variables:

**Table 34-1:** This table provides information on the types of materials typically specified for cast-in-place anchor applications. The table provides values for specified tensile strength $f_{uta}$ and specified yield strength $f_{ya}$ as well as the elongation and reduction in area requirements necessary to determine if a material should be considered as a brittle or ductile steel element. As shown in Table 34-1, all typical anchor materials satisfy the ductile steel element requirements of D.1. When using cast-in-place anchor materials not given in Table 34-1, the designer

*Table 34-1 Properties of Cast-in-Place Anchor Materials*

| Material specification[1] | Grade or type | Diameter (in.) | Tensile strength, for design $f_{ut}$ (ksi) | Tensile strength, min. (ksi) | Yield strength, min. | | Elongation, min. | | Reduction of area, min., (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | ksi | method | % | length | |
| AWS D1.1[2] | B | 1/2 – 1 | 60 | 60 | 50 | 0.2% | 20 | 2" | 50 |
| ASTM A307[3] | A | ≤ 4 | 60 | 60 | — | — | 18 | 2" | — |
| | C | ≤ 4 | 58 | 58-80 | 36 | — | 23 | 2" | — |
| ASTM A354[4] | BC | ≤ 4 | 125 | 125 | 109 | 0.2% | 16 | 2" | 50 |
| | BD | ≤ 4 | 125 | 150 | 130 | 0.2% | 14 | 2" | 40 |
| ASTM A449[5] | 1 | ≤ 1 | 120 | 120 | 92 | 0.2% | 14 | 4D | 35 |
| | | 1 – 1-1/2 | 105 | 105 | 81 | 0.2% | 14 | 4D | 35 |
| | | > 1-1/2 | 90 | 90 | 58 | 0.2% | 14 | 4D | 35 |
| ASTM F1554[6] | 36 | ≤ 2 | 58 | 58-80 | 36 | 0.2% | 23 | 2" | 40 |
| | 55 | ≤ 2 | 75 | 75-95 | 55 | 0.2% | 21 | 2" | 30 |
| | 105 | ≤ 2 | 125 | 125-150 | 105 | 0.2% | 15 | 2" | 45 |

Notes:

1. The materials listed are commonly used for concrete anchors. Although other materials may be used (e.g., ASTM A193 for high temperature applications, ASTM A320 for low temperature applications), those listed are preferred for normal use. Structural steel bolting materials such as ASTM A325 and ASTM A490 are not typically available in the lengths needed for concrete anchorage applications.
2. AWS D1.1-06 Structural Welding Code - Steel - This specification covers welded headed studs or welded hooked studs (unthreaded). None of the other listed specifications cover welded studs.
3. ASTM A307-07a Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength - This material is commonly used for concrete anchorage applications. Grade A is headed bolts and studs. Grade C is nonheaded bolts (studs), either straight or bent, and is equivalent to ASTM A36 steel. Note that although a reduction in area requirement is not provided, A307 may be considered a ductile steel element. Under the definition of "Ductile steel element" in D.1, the code states: "A steel element meeting the requirements of ASTM A307 shall be considered ductile."
4. ASTM A354-07a Standard Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners - The strength of Grade BD is equivalent to ASTM A490.
5. ASTM A449-07b Standard Specification for Quenched and Tempered Steel Bolts and Studs - This specification is referenced by ASTM A325 for "equivalent" anchor bolts.
6. ASTM F1554-07a Standard Specification for Anchor Bolts - This specification covers straight and bent, headed and headless, anchor bolts in three strength grades. Anchors are available in diameters ≤ 4 in. but reduction in area requirements vary for anchors > 2 in.

*Table 34-2 Dimensional Properties of Threaded Cast-in-Place Anchors*

| Anchor Diameter ($d_a$) (in.) | Gross Area of Anchor (in.$^2$) | Effective Area of Anchor ($A_{se,N}$, $A_{se,V}$) (in.$^2$) | Bearing Area of Heads and Nuts ($A_{brg}$) (in.$^2$) | | | |
|---|---|---|---|---|---|---|
| | | | Square | Heavy Square | Hex | Heavy Hex |
| 0.250 | 0.049 | 0.032 | 0.142 | 0.201 | 0.117 | 0.167 |
| 0.375 | 0.110 | 0.078 | 0.280 | 0.362 | 0.164 | 0.299 |
| 0.500 | 0.196 | 0.142 | 0.464 | 0.569 | 0.291 | 0.467 |
| 0.625 | 0.307 | 0.226 | 0.693 | 0.822 | 0.454 | 0.671 |
| 0.750 | 0.442 | 0.334 | 0.824 | 1.121 | 0.654 | 0.911 |
| 0.875 | 0.601 | 0.462 | 1.121 | 1.465 | 0.891 | 1.188 |
| 1.000 | 0.785 | 0.606 | 1.465 | 1.855 | 1.163 | 1.501 |
| 1.125 | 0.994 | 0.763 | 1.854 | 2.291 | 1.472 | 1.851 |
| 1.250 | 1.227 | 0.969 | 2.228 | 2.773 | 1.817 | 2.237 |
| 1.375 | 1.485 | 1.160 | 2.769 | 3.300 | 2.199 | 2.659 |
| 1.500 | 1.767 | 1.410 | 3.295 | 3.873 | 2.617 | 3.118 |
| 1.750 | 2.405 | 1.900 | — | — | — | 4.144 |
| 2.000 | 3.142 | 2.500 | — | — | — | 5.316 |

*Table 34-3 Sample Table of Anchor Data for a Fictitious Post-Installed Torque-Controlled Mechanical Expansion Anchor as Presumed Developed from Qualification Testing in Accordance with ACI 355.2-07.*

(Note: Fictitious data for example purposes only – data are not from a real anchor)

Anchor system is qualified for use in both cracked and uncracked concrete in accordance with test program of Table 4.2 of *ACI 355.2-07*. The material, ASTM F1554 grade 55, meets the ductile steel element requirements of *ACI 318-08 Appendix D* (tensile test elongation of at least 14 percent and reduction in area of at least 30 percent).

| Characteristic | Symbol | Units | Nominal anchor diameter | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Installation information | | | | | | | | | | |
| Outside diameter | $d_a$ | in. | 3/8 | | – | | 5/8 | | – | |
| Effective embedment depth | $h_{ef}$ | in. | 1.75 | | 2.5 | | 3 | | 3.5 | |
| | | | 2.75 | | 3.5 | | 4.5 | | 5 | |
| | | | 4.5 | | 5.5 | | 6.5 | | 8 | |
| Installation torque | $T_{inst}$ | ft-lb | 30 | | 65 | | 100 | | 175 | |
| Minimum edge distance | $c_{a,min}$ | in. | 1.75 | | 2.5 | | 3 | | 3.5 | |
| Minimum spacing | $s_{min}$ | in. | 1.75 | | 2.5 | | 3 | | 3.5 | |
| Minimum concrete thickness | $h_{min}$ | in. | $1.5h_{ef}$ | | $1.5h_{ef}$ | | $1.5h_{ef}$ | | $1.5h_{ef}$ | |
| Critical edge distance @ $h_{min}$ | $c_{ac}$ | in. | 2.1 | | 3.0 | | 3.6 | | 4.0 | |
| Anchor data | | | | | | | | | | |
| Anchor material | ASTM F1554 Grade 55 (meets ductile steel element requirements) | | | | | | | | | |
| Category number | 1, 2, or3 | — | 2 | | 2 | | 1 | | 1 | |
| Yield strength of anchor steel | $f_{ya}$ | psi | 55,000 | | 55,000 | | 55,000 | | 55,000 | |
| Ultimate strength of anchor steel | $f_{uta}$ | psi | 75,000 | | 75,000 | | 75,000 | | 75,000 | |
| Effective tensile stress area | $A_{se,N}$ | in.$^2$ | 0.0775 | | 0.142 | | 0.226 | | 0.334 | |
| Effective shear stress area | $A_{se,V}$ | in.$^2$ | 0.0775 | | 0.142 | | 0.226 | | 0.334 | |
| Effectiveness factor for uncracked concrete | $k_{uncr}$ | — | 24 | | 24 | | 24 | | 24 | |
| Effectiveness factor for cracked concrete used for ACI 318 design | $k_c$* | — | 17 | | 17 | | 17 | | 17 | |
| $\psi_{c,N}$ for ACI 318 design in cracked concrete | $\psi_{c,N}$* | — | 1.0 | | 1.0 | | 1.0 | | 1,0 | |
| $\psi_{c,N} = k_{uncr}/k_{cr}$ for ACI 318 design in uncracked concrete | $\psi_{c,N}$* | — | 1.4 | | 1.4 | | 1.4 | | 1.4 | |
| Pullout or pull-through resistance from tests | $N_p$ | lb | $h_{ef}$ | $N_p$ | $h_{ef}$ | $N_p$ | $h_{ef}$ | $N_p$ | $h_{ef}$ | $N_p$ |
| | | | 1.75 | 1354 | 2.5 | 2312 | 3 | 4469 | 3.5 | 5632 |
| | | | 2.75 | 2667 | 3.5 | 3830 | 4.5 | 8211 | 5 | 9617 |
| | | | 4.5 | 5583 | 5.5 | 7544 | 6.5 | 14,254 | 8 | 19,463 |
| Tension resistance of single anchor for seismic loads | $N_{eq}$ | lb | 1.75 | 903 | 2.5 | 1541 | 3 | 2979 | 3.5 | 3755 |
| | | | 4.5 | 3722 | 5.5 | 5029 | 6.5 | 9503 | 8 | 12,975 |
| Shear resistance of single anchor for seismic loads | $V_{eq}$ | lb | 2906 | | 5321 | | 8475 | | 12,543 | |
| Axial stiffness in service load range | $\beta$ | lb/in. | 55,000 | | 57,600 | | 59,200 | | 62,000 | |
| Coefficient of variation for axial stiffness in service load range. | $v$ | % | 12 | | 11 | | 10 | | 9 | |

*These are values used for $k_c$ and $\psi_{c,N}$ in ACI 318 for anchors qualified for use only in both cracked and uncracked concrete.

should refer to the appropriate material specification to be sure the material falls within the ductile steel element definition. Some high strength materials may not meet these requirements and must be considered as brittle steel elements.

**Table 34-2:** This table provides information on the effective cross-sectional area $A_{se}$ and bearing area $A_{brg}$ for threaded cast-in-place anchors up to 2 in. in diameter.

For both the elastic and plastic analysis methods of multiple-anchor connections subjected to moment, the exact location of the compressive resultant cannot be accurately determined by traditional concrete beam analysis methods. This is true for both the elastic linear stress-strain method (i.e., the transformed area method) and the ACI 318 stress block method since plane sections do not remain plane. For design purposes, the compression resultant from applied moment may be assumed to be located at the leading edge of the compression element of the attached member unless base plate stiffeners are provided. If base plate stiffeners are provided, the compressive resultant may be assumed to be located at the leading edge of the base plate.

Section D.3.3 was expanded in 2008 to clarify the ductility requirements when anchor design includes earthquake forces for structures assigned to Seismic Design Category C, D, E, or F. Further, for anchor designs controlled by concrete failure modes, D.3.3 provides the option to apply an additional strength reduction factor as discussed below. Section RD.3.3 provides a detailed discussion of these requirements.

Appendix D should not be used for the design of anchors in plastic hinge zones where high levels of cracking and spalling may be expected due to a seismic event (D.3.3.1). Per D.3.3.2, for SDC C, D, E, and F, Appendix D design provisions and anchor evaluation criteria of ACI 355.2 are based on cracks that might occur normally in concrete (the cracked concrete tests and simulated seismic tests in ACI 355.2 are based on anchor performance in cracks from 0.012 in. to 0.020 in.). The pullout strength, $N_p$, and the nominal steel strength of the anchor in shear, $V_{sa}$, must be based on the results of the Simulated Seismic Tests of ACI 355.2.

In regions of moderate or high seismic risk, or for structures assigned to SDC C, D, E, or F (see Table R1.1.9.1 for equivalent terminology used in building codes) all values for $\phi N_n$ and $\phi V_n$ associated with concrete failure modes must be reduced by multiplying those values by an additional factor of 0.75 (D.3.3.3). Further, the strength of the connection must be controlled by the strength of ductile steel elements and not the embedment strength or the strength of brittle steel elements (D.3.3.4). Alternatively, the structural attachment may be designed to yield at a load no greater than the design strength of the anchors governed by a concrete failure mode, reduced by the factor of 0.75 (D.3.3.5).

As an alternative to ductile behavior governing the design strength of anchor or attachment, D.3.3.6 permits taking the design strength of the non-ductile anchors as 0.4 times the strength governed by concrete failure, i.e. $(0.4)(0.75) = 0.3\phi N_n$ and $0.3\phi V_n$. The attachment of light frame stud walls typically involves multiple anchors, providing redundancy. Thus, for anchors of stud bearing walls, the 0.4 multiplier is increased to 0.5, i.e. $(0.5)(0.75) = 0.375\phi N_n$ and $0.375\phi V_n$.

## D.4 GENERAL REQUIREMENTS FOR STRENGTH OF ANCHORS

This section provides a general discussion of the failure modes that must be considered in the design of anchorages to concrete. The section also provides strength reduction factors, $\phi$, for each type of failure mode. The failure modes that must be considered include those related to the steel strength and those related to the strength of the embedment.

Failure modes related to steel strength are simply tensile failure [Fig. RD.4.1(a)(i)] and shear failure [Fig. RD.4.1(b)(i)] of the anchor steel. Anchor steel strength is relatively easy to compute but typically does not control the design of the connection unless there is a specific requirement that the steel strength of a ductile steel element must control the design.

Embedment failure modes that must be considered are illustrated in Appendix D Fig. RD.4.1. They include:

- concrete breakout - a concrete cone failure emanating from the embedded end of tension anchors [Fig. RD.4.1(a)(iii)] or from the entry point of shear anchors located near an edge [Fig. RD.4.1(b)(iii)]
- pullout - a straight pullout of the anchor such as might occur for an anchor with a small head [Fig. RD.4.1(a)(ii)]

**Table 34-3:** This table provides a fictitious sample information table for post-installed mechanical anchors that have been tested in accordance with ACI 355.2. This type of table will be available from manufactures that have tested their products in accordance with ACI 355.2. The table provides all of the values necessary for design of a particular post-installed mechanical anchor. The design of post-installed mechanical anchors must be based on this type of table unless values assumed in the design are specified in the project specifications (e.g., the pullout strength $N_p$).

As a further commentary on the five percent fractile in D.1 – Definitions, the five percent fractile is used to determine the nominal embedment strength of the anchor. It represents a value such that if 100 anchors are tested there is a 90% confidence that 95 of the anchors will exhibit strengths higher than the five percent fractile value. The five percent fractile is analogous to the use of $f'_c$ for concrete strength and $f_{ya}$ for steel strength in the nominal strength calculations in other parts of the ACI 318 code. For example, ACI 318 Section 5.3 requires that the required average compressive strength of the concrete be statistically greater than the specified value of $f'_c$ used in design calculations. For steel, $f_{ya}$ represents the specified yield strength of the material. Since ASTM specifications give the minimum specified yield strength, the value of $f_{ya}$ used in design is in effect a zero percent fractile (i.e., the actual steel used will have a yield value higher than the minimum specified value). All embedment strength calculations in Appendix D are based on a nominal strength calculated using 5 percent fractile values (e.g., the $k_c$ values used in calculating basic concrete breakout strength are based on the 5 percent fractile).

## D.2 Scope

These provisions apply to cast-in-place and post-installed mechanical anchors (such as those illustrated in Fig. RD.1) that are used to transmit structural loads between structural elements and safety related attachments to structural elements. The type of anchors included are cast-in-place headed studs, headed bolts, hooked bolts (J and L bolts), and post-installed mechanical anchors that have met the anchor assessment requirements of ACI 355.2. Other types of cast-in-place anchors (e.g., specialty inserts) and post-installed anchors (e.g., adhesive, grouted, and pneumatically actuated nails or bolts) are currently excluded from the scope of Appendix D as well as post-installed mechanical anchors that have not met the anchor assessment requirements of ACI 355.2. As noted in D.2.4, these design provisions do not apply to anchorages loaded with high cycle fatigue and impact loads.

## D.3 GENERAL REQUIREMENTS

The analysis methods prescribed in D.3 to determine loads on individual anchors in multiple anchor applications depend on the type of loading, rigidity of the attachment base plate, and the embedment of the anchors.

For multiple-anchor connections loaded concentrically in pure tension, the applied tensile load may be assumed to be evenly distributed among the anchors if the base plate has been designed so as not to yield. Prevention of yielding in the base plate will ensure that prying action does not develop in the connection.

For multiple-anchor connections loaded with an eccentric tension load or moment, distribution of loads to individual anchors should be determined by elastic analysis unless calculations indicate that sufficient ductility exists in the embedment of the anchors to permit a redistribution of load among individual anchors. If sufficient ductility is provided, a plastic design approach may be used. The plastic design approach requires ductile steel anchors sufficiently embedded so that embedment failure will not occur prior to a ductile steel failure. The plastic design approach assumes that the tension load (either from eccentric tension or moment) is equally distributed among the tension anchors. For connections subjected to moment, the plastic design approach is analogous to multiple layers of flexural reinforcement in a reinforced concrete beam. If the multiple layers of steel are adequately embedded and are a sufficient distance from the neutral axis of the member, they may be considered to have reached yield.

- side-face blowout - a spalling at the embedded head of anchors located near a free edge [Fig. RD.4.1(a)(iv)]
- concrete pryout - a shear failure mode that can occur with a short anchor popping out a wedge of concrete on the back side of the anchor [Fig. RD.4.1(b)(ii)]
- splitting - a tensile failure mode related to anchors placed in relatively thin concrete members [Fig. RD.4.1(a)(v)]

As noted in D.4.2, the use of any design model that results in predictions of strength that are in substantial agreement with test results is also permitted by the general requirements section. If the designer feels that the 45-degree cone method, or any other method satisfy this requirement he or she is permitted to use them. If not, the design provisions of the remaining sections of Appendix D should be used provided the anchor diameter does not exceed 2 in. and the embedment length does not exceed 25 in. These restrictions represent the upper limits of the database that the Appendix D design provisions for concrete breakout strength are based on.

In the selection of the appropriate $\phi$ related to embedment failure modes, the presence of supplementary reinforcement or anchor reinforcement designed to tie a potential failure prism to the structural member determines whether the $\phi$ for Condition A or Condition B applies. For the case of cast-in-place anchors loaded in shear directed toward a free edge, the supplementary reinforcement required for Condition A might be achieved by the use of hairpin reinforcement. It should be noted that for determining pullout strength for a single anchor, $N_{pn}$, and pryout strengths for a single anchor in shear, $V_{cp}$, or a group $V_{cpg}$, D.4.4(c) indicates that Condition B applies in all cases regardless of whether supplementary or anchor reinforcement is provided or not. In the case of post-installed anchors it is doubtful that hairpin reinforcement will have been installed prior to casting and Condition B will normally apply. Other patterns of existing reinforcement may help qualify post-installed anchors for Condition A. The selection of $\phi$ for post-installed anchors also depends on the anchor category determined from the ACI 355.2 product evaluation tests. As part of the ACI 355.2 product evaluation tests, product reliability tests (i.e., sensitivity to installation variables) are performed and the results used to establish the appropriate category for the anchor. Since each post-installed mechanical anchor may be assigned a different category, product data tables resulting from ACI 355.2 testing should be referred to. Example data are shown in Table 34-3.

Table 34-4 summarizes the strength reduction factors, $\phi$, to be used with the various governing conditions depending upon whether the load combinations of 9.2 or Appendix C are used.

## D.5 DESIGN REQUIREMENTS FOR TENSILE LOADING

Methods to determine the nominal tensile strength as controlled by steel strength and embedment strength are presented in the section on tensile loading. The nominal tensile strength of the steel is based on the specified tensile strength of the steel Eq. (D-3). The nominal tensile strength of the embedment is based on (1) concrete breakout strength, Eq. (D-4) for single anchors or Eq. (D-5) for groups of anchors, (2) pullout strength, Eq. (D-14), or (3) side-face blowout strength, Eq. (D-17) for single anchors or Eq. (D-18) for groups. When combined with the appropriate strength reduction factors from D.4.4 or D.4.5, the smallest of these nominal strengths values will control the design tensile strength of the anchorage.

### D.5.1 Steel Strength of Anchor in Tension

The tensile strength of the steel, $N_{sa}$, is determined from Eq. (D-3) using the effective cross-sectional area of the anchor $A_{se,N}$ and the specified tensile strength of the anchor steel $f_{uta}$.

For cast-in-place anchors (i.e., threaded anchors, headed studs and hooked bars), the effective cross-sectional area of the anchor $A_{se,N}$ is the net tensile stress area for threaded anchors and the gross area for headed studs that are welded to a base plate. These areas are provided in Table 34-2. For anchors of unusual geometry, the nominal steel strength may be taken as the lower 5% fractile of test results. For post-installed mechanical anchors the effective cross-sectional area of the anchor $A_{se,N}$ must be determined from the results of the ACI 355.2 product evaluation tests. Example data are shown in Table 34-3.

*Table 34-4 Strength Reduction Factors for Use with Appendix D*

| Strength Governed by | Strength Reduction Factor, $\phi$, for use with Load Combinations in: Section 9.2 | | Appendix C | |
|---|---|---|---|---|
| **Ductile steel element** | | | | |
| Tension, $N_{sa}$ | 0.75 | | 0.80 | |
| Shear, $V_{sa}$ | 0.65 | | 0.75 | |
| **Brittle steel element** | | | | |
| Tension, $N_{sa}$ | 0.65 | | 0.70 | |
| Shear, $V_{sa}$ | 0.60 | | 0.65 | |
| **Concrete** | Condition A | Condition B | Condition A | Condition B |
| Shear | | | | |
| Breakout, $V_{cb}$ and $V_{cbg}$ | 0.75 | 0.70 | 0.85 | 0.75 |
| Pryout, $V_{cp}$ | 0.70 | 0.70 | 0.75 | 0.75 |
| Tension | | | | |
| Cast-in headed studs, headed bolts, or hooked bolts | | | | |
| Breakout and side face blowout, $N_{cb}$, $N_{cbg}$, $N_{sb}$ and $N_{sbg}$ | 0.75 | 0.70 | 0.85 | 0.75 |
| Pullout, $N_{pn}$ | 0.70 | 0.70 | 0.75 | 0.75 |
| Post-installed anchors with category determined per ACI 355.2 | | | | |
| Category 1 (low sensitivity to installation and high reliability) | | | | |
| Breakout and side face blowout, $N_{cb}$, $N_{cbg}$, $N_{sb}$ and $N_{sbg}$ | 0.75 | 0.65 | 0.85 | 0.75 |
| Pullout, $N_{pn}$ | 0.65 | 0.65 | 0.75 | 0.75 |
| Category 2 (med. sensitivity to installation and med. reliability) | | | | |
| Breakout and side face blowout, $N_{cb}$, $N_{cbg}$, $N_{sb}$ and $N_{sbg}$ | 0.65 | 0.55 | 0.75 | 0.65 |
| Pullout, $N_{pn}$ | 0.55 | 0.55 | 0.65 | 0.65 |
| Category 3 (high sensitivity to installation and low reliability) | | | | |
| Breakout and side face blowout, $N_{cb}$, $N_{cbg}$, $N_{sb}$ and $N_{sbg}$ | 0.55 | 0.45 | 0.65 | 0.55 |
| Pullout, $N_{pn}$ | 0.45 | 0.45 | 0.55 | 0.55 |

The value of $f_{uta}$ used in Eq. (D-3) is limited to $1.9f_{ya}$ or 125,000 psi. The limit of $1.9f_{ya}$ is intended to ensure that the anchor does not yield under service loads and typically applies only to stainless steel materials. The limit of 125,000 psi is based on the database used in developing the Appendix D provisions. Table 34-1 provides values for $f_{ya}$ and $f_{uta}$ for typical anchor materials. Note that neither of the limits applies to the typical anchor materials given in Table 34-1. For anchors manufactured according to specifications having a range for specified tensile strength, $f_{uta}$ (e.g., ASTM F1554), the lower limit value should be used to calculate the design strength. Post-installed anchor manufacturers usually machine their own anchors. Thus, for post-installed mechanical anchors, both $f_{ya}$ and $f_{uta}$ must be determined from the results of the ACI 355.2 product evaluation tests. Example data are shown in Table 34-3.

## D.5.2 Concrete Breakout Strength of Anchor in Tension

Figure RD.4.1(a)(iii) shows a typical concrete breakout failure (i.e., concrete cone failure) for a single headed cast-in-place anchor loaded in tension. Eq. (D-4) gives the concrete breakout strength for a single anchor, $N_{cb}$, while Eq. (D-5) gives the concrete breakout strength for a group of anchors in tension, $N_{cbg}$.

The individual terms in Eq. (D-4) and Eq. (D-5) are discussed below:

$N_b$: The basic concrete breakout strength for a single anchor located away from edges and other anchors ($N_b$) is given by Eq. (D-7) or Eq. (D-8). As previously noted, the primary difference between these equations and those of the 45-degree concrete cone method is the use of $h_{ef}^{1.5}$ in Eq. (D-7) [or alternatively $h_{ef}^{5/3}$ for anchors with $h_{ef} \geq 11$ in. in Eq. (D-8)] rather than $h_{ef}^2$. The use of $h_{ef}^{1.5}$ accounts for fracture mechanics principles and can be thought of as follows:

$$N_b = \frac{k\sqrt{f'_c}h_{ef}^2}{h_{ef}^{0.5}}\left[\frac{\text{general } 45^\circ \text{ concrete cone equation}}{\text{modification factor for fracture mechanics}}\right]$$

Resulting in:

$$N_b = k_c\sqrt{f'_c}h_{ef}^{1.5}$$ *Eq. (D-7)*

The fracture mechanics approach accounts for the high tensile stresses that exist at the embedded head of the anchor while other approaches (such as the 45-degree concrete cone method) assume a uniform distribution of stresses over the assumed failure surface.

The numeric constant $k_c$ of 24 in Eq. (D-7) [or $k_c$ of 16 in Eq. (D-8) if $h_{ef} \geq 11$ in.] is based on the 5% fractile of test results on headed cast-in-place anchors in cracked concrete. These $k_c$ values must be used unless higher values of $k_c$ are justified by ACI 355.2 product-specific tests. The value of $k_c$ must not exceed 24. Note that the crack width used in tests to establish these $k_c$ values was 0.012 in. If larger crack widths are anticipated, confining reinforcement to control crack width to about 0.012 in. should be provided or special testing in larger cracks should be performed.

$\frac{A_{Nc}}{A_{Nco}}$: This factor accounts for adjacent anchors and/or free edges. For a single anchor located away from free edges, the $A_{Nco}$ term is the projected area of a 35-degree failure plane, measured relative to the surface of the concrete, and defined by a square with the sides $1.5h_{ef}$ from the centerline of the anchor [Fig. RD.5.2.1(a)]. The $A_{Nc}$ term is a rectilinear projected area of the 35-degree failure plane at the surface of the concrete with sides $1.5h_{ef}$ from the centerline of the anchor(s) as limited by adjacent anchors and/or free edges. The definition of $A_{Nc}$ is shown in Fig. RD.5.2.1(b). For a single anchor located at least $1.5h_{ef}$ from the closest free edge and $3h_{ef}$ from other anchors, $A_{Nc}$ equals $A_{Nco}$.

Where a plate or washer is used to increase the bearing area of the head of an anchor, $1.5h_{ef}$ can be measured from the effective perimeter of the plate or washer where the effective perimeter is defined in D.5.2.8. Where a plate or washer is used, the projected area $A_{Nc}$ can be based on $1.5h_{ef}$ measured from the effective perimeter of the plate or washer where the effective perimeter is defined in D.5.2.8 and shown in Fig. 34-1.

$\psi_{ec,N}$: This factor is applicable when multiple rows of tension anchors are present and the elastic design approach is used. In this case, the individual rows of tension anchors are assumed to carry different levels of load with the centerline of action of the applied tension load at an eccentricity ($e'_N$) from the centroid of anchors subject to tension due to loads from a given load combination. If the plastic design approach is used, all tension anchors are assumed to carry the same load and the eccentricity factor, $\psi_{ec,N}$, is taken as 1.0

$\psi_{ed,N}$: This factor accounts for the non-uniform distribution of stresses when an anchor is located near a free edge of the concrete that are not accounted for by the $\frac{A_{Nc}}{A_{Nco}}$ term.

$\psi_{c,N}$ : This factor is taken as 1.0 if cracks in the concrete are likely to occur at the location of the anchor(s). If calculations indicate that concrete cracking is not likely to occur under service loads (e.g., $f_t < f_r$), then $\psi_{e,N}$ may be taken as 1.25 for cast-in-place anchors or 1.4 for post-installed anchors.

$\psi_{cp,N}$: This factor is taken as 1.0 except when the design assumes uncracked concrete, uses post-installed anchors, and without supplementary reinforcement to control splitting.

The 2008 Code introduced a definition for "Anchor reinforcement" in D.1. The purpose of this reinforcement is to safeguard against a concrete breakout failure. Anchor reinforcement can be designed to develop the full factored tension and/or shear force transmitted to a single anchor or group of anchors. Guidance for designing this reinforcement is given in RD.5.2.9, and for placing anchor reinforcement is illustrated in Fig. RD.5.2.9.

## D.5.3 Pullout Strength of Anchor in Tension

A schematic of the pullout failure mode is shown in Fig. RD.4.1(a)(ii). The pullout strength of cast-in-place anchors is related to the bearing area at the embedded end of headed anchors, $A_{brg}$, and the properties of embedded hooks ($e_h$ and $d_o$) for J-bolts and L-bolts. Obviously, if an anchor has no head or hook it will simply pull out of the concrete and not be able to achieve the concrete breakout strength associated with a full concrete cone failure (D.5.2). With an adequate head or hook size, pullout will not occur and the concrete breakout strength can be achieved. Equation (D-14) provides the general requirement for pullout while Eq. (D-15) and Eq. (D-16) provide the specific requirements for headed and hooked anchors, respectively. Equation (D-14) concerns pullout strength of a single anchor. For a group of anchors, pullout strength of each anchor should be considered separately.

For headed anchors, the bearing area of the embedded head ($A_{brg}$) is the gross area of the head less the gross area of the anchor shaft (i.e., not the area of the embedded head). Washers or plates with an area larger than the head of an anchor can be used to increase the bearing area, $A_{brg}$, thus increasing the pullout strength (see D.5.2.8). In regions of moderate or high seismic risk, or for structures assigned to intermediate or high seismic performance or design categories, where a headed bolt is being designed as a ductile steel element according to D.3.3.4, it may be necessary to use a bolt with a larger head or a washer in order to increase the design pullout strength, $\phi N_{pn}$, to assure that yielding of the steel takes place prior failure of the embedded portion of the an chor. Table 34-2 provides values for $A_{brg}$ for standard bolt heads and nuts. Tables 34-5A, B and C can be used to quickly determine scenarios where the head of a bolt will not provide adequate pullout strength and will need to be increased in size.

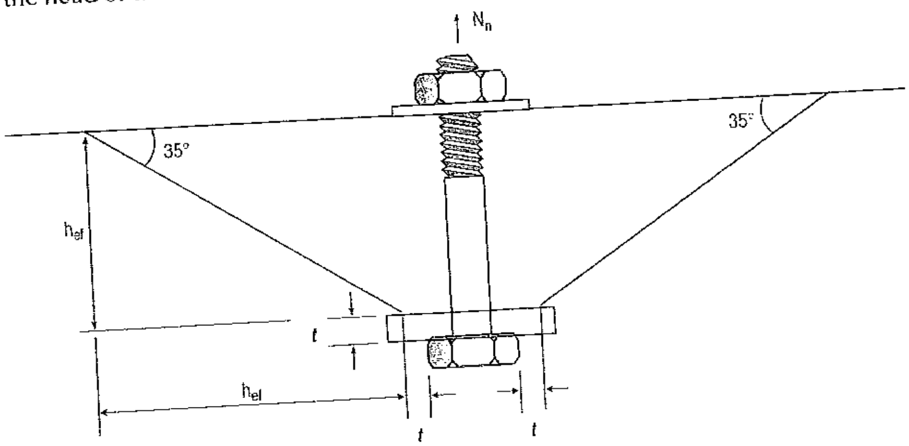


*Figure 34-1 Effect of Washer Plate on Projected Area of Concrete Breakout*

For J-bolts and L-bolts, the minimum length of the hook measured from the inside surface of the shaft of the anchor is $3d_a$ while the maximum length for calculating pullout strength by Eq. (D-16) is $4.5d_a$. For other than high strength concrete, it is difficult to achieve design pullout strength of a hooked bolt that is equal to or greater than the design tensile strength of the steel. For example, a 1/2 in. diameter hooked bolt with the maximum hook length of $4.5d_a$ permitted in evaluating pullout strength in Eq. (D-16) requires that $f'_c$ be at least 8700 psi to develop the design tensile strength of an ASTM A307, Grade C, or ASTM F1554, Grade 36 anchor ($f_{uta}$ = 58,000 psi). This essentially prohibits the use of hooked bolts in many applications subject to seismic tensile loading due to the limitations of D.3.3.4 that the anchor strength must be governed by the ductile anchor steel unless the reduction multipliers of D.3.3.6 are applied.

For post-installed mechanical anchors, the value for the pullout strength, $N_p$, must be determined from the results of the ACI 355.2 product evaluation tests. Example data are shown in Table 34-3.

### D.5.4 Concrete Side-Face Blowout Strength of Headed Anchor in Tension

The side-face blowout strength is associated with the lateral pressure that develops around the embedded end of headed anchors under load. Where the minimum edge distance for a single headed anchor is less than 0.4 $h_{ef}$, side-face blowout must be considered using Eq. (D-17). If an orthogonal free edge (i.e., an anchor in a corner) is located less than three times the distance from the anchor to the nearest edge) then an additional reduction factor of $[(1+ c_{a2}/c_{a1})/4]$, where $c_{a1}$ is the distance to the nearest edge and $c_{a2}$ is the distance to the orthogonal edge, must be applied to Eq. (D-17).

For multiple anchor groups, the side-face blowout strength is given by Eq. (D-18) provided the spacing between individual anchors parallel to a free edge is greater than or equal to six times the distance to the free edge. If the spacing of the anchors in the group is less than six times the distance to the free edge, Eq. (D-18) must be used.

## D.6 DESIGN REQUIREMENTS FOR SHEAR LOADING

Methods to determine the nominal shear strength as controlled by steel strength and embedment strength are specified in D.6. The nominal shear strength of the steel is based on the specified tensile strength of the steel using Eq. (D-19) for headed studs, Eq. (D-20) for headed and hooked bolts, and for post-installed anchors. The nominal shear strength of the embedment is based on concrete breakout strength Eq. (D-21) for single anchors or Eq. (D-22) for groups of anchors, or pryout strength Eq. (D-30) for single anchors or Eq. (D-31) for groups. When combined with the appropriate strength reduction factors from D.4.4, the smaller of these strengths will control the design shear strength of the anchorage.

### D.6.1 Steel Strength of Anchor in Shear

For cast-in-place anchors, the shear strength of the steel is determined from Eq. (D-19) for headed studs and Eq. (D-20) for headed and hooked bolts using the effective cross-sectional area of the anchor, $A_{se,V}$, and the specified tensile strength of the anchor steel, $f_{uta}$. For post-installed mechanical anchors, the shear strength of the steel is determined from Eq. (D-20) using the effective cross-sectional area of the anchor, $A_{se,V}$, and the specified tensile strength of the anchor steel, $f_{uta}$, unless the ACI 355.2 anchor qualification report provides a value for $V_{sa}$.

For cast-in-place anchors (i.e., headed anchors, headed studs and hooked bars), the effective cross-sectional area of the anchor ($A_{se,V}$) is the net tensile stress area for threaded anchors and the gross area for headed studs that are welded to a base plate. These areas are provided in Table 34-2. If the threads of headed anchors, L- or J-bolts are located well above the shear plane (at least two diameters) the gross area of the anchor may be used for shear. For anchors of unusual geometry, the nominal steel strength may be taken as the lower 5% fractile of test results. For post-installed mechanical anchors the effective cross-sectional area of the anchor, $A_{se,V}$ or the nominal shear strength, $V_{sa}$, must be determined from the results of the ACI 355.2 product evaluation tests. Example data are shown in Table 34-3.

The value of $f_{uta}$ used in Eq. (D-19) and Eq. (D-20) is limited to 1.9$f_{ya}$ or 125,000 psi. The limit of 1.9$f_{ya}$ is intended to ensure that the anchor does not yield under service loads and typically is applicable only to stainless steel materials. The limit of 125,000 psi is based on the database used in developing the Appendix D provisions. Table 34-1 provides values for $f_{ya}$ and $f_{uta}$ for typical anchor materials. Note that neither of the limits applies to the typical anchor materials given in Table 34-1. For anchors manufactured according to specifications having a range for specified tensile strength, $f_{uta}$ (e.g., ASTM F1554), the lower limit value should be used to calculate the design strength. Post-installed anchor manufacturers usually machine their own anchors. Thus, for post-installed mechanical anchors, $f_{ya}$ and $f_{uta}$ must be determined from the results of the ACI 355.2 product evaluation tests. Example data are shown in Table 34-3.

When built-up grout pads are present, the nominal shear strength values given by Eq. (D-19) and Eq. (D-20) must be reduced by 20% to account for the flexural stresses developed in the anchor if the grout pad fractures upon application of the shear load.

## D.6.2 Concrete Breakout Strength of Anchor in Shear

Fig. RD.4.1(b)(iii) shows typical concrete breakout failures for anchors loaded in shear directed toward a free edge. Equation (D-21) gives the concrete breakout strength for a single anchor, $V_{cb}$, while Eq. (D-22) gives the concrete breakout strength for groups of anchors in shear, $V_{cbg}$. In cases where the shear is directed away from the free edge, the concrete breakout strength in shear need not be considered.

The individual terms in Eq. (D-21) and Eq. (D-22) are discussed below:

$V_b$: The basic concrete breakout strength for a single anchor in cracked concrete loaded in shear, directed toward a free edge ($V_b$) without any other adjacent free edges or limited concrete thickness is given by Eq. (D-24) for typical bolted connections and Eq. (D-25) for connections with welded studs or other anchors welded to the attached base plate. The primary difference between these equations and those using the 45-degree concrete cone method is the use of $c_{a1}^{1.5}$ rather than $c_{a1}^{2}$. The use of $c_{a1}^{1.5}$ accounts for fracture mechanics principles in the same way that $h_{ef}^{1.5}$ does for tension anchors. The fracture mechanics approach accounts for the high tensile stresses that exist in the concrete at the point where the anchor first enters the concrete.

$\ell_e$, $d_a$: The terms involving $\ell_e$ and $d_a$ in Eq. (D-24) and Eq. (D-25) relate to the shear stiffness of the anchor. A stiff anchor is able to distribute the applied shear load further into the concrete than a flexible anchor.

$\frac{A_{Vc}}{A_{Vco}}$: This factor accounts for adjacent anchors, concrete thickness, and free edges. For a single anchor in a thick concrete member with shear directed toward a free edge, the $A_{Vco}$ term is the projected area on the side of the free edge of a 35-degree failure plane radiating from the point where the anchor first enters the concrete and directed toward the free edge [see Fig. RD.6.2.1(a)]. The $A_{Vc}$ term is a rectilinear projected area of the 35-degree failure plane on the side of the free edge with sides 1.5 $h_{ef}$ from the point where the anchor first enters the concrete as limited by adjacent anchors, concrete thickness and free edges. The definition of $A_{Vc}$ is shown in Fig. RD.6.2.1(b).

$\psi_{ec,V}$: This factor applies when the applied shear load does not act through the centroid of the anchors loaded in shear [see Fig. RD.6.2.5]

$\psi_{ed,V}$: This factor accounts for the non-uniform distribution of stresses when an anchor is located in a corner that is not accounted for by the $\frac{A_{Vc}}{A_{Vco}}$ term [see Fig. RD.6.2.1(d)].

$\psi_{c,V}$: This factor is taken as 1.0 if cracks in the concrete are likely to occur at the location of the anchor(s) and no supplemental reinforcement has been provided. If calculations indicate that concrete cracking is not likely to occur (e.g., $f_t < f_r$ at service loads), then $\psi_{c,V}$ may be taken as 1.4. Values of $\psi_{c,V} > 1.0$ may be used if cracking at service loads is likely, provided No. 4 bar or greater edge reinforcement is provided (see D.6.2.7).

$\psi_{h,V}$: This factor accounts for members where the thickness $h_a$ is less than $1.5_{ca1}$.

Properly designed and detailed **anchor reinforcement** can develop the factored shear force transmitted to an anchor, if the factored shear exceeds the concrete breakout strength. See Figs. RD.6.2.9(a) and (b).

## D.6.3 Concrete Pryout Strength of Anchor in Shear

The concrete pryout strength of an anchor in shear may control when an anchor is both short and relatively stiff. Fig. RD.4.1(b)(ii) shows this failure mode. As a mental exercise, this failure mode may be envisioned by thinking of a No. 8 bar embedded 2 in. in concrete with 3 ft. of the bar sticking out. A small push at the top of the bar will cause the bar to "pryout" of the concrete.

## D.7 INTERACTION OF TENSILE AND SHEAR FORCES

The interaction requirements for tension and shear are based on a trilinear approximation to the following interaction equation (see Fig. RD.7):

$$\left[\frac{N_{ua}}{\phi N_n}\right]^{\frac{5}{3}} + \left[\frac{V_{ua}}{\phi V_n}\right]^{\frac{5}{3}} = 1$$

In the trilinear simplification, D.7.1 permits the full value of $\phi N_n$ if $V_{ua} \leq 0.2\ \phi V_n$ and D.7.2 permits the full value of $\phi V_n$ if $N_{ua} \leq 0.2\phi N_n$. If both of these conditions are not satisfied, the linear interaction of Eq. (D-32) must be used.

The most important aspect of the interaction provisions is that both $\phi N_n$ and $\phi V_n$ are the smallest of the anchor strengths as controlled by the anchor steel or the embedment. Tests have shown that the interaction relationship is valid whether steel strength or embedment strength controls for $\phi N_n$ or $\phi V_n$.

## D.8 REQUIRED EDGE DISTANCES, SPACINGS, AND THICKNESSES TO PRECLUDE SPLITTING FAILURE

Section D.8 provides minimum edge distance, spacing, and member thickness requirements to preclude a possible splitting failure of the structural member. For untorqued cast-in-place anchors (e.g., headed studs or headed bolts that are not highly preloaded after the attachment is installed), the minimum edge distance and member thickness is controlled by the cover requirements of 7.7 and the minimum anchor spacing is $4d_a$. For torqued cast-in-place anchors (e.g., headed bolts that are highly pre-loaded after the attachment is installed), the minimum edge distance and spacing is $6d_a$ and the member thickness is controlled by the cover requirements of 7.7.

Post-installed mechanical anchors can exert large lateral pressures at the embedded expansion device during installation that can lead to a splitting failure. Minimum spacing, edge distance, and member thickness requirements for post-installed anchors should be determined from the product-specific test results developed in the ACI 355.2 product evaluation testing. Example data are shown in Table 34-3. In the absence of the product-specific test results, the following should be used: a minimum anchor spacing of $6d_a$; a minimum edge distance of $6d_a$ for undercut anchors, $8d_a$ for torque-controlled anchors, and $10d_a$ for displacement controlled anchors; and a minimum member thickness of $1.5h_{ef}$ but need not exceed $h_{ef}$ plus 4 in. Examples of each of these types of anchors are shown in ACI 355.2. In all cases, the minimum edge distance and member thickness should meet the minimum cover requirements of 7.7.

For untorqued anchors, D.8.4 provides a method to use a large diameter anchor nearer to an edge or with closer spacing than that required by D.8.1 to D.8.3. In this case, a fictitious anchor diameter $d'_a$ is used in evaluating the strength of the anchor and in determining the minimum edge and spacing requirements.

For post-installed mechanical anchors, D.8.6 provides conservative default values for the critical edge distance $c_{ac}$ used to determine $\psi_{cp,N}$. ACI 355.2 anchor qualification reports will provide values of $c_{ac}$ associated with individual products (see sample Table 34-3.)

## D.9 INSTALLATION OF ANCHORS

Cast-in-place anchors should be installed in accordance with construction documents. For threaded anchors, a metal or plywood template mounted above the surface of the concrete with nuts on each side of the template should be used to hold the anchors in a fixed position while the concrete is placed, consolidated, and hardens. Project specifications should require that post-installed anchors be installed in accordance with the manufacturer's installation instructions. As noted in RD.9, ACI 355.2 product evaluation testing is based on the manufacturer's installation instructions. As part of the ACI 355.2 product evaluation tests, product reliability tests (i.e., sensitivity to installation variables) are performed and the results are used to determine the category of the anchor to be used in the selection of the appropriate $\phi$ in D.4.4.

## DESIGN TABLES FOR SINGLE CAST-IN ANCHORS

Tables have been provided to assist in the design of single anchors subject to tensile or shear loads. Tables 34-5A, B, and C provide design tensile strengths, $\phi N_n$, of single anchors in concrete with $f'_c$ of 2500, 4000, and 6000 psi, respectively. Tables 34-6A, B, and C provide design shear strengths, $\phi V_n$, of single anchors in concrete with $f'_c$ of 2500, 4000, and 6000 psi, respectively. A number of specified tensile strengths of steel, $f_{uta}$, are included to accommodate most anchor materials in use today. Notes accompany each group of tables that explain the assumptions used to develop the tables and how to adjust values for conditions that differ from those assumed.

According to D.8.2, minimum edge distances for cast-in headed anchors that will not be torqued must be based on minimum cover prescribed in 7.7. Thus, technically, concrete cover as low as 3/4 in. is permitted. If such a small cover is provided to the anchor shaft, the head of the anchor would end up having a cover smaller than 3/4 in. For corrosion protection, and in consideration of tolerances on placement (location and alignment) of anchors, it is recommended to provide a minimum concrete cover on cast-in anchors of 1-1/2 in. Tables 34-5 and 34-6 include design strengths for cast-in anchors with a minimum cover of 1-1/2 in.

## NOTES FOR TENSION TABLES 34-5A, B, AND C

NP – Not practical. Resulting edge distance, $c_{a1}$, yields less than 1-1/2 in. cover.

All Notation are identical to those used in 2.1.

1. Design strengths in table are for single cast-in anchors near one edge only. The values do not apply where the distance between adjacent anchors is less than $3h_{ef}$, or where the perpendicular distance, $c_{a2}$, to the edge distance being considered, $c_{a1}$, is less than $1.5h_{ef}$.

2. When anchor design includes earhtquake forces for structures assigned to Seismic Design Category C, D, E or F, the concrete design strengths in the table must be reduced by 25%. In addition, the anchor must be designed so strength is governed by a ductile steel element, unless D.3.3.5 or D.3.3.6 is satisfied. Therefore, the design strengths based on the three concrete failure modes, $\phi N_{cb}$, $\phi N_{pn}$ and $\phi N_{sb}$, multiplied by 0.75 must exceed the design strength of the steel in tension, $\phi N_{sa}$. This requirement effectively precludes the use of hooked anchor bolts in the seismic zones noted above.

3. For design purposes the tensile strength of the anchor steel, $f_{uta}$, must not exceed $1.9f_{ya}$ or 125,000 psi.

4. Design strengths in table are based on strength reduction factor, $\phi$, of Section D.4.4. Factored tensile load $N_{ua}$ must be computed from the load combinations of 9.2. Design strengths for concrete breakout, $\phi N_{cb}$, pullout, $\phi N_{pn}$, and sideface blowout, $\phi N_{sb}$, are based on Condition B. Where supplementary reinforcement is provided to satisfy Condition A, design strengths for $\phi N_{cb}$ may be increased 7.1% to account for the increase in strength reduction factor from 0.70 to 0.75. This increase does not apply to pullout strength, $\phi N_{pn}$ or side-face blowout, $\phi N_{sb}$.

5. Design strengths for concrete breakout in tension, $\phi N_{cb}$, are based on $N_b$ determined in accordance with Eq. (D-7) and apply to headed and hooked anchors. To determine the design strength of headed bolts with embedment depth, $h_{ef}$, greater than 11 in. in accordance with Eq. (D-8), multiply the table value by $[2(h_{ef}^{5/3})]/[3(h_{ef}^{1.5})]$.

6. Where analysis indicates that there will be no cracking at service load levels ($f_t < f_r$) in the region of the anchor, the design strengths for concrete breakout in tension, $\phi N_{cb}$, may be increased 25%.

7. The design strengths for pullout in tension, $\phi N_{pn}$, for headed bolts with diameter, $d_a$, less than 1-3/4 in. are based on bolts with regular hex heads. The design strengths for 1-3/4 and 2-in. bolts are based on heavy hex heads. For bolts with $d_a$ less than 1-3/4 in. having heads with a larger bearing area, $A_{brg}$, than assumed, the design strengths may be increased by multiplying by the bearing area of the larger head and dividing by the bearing area of the regular hex head.

8. The design strengths for pullout in tension, $\phi N_{pn}$, for hooked bolts with hook-length, $e_h$, between 3 and 4.5 times diameter, $d_a$, may be determined by interpolation.

9. Where analysis indicates there will be no cracking at service load levels ($f_t < f_r$) in the region of the anchor, the design strengths for pullout in tension, $\phi N_{pn}$, may be increased 40%.

10. The design strengths for side-face blowout in tension, $\phi N_{sb}$, are applicable to headed bolts only and where edge distance, $c_{a1}$, is less than $0.4h_{ef}$. The values for $0.4h_{ef}$ are shown for interpolation purposes only. The design strengths for bolts with diameter, $d_a$, less than 1-3/4 in. are based on bolts with regular hex heads. The design strengths for 1-3/4 and 2 in. bolts are based on bolts with heavy hex heads. For bolts with $d_a$ less than 1-3/4 in. having heads with a larger bearing area, $A_{brg}$, than assumed, the design strengths may be increased by multiplying by the square root of the quotient resulting from dividing the bearing area of the larger head by the bearing area of the regular hex head $\left(\sqrt{A_{brg2} / A_{brg1}}\right)$.

11. Design strengths for concrete breakout, $\phi N_{cb}$, and side-face blowout, $\phi N_{sb}$, are for normalweight concrete. For anchors in lightweight concrete, $\phi N_{cb}$ and $\phi N_{sb}$ must be multiplied by modifier $\lambda$ from 8.6.

## NOTES FOR SHEAR TABLES 34-6A, B AND C

NP – Not practical. Resulting edge distance, $c_{a1}$, yields less than 1-1/2 in. cover.

All Notation are identical to those used in 2.1 starting with ACI 318-05.

1. Design strengths in table are for single cast-in anchors near one edge only. The values do not apply where the distance to an edge measured perpendicular to $c_{a1}$ is less than $1.5c_{a1}$. See Note 9.

   The values do not apply where the distance between adjacent anchors is less than $3c_{a1}$, where $c_{a1}$ is the distance from the center of the anchor to the edge in the direction of shear application.

2. When anchor design includes earthquake forces for structures assigned to Seismic Design Category C, D, E or F, the concrete design strengths in the table must be reduced by 25%. In addition, the anchor must be designed so failure is initiated by a ductile steel element, unless D.3.3.5 or D.3.3.6 is satisfied. This means that all the design strengths based on the two concrete failure modes, $\phi V_{cb}$ and $\phi V_{cp}$, multiplied by 0.75 must equal or exceed the design strength of the steel in shear, $\phi V_{sa}$.

3. Concrete pryout strength, $\phi V_{cp}$, is to be taken equal to tension breakout strength, $\phi N_{cb}$, where $h_{ef}$ is less than 2.5 in., and to be taken as twice $\phi N_{cb}$ where $h_{ef}$ is equal to or greater than 2.5 in. Condition B (see D.4.4) must be assumed even where supplementary reinforcement qualifying for Condition A is present (i.e., strength reduction factor, $\phi$, must be taken equal to 0.70).

4. For design purposes the tensile strength of the anchor steel, $f_{uta}$, must not exceed $1.9f_{ya}$ or 125,000 psi.

5. Design strengths in table are based on strength reduction factor, $\phi$, of Section D.4.4. Factored shear load $V_{ua}$ must be computed from the load combinations of 9.2. Design strengths for concrete breakout, $\phi V_{cb}$, are based on Condition B. Where supplementary reinforcement is provided to satisfy Condition A, design strengths may be increased 7.1% to account for the increase in strength reduction factor from 0.70 to 0.75.

6. Where analysis indicates that there will be no cracking at service load levels ($f_t < f_r$) in the region of the anchor, the design strengths for concrete breakout in shear, $\phi V_{cb}$, may be increased 40%.

7. In regions of members where analysis indicates cracking at service level loads, the strengths in the table for concrete breakout, $\phi V_{cb}$, may be increased in accordance with the factors in D.6.2.7 if edge reinforcement or edge reinforcement enclosed within stirrups is provided in accordance with that section.

8. The design strengths for concrete breakout, $\phi V_{cb}$, are based on the shear load being applied perpendicular to the edge. If the load is applied parallel to the edge, the strengths may be increased 100%.

9. Where the anchor is located near a corner with an edge distance perpendicular to direction of shear, $c_{a2}$, less than $1.5c_{a1}$, design strengths for concrete breakout, $\phi V_{cb}$, shall be reduced by multiplying by modification factor, $\psi_{ed,V}$, determined from Eq. (D-28). The calculated values in the table do not apply where two edge distances perpendicular to direction of shear, $c_{a2}$, are less than $1.5c_{a1}$. See D.6.2.4.

10. This value of thickness, h, is not practical since the head or hook would project below the bottom surface of the concrete. It was chosen to facilitate mental calculation of the actual edge distance, $c_{a1}$, since the variable used in the calculation $c_{a1}$ is a function of embedment depth, $h_{ef}$.

11. Linear interpolation for intermediate values of edge distance, $c_{a1}$, is permissible. Linear interpolation for intermediate values of embedment depth, $h_{ef}$, is unconservative.

12. For 1-1/2 in. cover and for $c_{a1} = 0.25h_{ef}$ and $0.50h_{ef}$, see portion of table for $h = h_{ef}$.

13. For 1-1/2 in. cover and for $c_{a1} = 0.25h_{ef}$ and $0.50h_{ef}$, see portion of table for $h = h_{ef}$. For $c_{a1} = h_{ef}$, see portion of table for $h = 1.5h_{ef}$.

14. Tabulated design strengths for concrete breakout, $\phi V_{cb}$, are for anchors in normalweight concrete. For anchors in lightweight concrete, $\phi V_{cb}$ must be multiplied by modifier $\lambda$ from 8.6.

15. For anchors located in members with a thickness $h_a$ less than $1.5_{ca1}$, concrete breakout, $\phi V_{cb}$, may be increased by the modifier $\psi_{h,V}$ computed from Eq. (D-29).

*Table 34-5A. Design Strengths for Single Cast-In Anchors Subject to Tensile Loads ($f'_c$ = 2500 psi)[1, 2, 4]*
*Notes pertaining to this table are given on Page 34-16*

| $d_o$ in. | $h_{ef}$ in. | $\phi N_s$ - Tension Strength of Anchor | | | | | | | $\phi N_{cb}$ - Tension Breakout[4, 5, 6, 11] | | | | | $\phi N_{pn}$ - Pullout[9] | | | $\phi N_{sb}$ - Sideface Blowout[4, 10, 11] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $f_{ut}$ - for design purposes[3] - psi | | | | | | | $c_{a1}$ - edge distance in. | | | | | head[7] | "J" or "L" hook[8] | | $c_{a1}$ - edge distance in. | | |
| | | 58,000 | 60,000 | 75,000 | 90,000 | 105,000 | 120,000 | 125,000 | 1-1/2-in. cover | 0.25 $h_{ef}$ | 0.5 $h_{ef}$ | $h_{ef}$ | ≥1.5 $h_{ef}$ | | $e_h$ = 3 $d_o$ | $e_h$ = 4.5 $d_o$ | 1-1/2-in. cover | 0.25 $h_{ef}$ | 0.4 $h_{ef}$ |
| 1/4 | 2 | 1,392 | 1,440 | 1,800 | 2,160 | 2,520 | 2,880 | 3,000 | 1,580 | NP | NP | 1,782 | 2,376 | 1,638 | 295 | 443 | 3,113 | NP | NP |
| | 3 | 1,392 | 1,440 | 1,800 | 2,160 | 2,520 | 2,880 | 3,000 | 2,401 | NP | NP | 3,274 | 4,365 | 1,638 | 295 | 443 | 3,113 | NP | NP |
| | 4 | 1,392 | 1,440 | 1,800 | 2,160 | 2,520 | 2,880 | 3,000 | 3,336 | NP | 3,584 | 5,040 | 6,720 | 1,638 | 295 | 443 | 3,113 | NP | NP |
| | 5 | 1,392 | 1,440 | 1,800 | 2,160 | 2,520 | 2,880 | 3,000 | 4,371 | NP | 5,009 | 7,044 | 9,391 | 1,638 | 295 | 443 | 3,113 | NP | 3,831 |
| | 6 | 1,392 | 1,440 | 1,800 | 2,160 | 2,520 | 2,880 | 3,000 | 5,496 | NP | 6,584 | 9,259 | 12,345 | 1,638 | 295 | 443 | 3,113 | NP | 4,597 |
| 3/8 | 2 | 3,393 | 3,510 | 4,388 | 5,265 | 6,143 | 7,020 | 7,313 | 1,613 | NP | NP | 1,782 | 2,376 | 2,296 | 664 | 997 | 3,827 | NP | NP |
| | 3 | 3,393 | 3,510 | 4,388 | 5,265 | 6,143 | 7,020 | 7,313 | 2,438 | NP | NP | 3,274 | 4,365 | 2,296 | 664 | 997 | 3,827 | NP | NP |
| | 4 | 3,393 | 3,510 | 4,388 | 5,265 | 6,143 | 7,020 | 7,313 | 3,377 | NP | 3,584 | 5,040 | 6,720 | 2,296 | 664 | 997 | 3,827 | NP | 4,536 |
| | 5 | 3,393 | 3,510 | 4,388 | 5,265 | 6,143 | 7,020 | 7,313 | 4,415 | NP | 5,009 | 7,044 | 9,391 | 2,296 | 664 | 997 | 3,827 | NP | 5,443 |
| | 6 | 3,393 | 3,510 | 4,388 | 5,265 | 6,143 | 7,020 | 7,313 | 5,543 | NP | 6,584 | 9,259 | 12,345 | 2,296 | 664 | 997 | 3,827 | NP | NP |
| 1/2 | 2 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 1,646 | NP | NP | 1,782 | 2,376 | 4,074 | 1,181 | 1,772 | 5,287 | NP | NP |
| | 3 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 2,475 | NP | NP | 3,274 | 4,365 | 4,074 | 1,181 | 1,772 | 5,287 | NP | NP |
| | 4 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 3,418 | NP | 3,584 | 5,040 | 6,720 | 4,074 | 1,181 | 1,772 | 5,287 | NP | NP |
| | 5 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 4,459 | NP | 5,009 | 7,044 | 9,391 | 4,074 | 1,181 | 1,772 | 5,287 | NP | 6,042 |
| | 6 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 5,591 | NP | 6,584 | 9,259 | 12,345 | 4,074 | 1,181 | 1,772 | 5,287 | NP | 7,250 |
| | 7 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 6,806 | 6,806 | 8,297 | 11,668 | 15,557 | 4,074 | 1,181 | 1,772 | 5,287 | 5,287 | 8,458 |
| | 8 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 8,099 | 8,316 | 10,137 | 14,255 | 19,007 | 4,074 | 1,181 | 1,772 | 5,287 | 6,042 | 9,667 |
| 5/8 | 3 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 2,513 | NP | NP | 3,274 | 4,365 | 6,356 | 1,846 | 2,769 | 6,839 | NP | NP |
| | 4 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 3,459 | NP | 3,584 | 5,040 | 6,720 | 6,356 | 1,846 | 2,769 | 6,839 | NP | NP |
| | 5 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 4,504 | NP | 5,009 | 7,044 | 9,391 | 6,356 | 1,846 | 2,769 | 6,839 | NP | 7,547 |
| | 6 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 5,639 | NP | 6,584 | 9,259 | 12,345 | 6,356 | 1,846 | 2,769 | 6,839 | NP | 9,056 |
| | 7 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 6,857 | NP | 8,297 | 11,668 | 15,557 | 6,356 | 1,846 | 2,769 | 6,839 | NP | 10,565 |
| | 8 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 8,153 | 8,316 | 10,137 | 14,255 | 19,007 | 6,356 | 1,846 | 2,769 | 6,839 | 7,547 | 12,074 |
| | 9 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 9,522 | 9,923 | 12,096 | 17,010 | 22,680 | 6,356 | 1,846 | 2,769 | 6,839 | 8,490 | 13,584 |
| | 10 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 10,960 | 11,621 | 14,167 | 19,922 | 26,563 | 6,356 | 1,846 | 2,769 | 6,839 | 9,433 | 15,093 |
| 3/4 | 4 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 3,500 | NP | 3,584 | 5,040 | 6,720 | 9,156 | 2,658 | 3,987 | 8,491 | NP | NP |
| | 5 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 4,549 | NP | 5,009 | 7,044 | 9,391 | 9,156 | 2,658 | 3,987 | 8,491 | NP | 9,057 |
| | 6 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 5,687 | NP | 6,584 | 9,259 | 12,345 | 9,156 | 2,658 | 3,987 | 8,491 | NP | 10,869 |
| | 7 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 6,908 | NP | 8,297 | 11,668 | 15,557 | 9,156 | 2,658 | 3,987 | 8,491 | NP | 12,680 |
| | 8 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 8,207 | 8,316 | 10,137 | 14,255 | 19,007 | 9,156 | 2,658 | 3,987 | 8,491 | 9,057 | 14,492 |
| | 9 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 9,579 | 9,923 | 12,096 | 17,010 | 22,680 | 9,156 | 2,658 | 3,987 | 8,491 | 10,190 | 16,303 |
| | 10 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 11,020 | 11,621 | 14,167 | 19,922 | 26,563 | 9,156 | 2,658 | 3,987 | 8,491 | 11,322 | 18,115 |
| | 12 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 14,097 | 15,277 | 18,623 | 26,189 | 34,918 | 9,156 | 2,658 | 3,987 | 8,491 | 13,586 | 21,738 |
| 7/8 | 4 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 3,500 | NP | 3,584 | 5,040 | 6,720 | 9,156 | 2,658 | 3,987 | 8,491 | NP | NP |
| | 6 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 5,736 | NP | 6,584 | 9,259 | 12,345 | 12,474 | 3,618 | 5,426 | 10,242 | NP | 12,686 |
| | 8 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 8,261 | 8,316 | 10,137 | 14,255 | 19,007 | 12,474 | 3,618 | 5,426 | 10,242 | 10,572 | 16,915 |
| | 12 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 14,161 | 15,277 | 18,623 | 26,189 | 34,918 | 12,474 | 3,618 | 5,426 | 10,242 | 15,858 | 25,373 |
| | 15 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 19,235 | 21,350 | 26,026 | 36,600 | 48,800 | 12,474 | 3,618 | 5,426 | 10,242 | 19,822 | 31,716 |
| | 18 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 24,803 | 28,065 | 34,213 | 48,112 | 64,149 | 12,474 | 3,618 | 5,426 | 10,242 | 23,787 | 38,059 |
| | 25 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 39,505 | 45,938 | 56,000 | 78,750 | 105,000 | 12,474 | 3,618 | 5,426 | 10,242 | 33,037 | 52,860 |

Table 34-5A. Design Strengths for Single Cast-In Anchors Subject to Tensile Loads ($f'_c$ = 2500 psi)[1, 2, 4] (cont'd.)
Notes pertaining to this table are given on Page 34-16

| $d_o$ in. | $h_{ef}$ in. | $\phi N_s$ - Tension Strength of Anchor | | | | | | | $\phi N_{cb}$ - Tension Breakout[4, 5, 6, 11] | | | | | $\phi N_{pn}$ - Pullout[9] | | | $\phi N_{sb}$ - Sideface Blowout[4, 10, 11] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $f_{ut}$ - for design purposes[3] - psi | | | | | | | $c_{a1}$ - edge distance in. | | | | | head[7] | "J" or "L" hook[8] | | $c_{a1}$ - edge distance in. | | |
| | | 58,000 | 60,000 | 75,000 | 90,000 | 105,000 | 120,000 | 125,000 | 1-1/2-in. cover | $0.25h_{ef}$ | $0.5h_{ef}$ | $h_{ef}$ | $\geq 1.5h_{ef}$ | | $e_h = 3d_o$ | $e_h = 4.5d_o$ | 1-1/2-in. cover | $0.25h_{ef}$ | $0.4h_{ef}$ |
| 1 | 6 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 5,784 | NP | 6,584 | 9,259 | 12,345 | 16,282 | 4,725 | 7,088 | 12,078 | NP | 14,494 |
| | 9 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 9,693 | 9,923 | 12,096 | 17,010 | 22,680 | 16,282 | 4,725 | 7,088 | 12,078 | 13,588 | 21,741 |
| | 12 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 14,226 | 15,277 | 18,623 | 26,189 | 34,918 | 16,282 | 4,725 | 7,088 | 12,078 | 18,118 | 28,988 |
| | 15 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 19,307 | 21,350 | 26,026 | 36,600 | 48,800 | 16,282 | 4,725 | 7,088 | 12,078 | 22,647 | 36,235 |
| | 18 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 24,881 | 28,065 | 34,213 | 48,112 | 64,149 | 16,282 | 4,725 | 7,088 | 12,078 | 27,176 | 43,482 |
| | 21 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 30,908 | 35,366 | 43,113 | 60,627 | 80,837 | 16,282 | 4,725 | 7,088 | 12,078 | 31,706 | 50,729 |
| | 25 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 39,595 | 45,938 | 56,000 | 78,750 | 105,000 | 16,282 | 4,725 | 7,088 | 12,078 | 37,745 | 60,392 |
| 1-1/8 | 6 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 5,833 | NP | 6,584 | 9,259 | 12,345 | 20,608 | 5,980 | 8,970 | 14,013 | NP | 16,306 |
| | 9 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 9,750 | 9,923 | 12,096 | 17,010 | 22,680 | 20,608 | 5,980 | 8,970 | 14,013 | 15,287 | 24,459 |
| | 12 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 14,291 | 15,277 | 18,623 | 26,189 | 34,918 | 20,608 | 5,980 | 8,970 | 14,013 | 20,383 | 32,612 |
| | 15 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 19,378 | 21,350 | 26,026 | 36,600 | 48,800 | 20,608 | 5,980 | 8,970 | 14,013 | 25,478 | 40,766 |
| | 18 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 24,958 | 28,065 | 34,213 | 48,112 | 64,149 | 20,608 | 5,980 | 8,970 | 14,013 | 30,574 | 48,919 |
| | 21 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 30,991 | 35,366 | 43,113 | 60,627 | 80,837 | 20,608 | 5,980 | 8,970 | 14,013 | 35,670 | 57,072 |
| | 25 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 39,685 | 45,938 | 56,000 | 78,750 | 105,000 | 20,608 | 5,980 | 8,970 | 14,013 | 42,464 | 67,943 |
| 1-1/4 | 6 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 5,882 | NP | 6,584 | 9,259 | 12,345 | 25,438 | 7,383 | 11,074 | 16,041 | NP | 18,117 |
| | 9 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 9,807 | 9,923 | 12,096 | 17,010 | 22,680 | 25,438 | 7,383 | 11,074 | 16,041 | 16,984 | 27,175 |
| | 12 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 14,355 | 15,277 | 18,623 | 26,189 | 34,918 | 25,438 | 7,383 | 11,074 | 16,041 | 22,646 | 36,233 |
| | 15 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 19,450 | 21,350 | 26,026 | 36,600 | 48,800 | 25,438 | 7,383 | 11,074 | 16,041 | 28,307 | 45,292 |
| | 18 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 25,036 | 28,065 | 34,213 | 48,112 | 64,149 | 25,438 | 7,383 | 11,074 | 16,041 | 33,969 | 54,350 |
| | 21 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 31,075 | 35,366 | 43,113 | 60,627 | 80,837 | 25,438 | 7,383 | 11,074 | 16,041 | 39,630 | 63,408 |
| | 25 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 39,776 | 45,938 | 56,000 | 78,750 | 105,000 | 25,438 | 7,383 | 11,074 | 16,041 | 47,179 | 75,486 |
| 1-3/8 | 6 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 5,931 | NP | 6,584 | 9,259 | 12,345 | 30,786 | 8,933 | 13,400 | 18,166 | NP | 19,930 |
| | 9 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 9,865 | 9,923 | 12,096 | 17,010 | 22,680 | 30,786 | 8,933 | 13,400 | 18,166 | 18,685 | 29,895 |
| | 12 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 14,420 | 15,277 | 18,623 | 26,189 | 34,918 | 30,786 | 8,933 | 13,400 | 18,166 | 24,913 | 39,860 |
| | 15 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 19,521 | 21,350 | 26,026 | 36,600 | 48,800 | 30,786 | 8,933 | 13,400 | 18,166 | 31,141 | 49,826 |
| | 18 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 25,114 | 28,065 | 34,213 | 48,112 | 64,149 | 30,786 | 8,933 | 13,400 | 18,166 | 37,369 | 59,791 |
| | 21 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 31,158 | 35,366 | 43,113 | 60,627 | 80,837 | 30,786 | 8,933 | 13,400 | 18,166 | 43,597 | 69,756 |
| | 25 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 39,866 | 45,938 | 56,000 | 78,750 | 105,000 | 30,786 | 8,933 | 13,400 | 18,166 | 51,902 | 83,043 |
| 1-1/2 | 12 | 61,335 | 63,450 | 79,313 | 95,175 | 111,038 | 126,900 | 132,188 | 14,486 | 15,277 | 18,623 | 26,189 | 34,918 | 36,638 | 10,631 | 15,947 | 20,383 | 27,178 | 43,484 |
| | 15 | 61,335 | 63,450 | 79,313 | 95,175 | 111,038 | 126,900 | 132,188 | 19,593 | 21,350 | 26,026 | 36,600 | 48,800 | 36,638 | 10,631 | 15,947 | 20,383 | 33,972 | 54,355 |
| | 18 | 61,335 | 63,450 | 79,313 | 95,175 | 111,038 | 126,900 | 132,188 | 25,192 | 28,065 | 34,213 | 48,112 | 64,149 | 36,638 | 10,631 | 15,947 | 20,383 | 40,766 | 65,226 |
| | 21 | 61,335 | 63,450 | 79,313 | 95,175 | 111,038 | 126,900 | 132,188 | 31,242 | 35,366 | 43,113 | 60,627 | 80,837 | 36,638 | 10,631 | 15,947 | 20,383 | 47,561 | 76,097 |
| | 25 | 61,335 | 63,450 | 79,313 | 95,175 | 111,038 | 126,900 | 132,188 | 39,957 | 45,938 | 56,000 | 78,750 | 105,000 | 36,638 | 10,631 | 15,947 | 20,383 | 56,620 | 90,592 |
| 1-3/4 | 12 | 82,650 | 85,500 | 106,875 | 128,250 | 149,625 | 171,000 | 178,125 | 14,616 | 15,277 | 18,623 | 26,189 | 34,918 | 58,016 | 14,470 | 21,705 | 27,075 | 34,199 | 54,719 |
| | 15 | 82,650 | 85,500 | 106,875 | 128,250 | 149,625 | 171,000 | 178,125 | 19,737 | 21,350 | 26,026 | 36,600 | 48,800 | 58,016 | 14,470 | 21,705 | 27,075 | 42,749 | 68,399 |
| | 18 | 82,650 | 85,500 | 106,875 | 128,250 | 149,625 | 171,000 | 178,125 | 25,348 | 28,065 | 34,213 | 48,112 | 64,149 | 58,016 | 14,470 | 21,705 | 27,075 | 51,299 | 82,079 |
| | 21 | 82,650 | 85,500 | 106,875 | 128,250 | 149,625 | 171,000 | 178,125 | 31,409 | 35,366 | 43,113 | 60,627 | 80,837 | 58,016 | 14,470 | 21,705 | 27,075 | 59,849 | 95,758 |
| | 25 | 82,650 | 85,500 | 106,875 | 128,250 | 149,625 | 171,000 | 178,125 | 40,138 | 45,938 | 56,000 | 78,750 | 105,000 | 58,016 | 14,470 | 21,705 | 27,075 | 71,249 | 113,998 |
| 2 | 12 | 108,750 | 112,500 | 140,625 | 168,750 | 196,875 | 225,000 | 234,375 | 14,747 | 15,277 | 18,623 | 26,189 | 34,918 | 74,424 | 18,900 | 28,350 | 32,279 | 38,735 | 61,976 |
| | 15 | 108,750 | 112,500 | 140,625 | 168,750 | 196,875 | 225,000 | 234,375 | 19,881 | 21,350 | 26,026 | 36,600 | 48,800 | 74,424 | 18,900 | 28,350 | 32,279 | 48,419 | 77,470 |
| | 18 | 108,750 | 112,500 | 140,625 | 168,750 | 196,875 | 225,000 | 234,375 | 25,504 | 28,065 | 34,213 | 48,112 | 64,149 | 74,424 | 18,900 | 28,350 | 32,279 | 58,102 | 92,964 |
| | 21 | 108,750 | 112,500 | 140,625 | 168,750 | 196,875 | 225,000 | 234,375 | 31,577 | 35,366 | 43,113 | 60,627 | 80,837 | 74,424 | 18,900 | 28,350 | 32,279 | 67,786 | 108,458 |
| | 25 | 108,750 | 112,500 | 140,625 | 168,750 | 196,875 | 225,000 | 234,375 | 40,320 | 45,938 | 56,000 | 78,750 | 105,000 | 74,424 | 18,900 | 28,350 | 32,279 | 80,698 | 129,116 |

*Table 34-5B. Design Strengths for Single Cast-In Anchors Subject to Tensile Loads ($f'_c$ = 4000 psi)[1, 2, 4]*
*Notes pertaining to this table are given on Page 34-16*

| $d_o$ in. | $h_{ef}$ in. | $\phi N_s$ - Tension Strength of Anchor | | | | | | | $\phi N_{cb}$ - Tension Breakout[4, 5, 6, 11] | | | | | $\phi N_{pn}$ - Pullout[9] | | | $\phi N_{sb}$ - Sideface Blowout[4, 10, 11] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $f_{ut}$ - for design purposes[3] - psi | | | | | | | $c_{a1}$ - edge distance in. | | | | | head[7] | "J" or "L" hook[8] | | $c_{a1}$ - edge distance in. | | |
| | | 58,000 | 60,000 | 75,000 | 90,000 | 105,000 | 120,000 | 125,000 | 1-1/2-in. cover | $0.25h_{ef}$ | $0.5h_{ef}$ | $h_{ef}$ | $\geq 1.5h_{ef}$ | | $e_h = 3d_o$ | $e_h = 4.5d_o$ | 1-1/2-in. cover | $0.25h_{ef}$ | $0.4h_{ef}$ |
| 1/4 | 2 | 1,392 | 1,440 | 1,800 | 2,160 | 2,520 | 2,880 | 3,000 | 1,998 | NP | NP | 2,254 | 3,005 | 2,621 | 473 | 709 | 3,937 | NP | NP |
| | 3 | 1,392 | 1,440 | 1,800 | 2,160 | 2,520 | 2,880 | 3,000 | 3,037 | NP | NP | 4,141 | 5,521 | 2,621 | 473 | 709 | 3,937 | NP | NP |
| | 4 | 1,392 | 1,440 | 1,800 | 2,160 | 2,520 | 2,880 | 3,000 | 4,220 | NP | 4,533 | 6,375 | 8,500 | 2,621 | 473 | 709 | 3,937 | NP | NP |
| | 5 | 1,392 | 1,440 | 1,800 | 2,160 | 2,520 | 2,880 | 3,000 | 5,528 | NP | 6,336 | 8,910 | 11,879 | 2,621 | 473 | 709 | 3,937 | NP | 4,846 |
| | 6 | 1,392 | 1,440 | 1,800 | 2,160 | 2,520 | 2,880 | 3,000 | 6,952 | NP | 8,328 | 11,712 | 15,616 | 2,621 | 473 | 709 | 3,937 | NP | 5,815 |
| 3/8 | 2 | 3,393 | 3,510 | 4,388 | 5,265 | 6,143 | 7,020 | 7,313 | 2,040 | NP | NP | 2,254 | 3,005 | 3,674 | 1,063 | 1,595 | 4,841 | NP | NP |
| | 3 | 3,393 | 3,510 | 4,388 | 5,265 | 6,143 | 7,020 | 7,313 | 3,084 | NP | NP | 4,141 | 5,521 | 3,674 | 1,063 | 1,595 | 4,841 | NP | NP |
| | 4 | 3,393 | 3,510 | 4,388 | 5,265 | 6,143 | 7,020 | 7,313 | 4,271 | NP | 4,533 | 6,375 | 8,500 | 3,674 | 1,063 | 1,595 | 4,841 | NP | NP |
| | 5 | 3,393 | 3,510 | 4,388 | 5,265 | 6,143 | 7,020 | 7,313 | 5,584 | NP | 6,336 | 8,910 | 11,879 | 3,674 | 1,063 | 1,595 | 4,841 | NP | 5,737 |
| | 6 | 3,393 | 3,510 | 4,388 | 5,265 | 6,143 | 7,020 | 7,313 | 7,012 | NP | 8,328 | 11,712 | 15,616 | 3,674 | 1,063 | 1,595 | 4,841 | NP | 6,885 |
| 1/2 | 2 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 2,082 | NP | NP | 2,254 | 3,005 | 6,518 | 1,890 | 2,835 | 6,687 | NP | NP |
| | 3 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 3,131 | NP | NP | 4,141 | 5,521 | 6,518 | 1,890 | 2,835 | 6,687 | NP | NP |
| | 4 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 4,323 | NP | 4,533 | 6,375 | 8,500 | 6,518 | 1,890 | 2,835 | 6,687 | NP | NP |
| | 5 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 5,641 | NP | 6,336 | 8,910 | 11,879 | 6,518 | 1,890 | 2,835 | 6,687 | NP | 7,642 |
| | 6 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 7,072 | NP | 8,328 | 11,712 | 15,616 | 6,518 | 1,890 | 2,835 | 6,687 | NP | 9,171 |
| | 7 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 8,609 | 8,609 | 10,495 | 14,759 | 19,678 | 6,518 | 1,890 | 2,835 | 6,687 | 6,687 | 10,699 |
| | 8 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 10,245 | 10,518 | 12,823 | 18,032 | 24,042 | 6,518 | 1,890 | 2,835 | 6,687 | 7,642 | 12,228 |
| 5/8 | 3 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 3,179 | NP | NP | 4,141 | 5,521 | 10,170 | 2,953 | 4,430 | 8,651 | NP | NP |
| | 4 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 4,375 | NP | 4,533 | 6,375 | 8,500 | 10,170 | 2,953 | 4,430 | 8,651 | NP | NP |
| | 5 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 5,697 | NP | 6,336 | 8,910 | 11,879 | 10,170 | 2,953 | 4,430 | 8,651 | NP | 9,546 |
| | 6 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 7,133 | NP | 8,328 | 11,712 | 15,616 | 10,170 | 2,953 | 4,430 | 8,651 | NP | 11,455 |
| | 7 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 8,674 | NP | 10,495 | 14,759 | 19,678 | 10,170 | 2,953 | 4,430 | 8,651 | NP | 13,364 |
| | 8 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 10,313 | 10,518 | 12,823 | 18,032 | 24,042 | 10,170 | 2,953 | 4,430 | 8,651 | 9,546 | 15,273 |
| | 9 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 12,044 | 12,551 | 15,300 | 21,516 | 28,688 | 10,170 | 2,953 | 4,430 | 8,651 | 10,739 | 17,182 |
| | 10 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 13,864 | 14,700 | 17,920 | 25,200 | 33,600 | 10,170 | 2,953 | 4,430 | 8,651 | 11,932 | 19,091 |
| 3/4 | 4 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 4,428 | NP | 4,533 | 6,375 | 8,500 | 14,650 | 4,253 | 6,379 | 10,741 | NP | NP |
| | 5 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 5,754 | NP | 6,336 | 8,910 | 11,879 | 14,650 | 4,253 | 6,379 | 10,741 | NP | 11,457 |
| | 6 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 7,194 | NP | 8,328 | 11,712 | 15,616 | 14,650 | 4,253 | 6,379 | 10,741 | NP | 13,748 |
| | 7 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 8,738 | NP | 10,495 | 14,759 | 19,678 | 14,650 | 4,253 | 6,379 | 10,741 | NP | 16,040 |
| | 8 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 10,381 | 10,518 | 12,823 | 18,032 | 24,042 | 14,650 | 4,253 | 6,379 | 10,741 | 11,457 | 18,331 |
| | 9 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 12,116 | 12,551 | 15,300 | 21,516 | 28,688 | 14,650 | 4,253 | 6,379 | 10,741 | 12,889 | 20,622 |
| | 10 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 13,939 | 14,700 | 17,920 | 25,200 | 33,600 | 14,650 | 4,253 | 6,379 | 10,741 | 14,321 | 22,914 |
| | 12 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 17,831 | 19,324 | 23,556 | 33,126 | 44,168 | 14,650 | 4,253 | 6,379 | 10,741 | 17,185 | 27,497 |
| 7/8 | 4 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 4,428 | NP | 4,533 | 6,375 | 8,500 | 14,650 | 4,253 | 6,379 | 10,741 | NP | NP |
| | 6 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 7,255 | NP | 8,328 | 11,712 | 15,616 | 19,958 | 5,788 | 8,682 | 12,955 | NP | 16,047 |
| | 8 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 10,450 | 10,518 | 12,823 | 18,032 | 24,042 | 19,958 | 5,788 | 8,682 | 12,955 | 13,373 | 21,396 |
| | 12 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 17,913 | 19,324 | 23,556 | 33,126 | 44,168 | 19,958 | 5,788 | 8,682 | 12,955 | 20,059 | 32,094 |
| | 15 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 24,331 | 27,006 | 32,921 | 46,295 | 61,727 | 19,958 | 5,788 | 8,682 | 12,955 | 25,074 | 40,118 |
| | 18 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 31,374 | 35,500 | 43,276 | 60,857 | 81,142 | 19,958 | 5,788 | 8,682 | 12,955 | 30,088 | 48,141 |
| | 25 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 49,970 | 58,107 | 70,835 | 99,612 | 132,816 | 19,958 | 5,788 | 8,682 | 12,955 | 41,789 | 66,863 |

*Table 34-5B. Design Strengths for Single Cast-In Anchors Subject to Tensile Loads ($f'_c$ = 4000 psi)[1, 2, 4] (cont'd.)*
*Notes pertaining to this table are given on Page 34-16*

| $d_o$ in. | $h_{ef}$ in. | $\phi N_s$ - Tension Strength of Anchor | | | | | | | $\phi N_{cb}$ - Tension Breakout[4, 5, 6, 11] | | | | | $\phi N_{pn}$ - Pullout[9] | | | $\phi N_{sb}$ - Sideface Blowout[4, 10, 11] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $f_{ut}$ - for design purposes[3] - psi | | | | | | | $c_{a1}$ - edge distance in. | | | | | head[7] | "J" or "L" hook[8] | | $c_{a1}$ - edge distance in. | | |
| | | 58,000 | 60,000 | 75,000 | 90,000 | 105,000 | 120,000 | 125,000 | 1-1/2-in. cover | $0.25h_{ef}$ | $0.5h_{ef}$ | $h_{ef}$ | $\geq 1.5h_{ef}$ | | $e_h = 3d_o$ | $e_h = 4.5d_o$ | 1-1/2-in. cover | $0.25h_{ef}$ | $0.4h_{ef}$ |
| 1 | 6 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 7,316 | NP | 8,328 | 11,712 | 15,616 | 26,051 | 7,560 | 11,340 | 15,278 | NP | 18,334 |
| | 9 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 12,260 | 12,551 | 15,300 | 21,516 | 28,688 | 26,051 | 7,560 | 11,340 | 15,278 | 17,188 | 27,500 |
| | 12 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 17,995 | 19,324 | 23,556 | 33,126 | 44,168 | 26,051 | 7,560 | 11,340 | 15,278 | 22,917 | 36,667 |
| | 15 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 24,421 | 27,006 | 32,921 | 46,295 | 61,727 | 26,051 | 7,560 | 11,340 | 15,278 | 28,646 | 45,834 |
| | 18 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 31,472 | 35,500 | 43,276 | 60,857 | 81,142 | 26,051 | 7,560 | 11,340 | 15,278 | 34,376 | 55,001 |
| | 21 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 39,096 | 44,735 | 54,534 | 76,688 | 102,251 | 26,051 | 7,560 | 11,340 | 15,278 | 40,105 | 64,168 |
| | 25 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 50,084 | 58,107 | 70,835 | 99,612 | 132,816 | 26,051 | 7,560 | 11,340 | 15,278 | 47,744 | 76,390 |
| 1-1/8 | 6 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 7,378 | NP | 8,328 | 11,712 | 15,616 | 32,973 | 9,568 | 14,352 | 17,725 | NP | 20,626 |
| | 9 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 12,333 | 12,551 | 15,300 | 21,516 | 28,688 | 32,973 | 9,568 | 14,352 | 17,725 | 19,337 | 30,939 |
| | 12 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 18,076 | 19,324 | 23,556 | 33,126 | 44,168 | 32,973 | 9,568 | 14,352 | 17,725 | 25,782 | 41,252 |
| | 15 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 24,511 | 27,006 | 32,921 | 46,295 | 61,727 | 32,973 | 9,568 | 14,352 | 17,725 | 32,228 | 51,565 |
| | 18 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 31,570 | 35,500 | 43,276 | 60,857 | 81,142 | 32,973 | 9,568 | 14,352 | 17,725 | 38,674 | 61,878 |
| | 21 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 39,201 | 44,735 | 54,534 | 76,688 | 102,251 | 32,973 | 9,568 | 14,352 | 17,725 | 45,119 | 72,191 |
| | 25 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 50,198 | 58,107 | 70,835 | 99,612 | 132,816 | 32,973 | 9,568 | 14,352 | 17,725 | 53,713 | 85,941 |
| 1-1/4 | 6 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 7,440 | NP | 8,328 | 11,712 | 15,616 | 40,701 | 11,813 | 17,719 | 20,290 | NP | 22,916 |
| | 9 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 12,405 | 12,551 | 15,300 | 21,516 | 28,688 | 40,701 | 11,813 | 17,719 | 20,290 | 21,484 | 34,374 |
| | 12 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 18,158 | 19,324 | 23,556 | 33,126 | 44,168 | 40,701 | 11,813 | 17,719 | 20,290 | 28,645 | 45,832 |
| | 15 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 24,602 | 27,006 | 32,921 | 46,295 | 61,727 | 40,701 | 11,813 | 17,719 | 20,290 | 35,806 | 57,290 |
| | 18 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 31,668 | 35,500 | 43,276 | 60,857 | 81,142 | 40,701 | 11,813 | 17,719 | 20,290 | 42,967 | 68,748 |
| | 21 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 39,307 | 44,735 | 54,534 | 76,688 | 102,251 | 40,701 | 11,813 | 17,719 | 20,290 | 50,129 | 80,206 |
| | 25 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 50,313 | 58,107 | 70,835 | 99,612 | 132,816 | 40,701 | 11,813 | 17,719 | 20,290 | 59,677 | 95,483 |
| 1-3/8 | 6 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 7,502 | NP | 8,328 | 11,712 | 15,616 | 49,258 | 14,293 | 21,440 | 22,978 | NP | 25,210 |
| | 9 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 12,478 | 12,551 | 15,300 | 21,516 | 28,688 | 49,258 | 14,293 | 21,440 | 22,978 | 23,634 | 37,815 |
| | 12 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 18,241 | 19,324 | 23,556 | 33,126 | 44,168 | 49,258 | 14,293 | 21,440 | 22,978 | 31,512 | 50,420 |
| | 15 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 24,693 | 27,006 | 32,921 | 46,295 | 61,727 | 49,258 | 14,293 | 21,440 | 22,978 | 39,391 | 63,025 |
| | 18 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 31,767 | 35,500 | 43,276 | 60,857 | 81,142 | 49,258 | 14,293 | 21,440 | 22,978 | 47,269 | 75,630 |
| | 21 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 39,412 | 44,735 | 54,534 | 76,688 | 102,251 | 49,258 | 14,293 | 21,440 | 22,978 | 55,147 | 88,235 |
| | 25 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 50,427 | 58,107 | 70,835 | 99,612 | 132,816 | 49,258 | 14,293 | 21,440 | 22,978 | 65,651 | 105,041 |
| 1-1/2 | 12 | 61,335 | 63,450 | 79,313 | 95,175 | 111,038 | 126,900 | 132,188 | 18,323 | 19,324 | 23,556 | 33,126 | 44,168 | 58,621 | 17,010 | 25,515 | 25,783 | 34,377 | 55,004 |
| | 15 | 61,335 | 63,450 | 79,313 | 95,175 | 111,038 | 126,900 | 132,188 | 24,783 | 27,006 | 32,921 | 46,295 | 61,727 | 58,621 | 17,010 | 25,515 | 25,783 | 42,972 | 68,755 |
| | 18 | 61,335 | 63,450 | 79,313 | 95,175 | 111,038 | 126,900 | 132,188 | 31,865 | 35,500 | 43,276 | 60,857 | 81,142 | 58,621 | 17,010 | 25,515 | 25,783 | 51,566 | 82,505 |
| | 21 | 61,335 | 63,450 | 79,313 | 95,175 | 111,038 | 126,900 | 132,188 | 39,518 | 44,735 | 54,534 | 76,688 | 102,251 | 58,621 | 17,010 | 25,515 | 25,783 | 60,160 | 96,256 |
| | 25 | 61,335 | 63,450 | 79,313 | 95,175 | 111,038 | 126,900 | 132,188 | 50,542 | 58,107 | 70,835 | 99,612 | 132,816 | 58,621 | 17,010 | 25,515 | 25,783 | 71,619 | 114,591 |
| 1-3/4 | 12 | 82,650 | 85,500 | 106,875 | 128,250 | 149,625 | 171,000 | 178,125 | 18,488 | 19,324 | 23,556 | 33,126 | 44,168 | 92,826 | 23,153 | 34,729 | 34,247 | 43,259 | 69,215 |
| | 15 | 82,650 | 85,500 | 106,875 | 128,250 | 149,625 | 171,000 | 178,125 | 24,965 | 27,006 | 32,921 | 46,295 | 61,727 | 92,826 | 23,153 | 34,729 | 34,247 | 54,074 | 86,519 |
| | 18 | 82,650 | 85,500 | 106,875 | 128,250 | 149,625 | 171,000 | 178,125 | 32,063 | 35,500 | 43,276 | 60,857 | 81,142 | 92,826 | 23,153 | 34,729 | 34,247 | 64,889 | 103,822 |
| | 21 | 82,650 | 85,500 | 106,875 | 128,250 | 149,625 | 171,000 | 178,125 | 39,730 | 44,735 | 54,534 | 76,688 | 102,251 | 92,826 | 23,153 | 34,729 | 34,247 | 75,704 | 121,126 |
| | 25 | 82,650 | 85,500 | 106,875 | 128,250 | 149,625 | 171,000 | 178,125 | 50,771 | 58,107 | 70,835 | 99,612 | 132,816 | 92,826 | 23,153 | 34,729 | 34,247 | 90,123 | 144,198 |
| 2 | 12 | 108,750 | 112,500 | 140,625 | 168,750 | 196,875 | 225,000 | 234,375 | 18,654 | 19,324 | 23,556 | 33,126 | 44,168 | 119,078 | 30,240 | 45,360 | 40,830 | 48,996 | 78,394 |
| | 15 | 108,750 | 112,500 | 140,625 | 168,750 | 196,875 | 225,000 | 234,375 | 25,148 | 27,006 | 32,921 | 46,295 | 61,727 | 119,078 | 30,240 | 45,360 | 40,830 | 61,245 | 97,992 |
| | 18 | 108,750 | 112,500 | 140,625 | 168,750 | 196,875 | 225,000 | 234,375 | 32,261 | 35,500 | 43,276 | 60,857 | 81,142 | 119,078 | 30,240 | 45,360 | 40,830 | 73,494 | 117,591 |
| | 21 | 108,750 | 112,500 | 140,625 | 168,750 | 196,875 | 225,000 | 234,375 | 39,942 | 44,735 | 54,534 | 76,688 | 102,251 | 119,078 | 30,240 | 45,360 | 40,830 | 85,743 | 137,189 |
| | 25 | 108,750 | 112,500 | 140,625 | 168,750 | 196,875 | 225,000 | 234,375 | 51,001 | 58,107 | 70,835 | 99,612 | 132,816 | 119,078 | 30,240 | 45,360 | 40,830 | 102,075 | 163,320 |

*Table 34-5C. Design Strengths for Single Cast-In Anchors Subject to Tensile Loads ($f'_c$ = 6000 psi)[1, 2, 4]*
*Notes pertaining to this table are given on Page 34-16*

| $d_o$ in. | $h_{ef}$ in. | $\phi N_s$ - Tension Strength of Anchor | | | | | | | $\phi N_{cb}$ - Tension Breakout [4, 5, 6, 11] | | | | | | $\phi N_{pn}$ - Pullout [9] | | | $\phi N_{sb}$ - Sideface Blowout [4, 10, 11] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $f_{ut}$ - for design purposes [3] - psi | | | | | | | $c_{a1}$ - edge distance in. | | | | | | head [7] | "J" or "L" hook [8] | | $c_{a1}$ - edge distance in. | | |
| | | 58,000 | 60,000 | 75,000 | 90,000 | 105,000 | 120,000 | 125,000 | 1-1/2-in. cover | $0.25h_{ef}$ | $0.5h_{ef}$ | $h_{ef}$ | $\geq 1.5h_{ef}$ | | | $e_h = 3d_o$ | $e_h = 4.5d_o$ | 1-1/2-in. cover | $0.25h_{ef}$ | $0.4h_{ef}$ |
| 1/4 | 2 | 1,392 | 1,440 | 1,800 | 2,160 | 2,520 | 2,880 | 3,000 | 2,447 | NP | NP | 2,761 | 3,681 | | 3,931 | 709 | 1,063 | 4,822 | NP | NP |
| | 3 | 1,392 | 1,440 | 1,800 | 2,160 | 2,520 | 2,880 | 3,000 | 3,720 | NP | NP | 5,071 | 6,762 | | 3,931 | 709 | 1,063 | 4,822 | NP | NP |
| | 4 | 1,392 | 1,440 | 1,800 | 2,160 | 2,520 | 2,880 | 3,000 | 5,168 | NP | 5,552 | 7,808 | 10,411 | | 3,931 | 709 | 1,063 | 4,822 | NP | NP |
| | 5 | 1,392 | 1,440 | 1,800 | 2,160 | 2,520 | 2,880 | 3,000 | 6,771 | NP | 7,760 | 10,912 | 14,549 | | 3,931 | 709 | 1,063 | 4,822 | NP | 5,935 |
| | 6 | 1,392 | 1,440 | 1,800 | 2,160 | 2,520 | 2,880 | 3,000 | 8,514 | NP | 10,200 | 14,344 | 19,125 | | 3,931 | 709 | 1,063 | 4,822 | NP | 7,122 |
| 3/8 | 2 | 3,393 | 3,510 | 4,388 | 5,265 | 6,143 | 7,020 | 7,313 | 2,498 | NP | NP | 2,761 | 3,681 | | 5,510 | 1,595 | 2,392 | 5,929 | NP | NP |
| | 3 | 3,393 | 3,510 | 4,388 | 5,265 | 6,143 | 7,020 | 7,313 | 3,777 | NP | NP | 5,071 | 6,762 | | 5,510 | 1,595 | 2,392 | 5,929 | NP | NP |
| | 4 | 3,393 | 3,510 | 4,388 | 5,265 | 6,143 | 7,020 | 7,313 | 5,231 | NP | 5,552 | 7,808 | 10,411 | | 5,510 | 1,595 | 2,392 | 5,929 | NP | NP |
| | 5 | 3,393 | 3,510 | 4,388 | 5,265 | 6,143 | 7,020 | 7,313 | 6,840 | NP | 7,760 | 10,912 | 14,549 | | 5,510 | 1,595 | 2,392 | 5,929 | NP | 7,027 |
| | 6 | 3,393 | 3,510 | 4,388 | 5,265 | 6,143 | 7,020 | 7,313 | 8,588 | NP | 10,200 | 14,344 | 19,125 | | 5,510 | 1,595 | 2,392 | 5,929 | NP | 8,432 |
| 1/2 | 2 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 2,550 | NP | NP | 2,761 | 3,681 | | 9,778 | 2,835 | 4,253 | 8,190 | NP | NP |
| | 3 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 3,835 | NP | NP | 5,071 | 6,762 | | 9,778 | 2,835 | 4,253 | 8,190 | NP | NP |
| | 4 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 5,295 | NP | 5,552 | 7,808 | 10,411 | | 9,778 | 2,835 | 4,253 | 8,190 | NP | NP |
| | 5 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 6,908 | NP | 7,760 | 10,912 | 14,549 | | 9,778 | 2,835 | 4,253 | 8,190 | NP | 9,360 |
| | 6 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 8,662 | NP | 10,200 | 14,344 | 19,125 | | 9,778 | 2,835 | 4,253 | 8,190 | NP | 11,232 |
| | 7 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 10,544 | 10,544 | 12,854 | 18,076 | 24,101 | | 9,778 | 2,835 | 4,253 | 8,190 | 8,190 | 13,104 |
| | 8 | 6,177 | 6,390 | 7,988 | 9,585 | 11,183 | 12,780 | 13,313 | 12,547 | 12,882 | 15,704 | 22,084 | 29,446 | | 9,778 | 2,835 | 4,253 | 8,190 | 9,360 | 14,976 |
| 5/8 | 3 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 3,893 | NP | NP | 5,071 | 6,762 | | 15,254 | 4,430 | 6,645 | 10,595 | NP | NP |
| | 4 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 5,359 | NP | 5,552 | 7,808 | 10,411 | | 15,254 | 4,430 | 6,645 | 10,595 | NP | NP |
| | 5 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 6,978 | NP | 7,760 | 10,912 | 14,549 | | 15,254 | 4,430 | 6,645 | 10,595 | NP | 11,691 |
| | 6 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 8,736 | NP | 10,200 | 14,344 | 19,125 | | 15,254 | 4,430 | 6,645 | 10,595 | NP | 14,029 |
| | 7 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 10,623 | NP | 12,854 | 18,076 | 24,101 | | 15,254 | 4,430 | 6,645 | 10,595 | NP | 16,367 |
| | 8 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 12,630 | 12,882 | 15,704 | 22,084 | 29,446 | | 15,254 | 4,430 | 6,645 | 10,595 | 11,691 | 18,706 |
| | 9 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 14,751 | 15,372 | 18,739 | 26,352 | 35,136 | | 15,254 | 4,430 | 6,645 | 10,595 | 13,152 | 21,044 |
| | 10 | 9,831 | 10,170 | 12,713 | 15,255 | 17,798 | 20,340 | 21,188 | 16,979 | 18,004 | 21,947 | 30,864 | 41,151 | | 15,254 | 4,430 | 6,645 | 10,595 | 14,614 | 23,382 |
| 3/4 | 4 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 5,423 | NP | 5,552 | 7,808 | 10,411 | | 21,974 | 6,379 | 9,568 | 13,155 | NP | NP |
| | 5 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 7,047 | NP | 7,760 | 10,912 | 14,549 | | 21,974 | 6,379 | 9,568 | 13,155 | NP | 14,032 |
| | 6 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 8,811 | NP | 10,200 | 14,344 | 19,125 | | 21,974 | 6,379 | 9,568 | 13,155 | NP | 16,838 |
| | 7 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 10,702 | NP | 12,854 | 18,076 | 24,101 | | 21,974 | 6,379 | 9,568 | 13,155 | NP | 19,644 |
| | 8 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 12,714 | 12,882 | 15,704 | 22,084 | 29,446 | | 21,974 | 6,379 | 9,568 | 13,155 | 14,032 | 22,451 |
| | 9 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 14,839 | 15,372 | 18,739 | 26,352 | 35,136 | | 21,974 | 6,379 | 9,568 | 13,155 | 15,786 | 25,257 |
| | 10 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 17,071 | 18,004 | 21,947 | 30,864 | 41,151 | | 21,974 | 6,379 | 9,568 | 13,155 | 17,540 | 28,064 |
| | 12 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 21,839 | 23,667 | 28,851 | 40,571 | 54,095 | | 21,974 | 6,379 | 9,568 | 13,155 | 21,048 | 33,676 |
| 7/8 | 4 | 14,529 | 15,030 | 18,788 | 22,545 | 26,303 | 30,060 | 31,313 | 5,423 | NP | 5,552 | 7,808 | 10,411 | | 21,974 | 6,379 | 9,568 | 13,155 | NP | NP |
| | 6 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 8,886 | NP | 10,200 | 14,344 | 19,125 | | 29,938 | 8,682 | 13,023 | 15,866 | NP | 19,654 |
| | 8 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 12,798 | 12,882 | 15,704 | 22,084 | 29,446 | | 29,938 | 8,682 | 13,023 | 15,866 | 16,378 | 26,205 |
| | 12 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 21,939 | 23,667 | 28,851 | 40,571 | 54,095 | | 29,938 | 8,682 | 13,023 | 15,866 | 24,567 | 39,307 |
| | 15 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 29,799 | 33,075 | 40,320 | 56,700 | 75,600 | | 29,938 | 8,682 | 13,023 | 15,866 | 30,709 | 49,134 |
| | 18 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 38,425 | 43,478 | 53,002 | 74,534 | 99,379 | | 29,938 | 8,682 | 13,023 | 15,866 | 36,851 | 58,961 |
| | 25 | 20,097 | 20,790 | 25,988 | 31,185 | 36,383 | 41,580 | 43,313 | 61,200 | 71,166 | 86,755 | 121,999 | 162,665 | | 29,938 | 8,682 | 13,023 | 15,866 | 51,181 | 81,890 |

Table 34-5C. Design Strengths for Single Cast-In Anchors Subject to Tensile Loads ($f'_c$ = 6000 psi)[1, 2, 4] (cont'd.)
Notes pertaining to this table are given on Page 34-16

| $d_o$ in. | $h_{ef}$ in. | $\phi N_s$ - Tension Strength of Anchor | | | | | | | $\phi N_{cb}$ - Tension Breakout[4, 5, 6, 11] | | | | | $\phi N_{pn}$ - Pullout[9] | | | $\phi N_{sb}$ - Sideface Blowout[4, 10, 11] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $f_{ut}$ - for design purposes[3] - psi | | | | | | | $c_{a1}$ - edge distance in. | | | | | head[7] | "J" or "L" hook[8] | | $c_{a1}$ - edge distance in. | | |
| | | 58,000 | 60,000 | 75,000 | 90,000 | 105,000 | 120,000 | 125,000 | 1-1/2-in. cover | $0.25h_{ef}$ | $0.5h_{ef}$ | $h_{ef}$ | $\geq 1.5h_{ef}$ | | $e_h = 3d_o$ | $e_h = 4.5d_o$ | 1-1/2-in. cover | $0.25h_{ef}$ | $0.4h_{ef}$ |
| 1 | 6 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 8,961 | NP | 10,200 | 14,344 | 19,125 | 39,077 | 11,340 | 17,010 | 18,712 | NP | 22,454 |
| | 9 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 15,016 | 15,372 | 18,739 | 26,352 | 35,136 | 39,077 | 11,340 | 17,010 | 18,712 | 21,051 | 33,681 |
| | 12 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 22,039 | 23,667 | 28,851 | 40,571 | 54,095 | 39,077 | 11,340 | 17,010 | 18,712 | 28,068 | 44,908 |
| | 15 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 29,910 | 33,075 | 40,320 | 56,700 | 75,600 | 39,077 | 11,340 | 17,010 | 18,712 | 35,084 | 56,135 |
| | 18 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 38,545 | 43,478 | 53,002 | 74,534 | 99,379 | 39,077 | 11,340 | 17,010 | 18,712 | 42,101 | 67,362 |
| | 21 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 47,882 | 54,789 | 66,790 | 93,924 | 125,232 | 39,077 | 11,340 | 17,010 | 18,712 | 49,118 | 78,589 |
| | 25 | 26,361 | 27,270 | 34,088 | 40,905 | 47,723 | 54,540 | 56,813 | 61,340 | 71,166 | 86,755 | 121,999 | 162,665 | 39,077 | 11,340 | 17,010 | 18,712 | 58,474 | 93,559 |
| 1-1/8 | 6 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 9,036 | NP | 10,200 | 14,344 | 19,125 | 49,459 | 14,352 | 21,528 | 21,709 | NP | 25,261 |
| | 9 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 15,104 | 15,372 | 18,739 | 26,352 | 35,136 | 49,459 | 14,352 | 21,528 | 21,709 | 23,683 | 37,892 |
| | 12 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 22,139 | 23,667 | 28,851 | 40,571 | 54,095 | 49,459 | 14,352 | 21,528 | 21,709 | 31,577 | 50,523 |
| | 15 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 30,020 | 33,075 | 40,320 | 56,700 | 75,600 | 49,459 | 14,352 | 21,528 | 21,709 | 39,471 | 63,154 |
| | 18 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 38,665 | 43,478 | 53,002 | 74,534 | 99,379 | 49,459 | 14,352 | 21,528 | 21,709 | 47,365 | 75,784 |
| | 21 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 48,011 | 54,789 | 66,790 | 93,924 | 125,232 | 49,459 | 14,352 | 21,528 | 21,709 | 55,259 | 88,415 |
| | 25 | 33,191 | 34,335 | 42,919 | 51,503 | 60,086 | 68,670 | 71,531 | 61,480 | 71,166 | 86,755 | 121,999 | 162,665 | 49,459 | 14,352 | 21,528 | 21,709 | 65,785 | 105,256 |
| 1-1/4 | 6 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 9,112 | NP | 10,200 | 14,344 | 19,125 | 61,051 | 17,719 | 26,578 | 24,850 | NP | 28,066 |
| | 9 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 15,193 | 15,372 | 18,739 | 26,352 | 35,136 | 61,051 | 17,719 | 26,578 | 24,850 | 26,312 | 42,099 |
| | 12 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 22,239 | 23,667 | 28,851 | 40,571 | 54,095 | 61,051 | 17,719 | 26,578 | 24,850 | 35,083 | 56,132 |
| | 15 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 30,131 | 33,075 | 40,320 | 56,700 | 75,600 | 61,051 | 17,719 | 26,578 | 24,850 | 43,853 | 70,165 |
| | 18 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 38,786 | 43,478 | 53,002 | 74,534 | 99,379 | 61,051 | 17,719 | 26,578 | 24,850 | 52,624 | 84,198 |
| | 21 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 48,141 | 54,789 | 66,790 | 93,924 | 125,232 | 61,051 | 17,719 | 26,578 | 24,850 | 61,395 | 98,231 |
| | 25 | 42,152 | 43,605 | 54,506 | 65,408 | 76,309 | 87,210 | 90,844 | 61,620 | 71,166 | 86,755 | 121,999 | 162,665 | 61,051 | 17,719 | 26,578 | 24,850 | 73,089 | 116,942 |
| 1-3/8 | 6 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 9,188 | NP | 10,200 | 14,344 | 19,125 | 73,886 | 21,440 | 32,160 | 28,142 | NP | 30,876 |
| | 9 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 15,283 | 15,372 | 18,739 | 26,352 | 35,136 | 73,886 | 21,440 | 32,160 | 28,142 | 28,946 | 46,314 |
| | 12 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 22,340 | 23,667 | 28,851 | 40,571 | 54,095 | 73,886 | 21,440 | 32,160 | 28,142 | 38,595 | 61,751 |
| | 15 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 30,242 | 33,075 | 40,320 | 56,700 | 75,600 | 73,886 | 21,440 | 32,160 | 28,142 | 48,243 | 77,189 |
| | 18 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 38,906 | 43,478 | 53,002 | 74,534 | 99,379 | 73,886 | 21,440 | 32,160 | 28,142 | 57,892 | 92,627 |
| | 21 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 48,270 | 54,789 | 66,790 | 93,924 | 125,232 | 73,886 | 21,440 | 32,160 | 28,142 | 67,541 | 108,065 |
| | 25 | 50,460 | 52,200 | 65,250 | 78,300 | 91,350 | 104,400 | 108,750 | 61,760 | 71,166 | 86,755 | 121,999 | 162,665 | 73,886 | 21,440 | 32,160 | 28,142 | 80,406 | 128,649 |
| 1-1/2 | 12 | 61,335 | 63,450 | 79,313 | 95,175 | 111,038 | 126,900 | 132,188 | 22,441 | 23,667 | 28,851 | 40,571 | 54,095 | 87,931 | 25,515 | 38,273 | 31,578 | 42,103 | 67,365 |
| | 15 | 61,335 | 63,450 | 79,313 | 95,175 | 111,038 | 126,900 | 132,188 | 30,353 | 33,075 | 40,320 | 56,700 | 75,600 | 87,931 | 25,515 | 38,273 | 31,578 | 52,629 | 84,207 |
| | 18 | 61,335 | 63,450 | 79,313 | 95,175 | 111,038 | 126,900 | 132,188 | 39,027 | 43,478 | 53,002 | 74,534 | 99,379 | 87,931 | 25,515 | 38,273 | 31,578 | 63,155 | 101,048 |
| | 21 | 61,335 | 63,450 | 79,313 | 95,175 | 111,038 | 126,900 | 132,188 | 48,399 | 54,789 | 66,790 | 93,924 | 125,232 | 87,931 | 25,515 | 38,273 | 31,578 | 73,681 | 117,889 |
| | 25 | 61,335 | 63,450 | 79,313 | 95,175 | 111,038 | 126,900 | 132,188 | 61,901 | 71,166 | 86,755 | 121,999 | 162,665 | 87,931 | 25,515 | 38,273 | 31,578 | 87,715 | 140,345 |
| 1-3/4 | 12 | 82,650 | 85,500 | 106,875 | 128,250 | 149,625 | 171,000 | 178,125 | 22,643 | 23,667 | 28,851 | 40,571 | 54,095 | 139,238 | 34,729 | 52,093 | 41,944 | 52,982 | 84,771 |
| | 15 | 82,650 | 85,500 | 106,875 | 128,250 | 149,625 | 171,000 | 178,125 | 30,576 | 33,075 | 40,320 | 56,700 | 75,600 | 139,238 | 34,729 | 52,093 | 41,944 | 66,227 | 105,963 |
| | 18 | 82,650 | 85,500 | 106,875 | 128,250 | 149,625 | 171,000 | 178,125 | 39,269 | 43,478 | 53,002 | 74,534 | 99,379 | 139,238 | 34,729 | 52,093 | 41,944 | 79,472 | 127,156 |
| | 21 | 82,650 | 85,500 | 106,875 | 128,250 | 149,625 | 171,000 | 178,125 | 48,659 | 54,789 | 66,790 | 93,924 | 125,232 | 139,238 | 34,729 | 52,093 | 41,944 | 92,718 | 148,348 |
| | 25 | 82,650 | 85,500 | 106,875 | 128,250 | 149,625 | 171,000 | 178,125 | 62,182 | 71,166 | 86,755 | 121,999 | 162,665 | 139,238 | 34,729 | 52,093 | 41,944 | 110,378 | 176,605 |
| 2 | 12 | 108,750 | 112,500 | 140,625 | 168,750 | 196,875 | 225,000 | 234,375 | 22,846 | 23,667 | 28,851 | 40,571 | 54,095 | 178,618 | 45,360 | 68,040 | 50,006 | 60,008 | 96,012 |
| | 15 | 108,750 | 112,500 | 140,625 | 168,750 | 196,875 | 225,000 | 234,375 | 30,800 | 33,075 | 40,320 | 56,700 | 75,600 | 178,618 | 45,360 | 68,040 | 50,006 | 75,010 | 120,016 |
| | 18 | 108,750 | 112,500 | 140,625 | 168,750 | 196,875 | 225,000 | 234,375 | 39,511 | 43,478 | 53,002 | 74,534 | 99,379 | 178,618 | 45,360 | 68,040 | 50,006 | 90,012 | 144,019 |
| | 21 | 108,750 | 112,500 | 140,625 | 168,750 | 196,875 | 225,000 | 234,375 | 48,919 | 54,789 | 66,790 | 93,924 | 125,232 | 178,618 | 45,360 | 68,040 | 50,006 | 105,014 | 168,022 |
| | 25 | 108,750 | 112,500 | 140,625 | 168,750 | 196,875 | 225,000 | 234,375 | 62,463 | 71,166 | 86,755 | 121,999 | 162,665 | 178,618 | 45,360 | 68,040 | 50,006 | 125,016 | 200,026 |

Table 34-6A. Design Strengths for Single Cast-In Anchors Subject to Shear Loads ($f'_c$ = 2500 psi)[1, 2, 3, 5]
Notes pertaining to this table are given on Page 34-17

| $d_o$ in. | $h_{ef}$ in. | $\phi V_s$ - Shear Strength of Anchor | | | | | | | $\phi V_{cb}$ - Shear Breakout [5, 6, 7, 8, 9, 14, 15] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $f_{ut}$ - for design purposes [4] - psi | | | | | | | h = $h_{ef}$ [10] and $c_{a1}$ = [11] | | | | | | h = 1.5$h_{ef}$ and $c_{a1}$ = [11, 12] | | | h = 2.25$h_{ef}$ and $c_{a1}$ = [11, 13] | | |
| | | 58,000 | 60,000 | 75,000 | 90,000 | 105,000 | 120,000 | 125,000 | 1-1/2-in. cover | 0.25$h_{ef}$ | 0.5$h_{ef}$ | $h_{ef}$ | 1.5$h_{ef}$ | 3$h_{ef}$ | $h_{ef}$ | 1.5$h_{ef}$ | 3$h_{ef}$ | 1.5$h_{ef}$ | 2$h_{ef}$ | 3$h_{ef}$ |
| 1/4 | 2 | 724 | 749 | 936 | 1,123 | 1,310 | 1,498 | 1,560 | 316 | NP | NP | 350 | 429 | 606 | 525 | 643 | 910 | 965 | 1,114 | 1,364 |
| | 3 | 724 | 749 | 936 | 1,123 | 1,310 | 1,498 | 1,560 | 385 | NP | NP | 643 | 788 | 1,114 | 965 | 1,182 | 1,671 | 1,772 | 2,047 | 2,507 |
| | 4 | 724 | 749 | 936 | 1,123 | 1,310 | 1,498 | 1,560 | 385 | NP | 525 | 990 | 1,213 | 1,715 | 1,485 | 1,819 | 2,573 | 2,729 | 3,151 | 3,859 |
| | 5 | 724 | 749 | 936 | 1,123 | 1,310 | 1,498 | 1,560 | 385 | NP | 734 | 1,384 | 1,695 | 2,397 | 2,076 | 2,542 | 3,596 | 3,814 | 4,404 | 5,393 |
| | 6 | 724 | 749 | 936 | 1,123 | 1,310 | 1,498 | 1,560 | 385 | NP | 965 | 1,819 | 2,228 | 3,151 | 2,729 | 3,342 | 4,727 | 5,013 | 5,789 | 7,090 |
| 3/8 | 2 | 1,764 | 1,825 | 2,282 | 2,738 | 3,194 | 3,650 | 3,803 | 363 | NP | NP | 395 | 484 | 685 | 593 | 726 | 1,027 | 1,090 | 1,258 | 1,541 |
| | 3 | 1,764 | 1,825 | 2,282 | 2,738 | 3,194 | 3,650 | 3,803 | 499 | NP | NP | 788 | 965 | 1,364 | 1,182 | 1,447 | 2,047 | 2,171 | 2,507 | 3,070 |
| | 4 | 1,764 | 1,825 | 2,282 | 2,738 | 3,194 | 3,650 | 3,803 | 499 | NP | 643 | 1,213 | 1,485 | 2,101 | 1,819 | 2,228 | 3,151 | 3,342 | 3,859 | 4,727 |
| | 5 | 1,764 | 1,825 | 2,282 | 2,738 | 3,194 | 3,650 | 3,803 | 499 | NP | 899 | 1,695 | 2,076 | 2,936 | 2,542 | 3,114 | 4,404 | 4,671 | 5,393 | 6,606 |
| | 6 | 1,764 | 1,825 | 2,282 | 2,738 | 3,194 | 3,650 | 3,803 | 499 | NP | 1,182 | 2,228 | 2,729 | 3,859 | 3,342 | 4,093 | 5,789 | 6,140 | 7,090 | 8,683 |
| 1/2 | 2 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 403 | NP | NP | 431 | 528 | 747 | 647 | 792 | 1,120 | 1,188 | 1,372 | 1,680 |
| | 3 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 574 | NP | NP | 859 | 1,052 | 1,487 | 1,288 | 1,578 | 2,231 | 2,366 | 2,733 | 3,347 |
| | 4 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 608 | NP | 743 | 1,400 | 1,715 | 2,426 | 2,101 | 2,573 | 3,638 | 3,859 | 4,456 | 5,458 |
| | 5 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 608 | NP | 1,038 | 1,957 | 2,397 | 3,390 | 2,936 | 3,596 | 5,085 | 5,393 | 6,228 | 7,627 |
| | 6 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 608 | NP | 1,364 | 2,573 | 3,151 | 4,456 | 3,859 | 4,727 | 6,684 | 7,090 | 8,187 | 10,026 |
| | 7 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 608 | 608 | 1,719 | 3,242 | 3,971 | 5,615 | 4,863 | 5,956 | 8,423 | 8,934 | 10,316 | 12,635 |
| | 8 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 608 | 743 | 2,101 | 3,961 | 4,851 | 6,861 | 5,942 | 7,277 | 10,291 | 10,915 | 12,604 | 15,437 |
| 5/8 | 3 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 647 | NP | NP | 918 | 1,125 | 1,590 | 1,377 | 1,687 | 2,386 | 2,530 | 2,922 | 3,578 |
| | 4 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 685 | NP | 794 | 1,497 | 1,834 | 2,594 | 2,246 | 2,751 | 3,890 | 4,126 | 4,765 | 5,836 |
| | 5 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 716 | NP | 1,160 | 2,188 | 2,680 | 3,790 | 3,282 | 4,020 | 5,685 | 6,030 | 6,963 | 8,528 |
| | 6 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 716 | NP | 1,525 | 2,876 | 3,523 | 4,982 | 4,315 | 5,284 | 7,473 | 7,927 | 9,153 | 11,210 |
| | 7 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 716 | NP | 1,922 | 3,625 | 4,439 | 6,278 | 5,437 | 6,659 | 9,417 | 9,989 | 11,534 | 14,126 |
| | 8 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 716 | 830 | 2,349 | 4,429 | 5,424 | 7,671 | 6,643 | 8,136 | 11,506 | 12,204 | 14,092 | 17,259 |
| | 9 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 716 | 991 | 2,802 | 5,284 | 6,472 | 9,153 | 7,927 | 9,708 | 13,729 | 14,562 | 16,815 | 20,594 |
| | 10 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 716 | 1,160 | 3,282 | 6,189 | 7,580 | 10,720 | 9,284 | 11,370 | 16,080 | 17,055 | 19,694 | 24,120 |
| 3/4 | 4 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 761 | NP | 839 | 1,582 | 1,937 | 2,739 | 2,372 | 2,906 | 4,109 | 4,358 | 5,033 | 6,164 |
| | 5 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 796 | NP | 1,226 | 2,311 | 2,831 | 4,003 | 3,467 | 4,246 | 6,005 | 6,369 | 7,354 | 9,007 |
| | 6 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 826 | NP | 1,671 | 3,151 | 3,859 | 5,458 | 4,727 | 5,789 | 8,187 | 8,683 | 10,026 | 12,280 |
| | 7 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 826 | NP | 2,106 | 3,971 | 4,863 | 6,878 | 5,956 | 7,295 | 10,316 | 10,942 | 12,635 | 15,474 |
| | 8 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 826 | 910 | 2,573 | 4,851 | 5,942 | 8,403 | 7,277 | 8,912 | 12,604 | 13,369 | 15,437 | 18,906 |
| | 9 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 826 | 1,085 | 3,070 | 5,789 | 7,090 | 10,026 | 8,683 | 10,635 | 15,040 | 15,952 | 18,420 | 22,560 |
| | 10 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 826 | 1,271 | 3,596 | 6,780 | 8,304 | 11,743 | 10,170 | 12,455 | 17,615 | 18,683 | 21,574 | 26,422 |
| | 12 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 826 | 1,671 | 4,727 | 8,912 | 10,915 | 15,437 | 13,369 | 16,373 | 23,155 | 24,560 | 28,359 | 34,733 |
| 7/8 | 4 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 838 | NP | 878 | 1,656 | 2,029 | 2,869 | 2,485 | 3,043 | 4,304 | 4,565 | 5,271 | 6,455 |
| | 6 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 908 | NP | 1,750 | 3,300 | 4,042 | 5,716 | 4,950 | 6,063 | 8,574 | 9,094 | 10,501 | 12,861 |
| | 8 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 937 | 983 | 2,779 | 5,240 | 6,418 | 9,076 | 7,860 | 9,627 | 13,614 | 14,440 | 16,674 | 20,421 |
| | 12 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 937 | 1,805 | 5,105 | 9,627 | 11,790 | 16,674 | 14,440 | 17,685 | 25,010 | 26,528 | 30,631 | 37,516 |
| | 15 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 937 | 2,523 | 7,135 | 13,453 | 16,477 | 23,302 | 20,180 | 24,716 | 34,953 | 37,073 | 42,809 | 52,430 |
| | 18 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 937 | 3,316 | 9,379 | 17,685 | 21,660 | 30,631 | 26,528 | 32,489 | 45,947 | 48,734 | 56,273 | 68,921 |
| | 25 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 937 | 5,428 | 15,352 | 28,947 | 35,453 | 50,138 | 43,421 | 53,179 | 75,207 | 79,769 | 92,109 | 112,811 |

## Table 34-6A. Design Strengths for Single Cast-In Anchors Subject to Shear Loads ($f'_c$ = 2500psi)[1, 2, 3, 5] (cont'd.)

Notes pertaining to this table are given on Page 34-17

| $d_o$ in. | $h_{ef}$ in. | φ$V_s$ - Shear Strength of Anchor: $f_{ut}$ - for design purposes[4] - psi: 58,000 | 60,000 | 75,000 | 90,000 | 105,000 | 120,000 | 125,000 | φ$V_{cb}$ - Shear Breakout[6, 7, 8, 9, 14, 15]: h = $h_{ef}$[10] and $c_{a1}$ =[1]: 1-1/2-in. cover | 0.25$h_{ef}$ | 0.5$h_{ef}$ | $h_{ef}$ | 1.5$h_{ef}$ | 3$h_{ef}$ | h = 1.5$h_{ef}$ and $c_{a1}$ =[11, 12]: $h_{ef}$ | 1.5$h_{ef}$ | 3$h_{ef}$ | h = 2.25$h_{ef}$ and $c_{a1}$ =[11, 13]: 1.5$h_{ef}$ | 2$h_{ef}$ | 3$h_{ef}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 992 | NP | 1,822 | 3,435 | 4,207 | 5,950 | 5,153 | 6,311 | 8,924 | 9,466 | 10,930 | 13,387 |
| | 9 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,050 | 1,253 | 3,545 | 6,684 | 8,187 | 11,578 | 10,026 | 12,280 | 17,366 | 18,420 | 21,269 | 26,050 |
| | 12 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,050 | 1,930 | 5,458 | 10,291 | 12,604 | 17,825 | 15,437 | 18,906 | 26,737 | 28,359 | 32,746 | 40,106 |
| | 15 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,050 | 2,697 | 7,627 | 14,382 | 17,615 | 24,911 | 21,574 | 26,422 | 37,366 | 39,633 | 45,764 | 56,050 |
| | 18 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,050 | 3,545 | 10,026 | 18,906 | 23,155 | 32,746 | 28,359 | 34,733 | 49,119 | 52,099 | 60,159 | 73,679 |
| | 21 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,050 | 4,467 | 12,635 | 23,824 | 29,179 | 41,265 | 35,737 | 43,768 | 61,898 | 65,652 | 75,809 | 92,846 |
| | 25 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,050 | 5,802 | 16,412 | 30,946 | 37,901 | 53,600 | 46,419 | 56,851 | 80,400 | 85,277 | 98,469 | 120,600 |
| 1-1/8 | 6 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,076 | NP | 1,887 | 3,559 | 4,358 | 6,164 | 5,338 | 6,538 | 9,245 | 9,806 | 11,323 | 13,868 |
| | 9 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,167 | 1,329 | 3,760 | 7,090 | 8,683 | 12,280 | 10,635 | 13,025 | 18,420 | 19,537 | 22,560 | 27,630 |
| | 12 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,167 | 2,047 | 5,789 | 10,915 | 13,369 | 18,906 | 16,373 | 20,053 | 28,359 | 30,079 | 34,733 | 42,539 |
| | 15 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,167 | 2,860 | 8,090 | 15,255 | 18,683 | 26,422 | 22,882 | 28,025 | 39,633 | 42,037 | 48,540 | 59,450 |
| | 18 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,167 | 3,760 | 10,635 | 20,053 | 24,560 | 34,733 | 30,079 | 36,840 | 52,099 | 55,259 | 63,808 | 78,149 |
| | 21 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,167 | 4,738 | 13,401 | 25,270 | 30,949 | 43,768 | 37,904 | 46,423 | 65,652 | 69,635 | 80,407 | 98,478 |
| | 25 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,167 | 6,154 | 17,407 | 32,823 | 40,200 | 56,851 | 49,235 | 60,300 | 85,277 | 90,450 | 104,442 | 127,915 |
| 1-1/4 | 6 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,161 | NP | 1,948 | 3,673 | 4,498 | 6,362 | 5,509 | 6,747 | 9,542 | 10,121 | 11,687 | 14,314 |
| | 9 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,259 | 1,372 | 3,881 | 7,317 | 8,962 | 12,674 | 10,976 | 13,443 | 19,011 | 20,165 | 23,284 | 28,517 |
| | 12 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,286 | 2,157 | 6,102 | 11,506 | 14,092 | 19,929 | 17,259 | 21,138 | 29,893 | 31,706 | 36,611 | 44,840 |
| | 15 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,286 | 3,015 | 8,526 | 16,080 | 19,694 | 27,851 | 24,120 | 29,541 | 41,777 | 44,311 | 51,166 | 62,665 |
| | 18 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,286 | 3,963 | 11,210 | 21,138 | 25,888 | 36,611 | 31,706 | 38,832 | 54,917 | 58,248 | 67,260 | 82,376 |
| | 21 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,286 | 4,994 | 14,126 | 26,636 | 32,623 | 46,136 | 39,955 | 48,934 | 69,204 | 73,401 | 84,757 | 103,805 |
| | 25 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,286 | 6,487 | 18,349 | 34,599 | 42,374 | 59,926 | 51,898 | 63,562 | 89,890 | 95,342 | 110,092 | 134,834 |
| 1-3/8 | 6 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 1,248 | NP | 2,004 | 3,779 | 4,629 | 6,546 | 5,669 | 6,943 | 9,819 | 10,415 | 12,026 | 14,729 |
| | 9 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 1,353 | 1,412 | 3,993 | 7,530 | 9,222 | 13,042 | 11,295 | 13,833 | 19,563 | 20,749 | 23,959 | 29,344 |
| | 12 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 1,409 | 2,263 | 6,400 | 12,067 | 14,780 | 20,901 | 18,101 | 22,169 | 31,352 | 33,254 | 38,398 | 47,028 |
| | 15 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 1,409 | 3,162 | 8,944 | 16,865 | 20,655 | 29,211 | 25,297 | 30,983 | 43,816 | 46,474 | 53,663 | 65,724 |
| | 18 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 1,409 | 4,157 | 11,757 | 22,169 | 27,152 | 38,398 | 33,254 | 40,728 | 57,598 | 61,092 | 70,542 | 86,396 |
| | 21 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 1,409 | 5,238 | 14,816 | 27,937 | 34,215 | 48,388 | 41,905 | 51,323 | 72,581 | 76,984 | 88,894 | 108,872 |
| | 25 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 1,409 | 6,804 | 19,244 | 36,287 | 44,443 | 62,851 | 54,431 | 66,664 | 94,277 | 99,996 | 115,465 | 141,416 |
| 1-1/2 | 12 | 31,894 | 32,994 | 41,243 | 49,491 | 57,740 | 65,988 | 68,738 | 1,535 | 2,363 | 6,684 | 12,604 | 15,437 | 21,831 | 18,906 | 23,155 | 32,746 | 34,733 | 40,106 | 49,119 |
| | 15 | 31,894 | 32,994 | 41,243 | 49,491 | 57,740 | 65,988 | 68,738 | 1,535 | 3,303 | 9,342 | 17,615 | 21,574 | 30,510 | 26,422 | 32,360 | 45,764 | 48,540 | 56,050 | 68,647 |
| | 18 | 31,894 | 32,994 | 41,243 | 49,491 | 57,740 | 65,988 | 68,738 | 1,535 | 4,342 | 12,280 | 23,155 | 28,359 | 40,106 | 34,733 | 42,539 | 60,159 | 63,808 | 73,679 | 90,238 |
| | 21 | 31,894 | 32,994 | 41,243 | 49,491 | 57,740 | 65,988 | 68,738 | 1,535 | 5,471 | 15,474 | 29,179 | 35,737 | 50,539 | 43,768 | 53,605 | 75,809 | 80,407 | 92,846 | 113,713 |
| | 25 | 31,894 | 32,994 | 41,243 | 49,491 | 57,740 | 65,988 | 68,738 | 1,535 | 7,106 | 20,100 | 37,901 | 46,419 | 65,646 | 56,851 | 69,628 | 98,469 | 104,442 | 120,600 | 147,704 |
| 1-3/4 | 12 | 42,978 | 44,460 | 55,575 | 66,690 | 77,805 | 88,920 | 92,625 | 1,743 | 2,475 | 7,001 | 13,201 | 16,167 | 22,864 | 19,801 | 24,251 | 34,296 | 36,377 | 42,004 | 51,444 |
| | 15 | 42,978 | 44,460 | 55,575 | 66,690 | 77,805 | 88,920 | 92,625 | 1,798 | 3,567 | 10,090 | 19,026 | 23,302 | 32,954 | 28,539 | 34,953 | 49,431 | 52,430 | 60,541 | 74,147 |
| | 18 | 42,978 | 44,460 | 55,575 | 66,690 | 77,805 | 88,920 | 92,625 | 1,798 | 4,689 | 13,264 | 25,010 | 30,631 | 43,319 | 37,516 | 45,947 | 64,979 | 68,921 | 79,583 | 97,468 |
| | 21 | 42,978 | 44,460 | 55,575 | 66,690 | 77,805 | 88,920 | 92,625 | 1,798 | 5,909 | 16,714 | 31,517 | 38,600 | 54,589 | 47,275 | 57,900 | 81,883 | 86,850 | 100,286 | 122,824 |
| | 25 | 42,978 | 44,460 | 55,575 | 66,690 | 77,805 | 88,920 | 92,625 | 1,798 | 7,676 | 21,710 | 40,938 | 50,138 | 70,906 | 61,406 | 75,207 | 106,359 | 112,811 | 130,262 | 159,538 |
| 2 | 12 | 56,550 | 58,500 | 73,125 | 87,750 | 102,375 | 117,000 | 121,875 | 1,960 | 2,576 | 7,287 | 13,740 | 16,828 | 23,799 | 20,610 | 25,242 | 35,698 | 37,863 | 43,721 | 53,547 |
| | 15 | 56,550 | 58,500 | 73,125 | 87,750 | 102,375 | 117,000 | 121,875 | 2,049 | 3,765 | 10,648 | 20,079 | 24,591 | 34,778 | 30,118 | 36,887 | 52,166 | 55,331 | 63,891 | 78,250 |
| | 18 | 56,550 | 58,500 | 73,125 | 87,750 | 102,375 | 117,000 | 121,875 | 2,076 | 5,013 | 14,180 | 26,737 | 32,746 | 46,310 | 40,106 | 49,119 | 69,465 | 73,679 | 85,077 | 104,198 |

## Table 34-6B. Design Strengths for Single Cast-In Anchors Subject to Shear Loads ($f'_c$ = 4000 psi)[1, 2, 3, 5]

Notes pertaining to this table are given on Page 34-17

| $d_o$ in. | $h_{ef}$ in. | $\phi V_s$ - Shear Strength of Anchor | | | | | | | $\phi V_{cb}$ - Shear Breakout [5, 6, 7, 8, 9, 14, 15] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $f_{ut}$ - for design purposes [4] - psi | | | | | | | $h = h_{ef}$ [10] and $c_{a1}$ = [11] | | | | | | $h = 1.5h_{ef}$ and $c_{a1}$ = [11, 12] | | | $h = 2.25h_{ef}$ and $c_{a1}$ = [11, 13] | | |
| | | 58,000 | 60,000 | 75,000 | 90,000 | 105,000 | 120,000 | 125,000 | 1-1/2-in. cover | $0.25h_{ef}$ | $0.5h_{ef}$ | $h_{ef}$ | $1.5h_{ef}$ | $3h_{ef}$ | $h_{ef}$ | $1.5h_{ef}$ | $3h_{ef}$ | $1.5h_{ef}$ | $2h_{ef}$ | $3h_{ef}$ |
| 1/4 | 2 | 724 | 749 | 936 | 1,123 | 1,310 | 1,498 | 1,560 | 399 | NP | NP | 443 | 542 | 767 | 664 | 814 | 1,151 | 1,220 | 1,409 | 1,726 |
| | 3 | 724 | 749 | 936 | 1,123 | 1,310 | 1,498 | 1,560 | 487 | NP | NP | 814 | 996 | 1,409 | 1,220 | 1,495 | 2,114 | 2,242 | 2,589 | 3,171 |
| | 4 | 724 | 749 | 936 | 1,123 | 1,310 | 1,498 | 1,560 | 487 | NP | 664 | 1,253 | 1,534 | 2,170 | 1,879 | 2,301 | 3,254 | 3,452 | 3,986 | 4,882 |
| | 5 | 724 | 749 | 936 | 1,123 | 1,310 | 1,498 | 1,560 | 487 | NP | 928 | 1,751 | 2,144 | 3,032 | 2,626 | 3,216 | 4,548 | 4,824 | 5,570 | 6,822 |
| | 6 | 724 | 749 | 936 | 1,123 | 1,310 | 1,498 | 1,560 | 487 | NP | 1,220 | 2,301 | 2,818 | 3,986 | 3,452 | 4,228 | 5,979 | 6,341 | 7,322 | 8,968 |
| 3/8 | 2 | 1,764 | 1,825 | 2,282 | 2,738 | 3,194 | 3,650 | 3,803 | 459 | NP | NP | 500 | 613 | 866 | 750 | 919 | 1,299 | 1,378 | 1,591 | 1,949 |
| | 3 | 1,764 | 1,825 | 2,282 | 2,738 | 3,194 | 3,650 | 3,803 | 631 | NP | NP | 996 | 1,220 | 1,726 | 1,495 | 1,831 | 2,589 | 2,746 | 3,171 | 3,883 |
| | 4 | 1,764 | 1,825 | 2,282 | 2,738 | 3,194 | 3,650 | 3,803 | 631 | NP | 814 | 1,534 | 1,879 | 2,657 | 2,301 | 2,818 | 3,986 | 4,228 | 4,882 | 5,979 |
| | 5 | 1,764 | 1,825 | 2,282 | 2,738 | 3,194 | 3,650 | 3,803 | 631 | NP | 1,137 | 2,144 | 2,626 | 3,714 | 3,216 | 3,939 | 5,570 | 5,908 | 6,822 | 8,355 |
| | 6 | 1,764 | 1,825 | 2,282 | 2,738 | 3,194 | 3,650 | 3,803 | 631 | NP | 1,495 | 2,818 | 3,452 | 4,882 | 4,228 | 5,178 | 7,322 | 7,766 | 8,968 | 10,983 |
| 1/2 | 2 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 510 | NP | NP | 545 | 668 | 944 | 818 | 1,002 | 1,417 | 1,502 | 1,735 | 2,125 |
| | 3 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 726 | NP | NP | 1,086 | 1,330 | 1,881 | 1,629 | 1,996 | 2,822 | 2,993 | 3,456 | 4,233 |
| | 4 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 769 | NP | 939 | 1,771 | 2,170 | 3,068 | 2,657 | 3,254 | 4,602 | 4,882 | 5,637 | 6,904 |
| | 5 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 769 | NP | 1,313 | 2,476 | 3,032 | 4,288 | 3,714 | 4,548 | 6,432 | 6,822 | 7,878 | 9,648 |
| | 6 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 769 | NP | 1,726 | 3,254 | 3,986 | 5,637 | 4,882 | 5,979 | 8,455 | 8,968 | 10,355 | 12,683 |
| | 7 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 769 | 769 | 2,175 | 4,101 | 5,023 | 7,103 | 6,151 | 7,534 | 10,655 | 11,301 | 13,049 | 15,982 |
| | 8 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 769 | 939 | 2,657 | 5,010 | 6,136 | 8,678 | 7,516 | 9,205 | 13,017 | 13,807 | 15,943 | 19,526 |
| 5/8 | 3 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 818 | NP | NP | 1,161 | 1,422 | 2,012 | 1,742 | 2,134 | 3,018 | 3,201 | 3,696 | 4,526 |
| | 4 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 867 | NP | 1,004 | 1,894 | 2,320 | 3,281 | 2,841 | 3,480 | 4,921 | 5,220 | 6,027 | 7,381 |
| | 5 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 906 | NP | 1,468 | 2,768 | 3,390 | 4,794 | 4,152 | 5,085 | 7,191 | 7,627 | 8,807 | 10,787 |
| | 6 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 906 | NP | 1,930 | 3,638 | 4,456 | 6,302 | 5,458 | 6,684 | 9,453 | 10,026 | 11,578 | 14,180 |
| | 7 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 906 | NP | 2,432 | 4,585 | 5,615 | 7,941 | 6,878 | 8,423 | 11,912 | 12,635 | 14,589 | 17,868 |
| | 8 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 906 | 1,050 | 2,971 | 5,602 | 6,861 | 9,703 | 8,403 | 10,291 | 14,554 | 15,437 | 17,825 | 21,831 |
| | 9 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 906 | 1,253 | 3,545 | 6,684 | 8,187 | 11,578 | 10,026 | 12,280 | 17,366 | 18,420 | 21,269 | 26,050 |
| | 10 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 906 | 1,468 | 4,152 | 7,829 | 9,588 | 13,560 | 11,743 | 14,382 | 20,340 | 21,574 | 24,911 | 30,510 |
| 3/4 | 4 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 963 | NP | 1,061 | 2,001 | 2,450 | 3,465 | 3,001 | 3,675 | 5,198 | 5,513 | 6,366 | 7,796 |
| | 5 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 1,007 | NP | 1,550 | 2,923 | 3,581 | 5,064 | 4,385 | 5,371 | 7,595 | 8,056 | 9,303 | 11,393 |
| | 6 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 1,044 | NP | 2,114 | 3,986 | 4,882 | 6,904 | 5,979 | 7,322 | 10,355 | 10,983 | 12,683 | 15,533 |
| | 7 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 1,044 | NP | 2,664 | 5,023 | 6,151 | 8,699 | 7,534 | 9,227 | 13,049 | 13,841 | 15,982 | 19,574 |
| | 8 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 1,044 | 1,151 | 3,254 | 6,136 | 7,516 | 10,629 | 9,205 | 11,273 | 15,943 | 16,910 | 19,526 | 23,915 |
| | 9 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 1,044 | 1,373 | 3,883 | 7,322 | 8,968 | 12,683 | 10,983 | 13,452 | 19,024 | 20,178 | 23,299 | 28,536 |
| | 10 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 1,044 | 1,608 | 4,548 | 8,576 | 10,503 | 14,854 | 12,864 | 15,755 | 22,281 | 23,633 | 27,289 | 33,422 |
| | 12 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 1,044 | 2,114 | 5,979 | 11,273 | 13,807 | 19,526 | 16,910 | 20,711 | 29,289 | 31,066 | 35,872 | 43,934 |
| 7/8 | 4 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 1,060 | NP | 1,111 | 2,095 | 2,566 | 3,629 | 3,143 | 3,849 | 5,444 | 5,774 | 6,667 | 8,165 |
| | 6 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 1,149 | NP | 2,214 | 4,174 | 5,113 | 7,230 | 6,262 | 7,669 | 10,845 | 11,503 | 13,283 | 16,268 |
| | 8 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 1,185 | 1,243 | 3,515 | 6,628 | 8,118 | 11,480 | 9,942 | 12,177 | 17,220 | 18,265 | 21,091 | 25,831 |
| | 12 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 1,185 | 2,283 | 6,458 | 12,177 | 14,913 | 21,091 | 18,265 | 22,370 | 31,636 | 33,555 | 38,746 | 47,454 |
| | 15 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 1,185 | 3,191 | 9,025 | 17,017 | 20,842 | 29,475 | 25,526 | 31,263 | 44,213 | 46,894 | 54,149 | 66,319 |
| | 18 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 1,185 | 4,194 | 11,863 | 22,370 | 27,398 | 38,746 | 33,555 | 41,096 | 58,119 | 61,644 | 71,181 | 87,178 |
| | 25 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 1,185 | 6,865 | 19,418 | 36,616 | 44,845 | 63,420 | 54,923 | 67,267 | 95,130 | 100,901 | 116,510 | 142,695 |

## Table 34-6B. Design Strengths for Single Cast-In Anchors Subject to Shear Loads ($f'_c$ = 4000 psi)[1, 2, 3, 5] (cont'd.)

Notes pertaining to this table are given on Page 34-17

| $d_o$ in. | $h_{ef}$ in. | $\phi V_s$ - Shear Strength of Anchor: $f_{ut}$ - for design purposes[4] - psi | | | | | | | $\phi V_{cb}$ - Shear Breakout[5, 6, 7, 8, 9, 14, 15]: $h = h_{ef}$[10] and $c_{a1}$ =[11] | | | | | | $h = 1.5h_{ef}$ and $c_{a1}$ =[11, 12] | | | $h = 2.25h_{ef}$ and $c_{a1}$ =[11, 13] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 58,000 | 60,000 | 75,000 | 90,000 | 105,000 | 120,000 | 125,000 | 1-1/2-in. cover | $0.25h_{ef}$ | $0.5h_{ef}$ | $h_{ef}$ | $1.5h_{ef}$ | $3h_{ef}$ | $h_{ef}$ | $1.5h_{ef}$ | $3h_{ef}$ | $1.5h_{ef}$ | $2h_{ef}$ | $3h_{ef}$ |
| 1 | 6 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,254 | NP | 2,304 | 4,345 | 5,322 | 7,526 | 6,518 | 7,982 | 11,289 | 11,973 | 13,826 | 16,933 |
| | 9 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,329 | 1,585 | 4,484 | 8,455 | 10,355 | 14,645 | 12,683 | 15,533 | 21,967 | 23,299 | 26,904 | 32,950 |
| | 12 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,329 | 2,441 | 6,904 | 13,017 | 15,943 | 22,547 | 19,526 | 23,915 | 33,820 | 35,872 | 41,421 | 50,730 |
| | 15 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,329 | 3,411 | 9,648 | 18,192 | 22,281 | 31,510 | 27,289 | 33,422 | 47,265 | 50,132 | 57,888 | 70,898 |
| | 18 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,329 | 4,484 | 12,683 | 23,915 | 29,289 | 41,421 | 35,872 | 43,934 | 62,132 | 65,901 | 76,096 | 93,198 |
| | 21 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,329 | 5,650 | 15,982 | 30,136 | 36,909 | 52,197 | 45,204 | 55,363 | 78,295 | 83,044 | 95,891 | 117,442 |
| | 25 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,329 | 7,339 | 20,759 | 39,144 | 47,941 | 67,799 | 58,716 | 71,912 | 101,699 | 107,868 | 124,555 | 152,548 |
| 1-1/8 | 6 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,361 | NP | 2,387 | 4,501 | 5,513 | 7,796 | 6,752 | 8,269 | 11,695 | 12,404 | 14,323 | 17,542 |
| | 9 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,476 | 1,681 | 4,756 | 8,968 | 10,983 | 15,533 | 13,452 | 16,475 | 23,299 | 24,713 | 28,536 | 34,949 |
| | 12 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,476 | 2,589 | 7,322 | 13,807 | 16,910 | 23,915 | 20,711 | 25,365 | 35,872 | 38,048 | 43,934 | 53,806 |
| | 15 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,476 | 3,618 | 10,233 | 19,296 | 23,633 | 33,422 | 28,944 | 35,449 | 50,132 | 53;173 | 61,399 | 75,198 |
| | 18 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,476 | 4,756 | 13,452 | 25,365 | 31,066 | 43,934 | 38,048 | 46,599 | 65,901 | 69,898 | 80,711 | 98,851 |
| | 21 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,476 | 5,993 | 16,951 | 31,964 | 39,147 | 55,363 | 47,946 | 58,721 | 83,044 | 88,082 | 101,708 | 124,566 |
| | 25 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,476 | 7,785 | 22,018 | 41,518 | 50,849 | 71,912 | 62,277 | 76,274 | 107,868 | 114,411 | 132,110 | 161,801 |
| 1-1/4 | 6 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,469 | NP | 2,464 | 4,646 | 5,690 | 8,047 | 6,969 | 8,535 | 12,070 | 12,802 | 14,783 | 18,105 |
| | 9 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,593 | 1,735 | 4,909 | 9,256 | 11,336 | 16,032 | 13,884 | 17,004 | 24,048 | 25,506 | 29,452 | 36,071 |
| | 12 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,627 | 2,729 | 7,718 | 14,554 | 17,825 | 25,208 | 21,831 | 26,737 | 37,812 | 40,106 | 46,310 | 56,718 |
| | 15 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,627 | 3,814 | 10,787 | 20,340 | 24,911 | 35,229 | 30,510 | 37,366 | 52,844 | 56,050 | 64,721 | 79,266 |
| | 18 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,627 | 5,013 | 14,180 | 26,737 | 32,746 | 46,310 | 40,106 | 49,119 | 69,465 | 73,679 | 85,077 | 104,198 |
| | 21 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,627 | 6,317 | 17,868 | 33,693 | 41,265 | 58,358 | 50,539 | 61,898 | 87,536 | 92,846 | 107,210 | 131,305 |
| | 25 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,627 | 8,206 | 23,209 | 43,764 | 53,600 | 75,802 | 65,646 | 80,400 | 113,702 | 120,600 | 139,256 | 170,554 |
| 1-3/8 | 6 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 1,579 | NP | 2,535 | 4,781 | 5,855 | 8,280 | 7,171 | 8,783 | 12,420 | 13,174 | 15,212 | 18,631 |
| | 9 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 1,712 | 1,786 | 5,051 | 9,524 | 11,665 | 16,497 | 14,287 | 17,497 | 24,745 | 26,246 | 30,306 | 37,118 |
| | 12 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 1,782 | 2,862 | 8,095 | 15,264 | 18,695 | 26,438 | 22,896 | 28,042 | 39,658 | 42,063 | 48,571 | 59,487 |
| | 15 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 1,782 | 4,000 | 11,313 | 21,332 | 26,127 | 36,949 | 31,999 | 39,190 | 55,423 | 58,785 | 67,879 | 83,135 |
| | 18 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 1,782 | 5,258 | 14,872 | 28,042 | 34,345 | 48,571 | 42,063 | 51,517 | 72,856 | 77,275 | 89,230 | 109,284 |
| | 21 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 1,782 | 6,626 | 18,740 | 35,337 | 43,279 | 61,206 | 53,006 | 64,919 | 91,809 | 97,378 | 112,443 | 137,713 |
| | 25 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 1,782 | 8,606 | 24,342 | 45,900 | 56,216 | 79,501 | 68,850 | 84,324 | 119,252 | 126,486 | 146,053 | 178,878 |
| 1-1/2 | 12 | 31,894 | 32,994 | 41,243 | 49,491 | 57,740 | 65,988 | 68,738 | 1,942 | 2,989 | 8,455 | 15,943 | 19,526 | 27,614 | 23,915 | 29,289 | 41,421 | 43,934 | 50,730 | 62,132 |
| | 15 | 31,894 | 32,994 | 41,243 | 49,491 | 57,740 | 65,988 | 68,738 | 1,942 | 4,178 | 11,816 | 22,281 | 27,289 | 38,592 | 33,422 | 40,933 | 57,888 | 61,399 | 70,898 | 86,832 |
| | 18 | 31,894 | 32,994 | 41,243 | 49,491 | 57,740 | 65,988 | 68,738 | 1,942 | 5,492 | 15,533 | 29,289 | 35,872 | 50,730 | 43,934 | 53,808 | 76,096 | 80,711 | 93,198 | 114,143 |
| | 21 | 31,894 | 32,994 | 41,243 | 49,491 | 57,740 | 65,988 | 68,738 | 1,942 | 6,920 | 19,574 | 36,909 | 45,204 | 63,928 | 55,363 | 67,805 | 95,891 | 101,708 | 117,442 | 143,837 |
| | 25 | 31,894 | 32,994 | 41,243 | 49,491 | 57,740 | 65,988 | 68,738 | 1,942 | 8,989 | 25,425 | 47,941 | 58,716 | 83,037 | 71,912 | 88,074 | 124,555 | 132,110 | 152,548 | 186,832 |
| 1-3/4 | 12 | 42,978 | 44,460 | 55,575 | 66,690 | 77,805 | 88,920 | 92,625 | 2,205 | 3,131 | 8,855 | 16,698 | 20,450 | 28,921 | 25,046 | 30,675 | 43,382 | 46,013 | 53,131 | 65,073 |
| | 15 | 42,978 | 44,460 | 55,575 | 66,690 | 77,805 | 88,920 | 92,625 | 2,274 | 4,512 | 12,763 | 24,066 | 29,475 | 41,684 | 36,099 | 44,213 | 62,526 | 66,319 | 76,578 | 93,789 |
| | 18 | 42,978 | 44,460 | 55,575 | 66,690 | 77,805 | 88,920 | 92,625 | 2,274 | 5,932 | 16,777 | 31,636 | 38,746 | 54,795 | 47,454 | 58,119 | 82,193 | 87,178 | 100,665 | 123,289 |
| | 21 | 42,978 | 44,460 | 55,575 | 66,690 | 77,805 | 88,920 | 92,625 | 2,274 | 7,475 | 21,142 | 39,866 | 48,825 | 69,050 | 59,799 | 73,238 | 103,574 | 109,857 | 126,852 | 155,362 |
| | 25 | 42,978 | 44,460 | 55,575 | 66,690 | 77,805 | 88,920 | 92,625 | 2,274 | 9,709 | 27,462 | 51,782 | 63,420 | 89,690 | 77,674 | 95,130 | 134,535 | 142,695 | 164,770 | 201,802 |
| 2 | 12 | 56,550 | 58,500 | 73,125 | 87,750 | 102,375 | 117,000 | 121,875 | 2,479 | 3,259 | 9,217 | 17,380 | 21,286 | 30,103 | 26,070 | 31,929 | 45,155 | 47,894 | 55,303 | 67,732 |
| | 15 | 56,550 | 58,500 | 73,125 | 87,750 | 102,375 | 117,000 | 121,875 | 2,592 | 4,762 | 13,469 | 25,398 | 31,106 | 43,991 | 38,097 | 46,659 | 65,986 | 69,989 | 80,816 | 98,979 |
| | 18 | 56,550 | 58,500 | 73,125 | 87,750 | 102,375 | 117,000 | 121,875 | 2,626 | 6,341 | 17,936 | 33,820 | 41,421 | 58,578 | 50,730 | 62,132 | 87,868 | 93,198 | 107,615 | 131,801 |

*Table 34-6C. Design Strengths for Single Cast-In Anchors Subject to Shear Loads ($f'_c$ = 6000 psi)[1, 2, 3, 5]*

*Notes pertaining to this table are given on Page 34-17*

| $d_o$ in. | $h_{ef}$ in. | $\phi V_s$ - Shear Strength of Anchor | | | | | | | $\phi V_{cb}$ - Shear Breakout[5, 6, 7, 8, 9, 14, 15] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $f_{ut}$ - for design purposes[4] - psi | | | | | | | $h = h_{ef}$[10] and $c_{a1}$ =[11] | | | | | | $h = 1.5h_{ef}$ and $c_{a1}$ =[11, 12] | | | $h = 2.25h_{ef}$ and $c_{a1}$ =[11, 13] | | |
| | | 58,000 | 60,000 | 75,000 | 90,000 | 105,000 | 120,000 | 125,000 | 1-1/2-in. cover | $0.25h_{ef}$ | $0.5h_{ef}$ | $h_{ef}$ | $1.5h_{ef}$ | $3h_{ef}$ | $h_{ef}$ | $1.5h_{ef}$ | $3h_{ef}$ | $1.5h_{ef}$ | $2h_{ef}$ | $3h_{ef}$ |
| 1/4 | 2 | 724 | 749 | 936 | 1,123 | 1,310 | 1,498 | 1,560 | 489 | NP | NP | 542 | 664 | 939 | 814 | 996 | 1,409 | 1,495 | 1,726 | 2,114 |
| | 3 | 724 | 749 | 936 | 1,123 | 1,310 | 1,498 | 1,560 | 596 | NP | NP | 996 | 1,220 | 1,726 | 1,495 | 1,831 | 2,589 | 2,746 | 3,171 | 3,883 |
| | 4 | 724 | 749 | 936 | 1,123 | 1,310 | 1,498 | 1,560 | 596 | NP | 814 | 1,534 | 1,879 | 2,657 | 2,301 | 2,818 | 3,986 | 4,228 | 4,882 | 5,979 |
| | 5 | 724 | 749 | 936 | 1,123 | 1,310 | 1,498 | 1,560 | 596 | NP | 1,137 | 2,144 | 2,626 | 3,714 | 3,216 | 3,939 | 5,570 | 5,908 | 6,822 | 8,355 |
| | 6 | 724 | 749 | 936 | 1,123 | 1,310 | 1,498 | 1,560 | 596 | NP | 1,495 | 2,818 | 3,452 | 4,882 | 4,228 | 5,178 | 7,322 | 7,766 | 8,968 | 10,983 |
| 3/8 | 2 | 1,764 | 1,825 | 2,282 | 2,738 | 3,194 | 3,650 | 3,803 | 563 | NP | NP | 613 | 750 | 1,061 | 919 | 1,125 | 1,591 | 1,688 | 1,949 | 2,387 |
| | 3 | 1,764 | 1,825 | 2,282 | 2,738 | 3,194 | 3,650 | 3,803 | 772 | NP | NP | 1,220 | 1,495 | 2,114 | 1,831 | 2,242 | 3,171 | 3,363 | 3,883 | 4,756 |
| | 4 | 1,764 | 1,825 | 2,282 | 2,738 | 3,194 | 3,650 | 3,803 | 772 | NP | 996 | 1,879 | 2,301 | 3,254 | 2,818 | 3,452 | 4,882 | 5,178 | 5,979 | 7,322 |
| | 5 | 1,764 | 1,825 | 2,282 | 2,738 | 3,194 | 3,650 | 3,803 | 772 | NP | 1,393 | 2,626 | 3,216 | 4,548 | 3,939 | 4,824 | 6,822 | 7,236 | 8,355 | 10,233 |
| | 6 | 1,764 | 1,825 | 2,282 | 2,738 | 3,194 | 3,650 | 3,803 | 772 | NP | 1,831 | 3,452 | 4,228 | 5,979 | 5,178 | 6,341 | 8,968 | 9,512 | 10,983 | 13,452 |
| 1/2 | 2 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 625 | NP | NP | 668 | 818 | 1,157 | 1,002 | 1,227 | 1,735 | 1,840 | 2,125 | 2,602 |
| | 3 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 889 | NP | NP | 1,330 | 1,629 | 2,304 | 1,996 | 2,444 | 3,456 | 3,666 | 4,233 | 5,185 |
| | 4 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 942 | NP | 1,151 | 2,170 | 2,657 | 3,758 | 3,254 | 3,986 | 5,637 | 5,979 | 6,904 | 8,455 |
| | 5 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 942 | NP | 1,608 | 3,032 | 3,714 | 5,252 | 4,548 | 5,570 | 7,878 | 8,355 | 9,648 | 11,816 |
| | 6 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 942 | NP | 2,114 | 3,986 | 4,882 | 6,904 | 5,979 | 7,322 | 10,355 | 10,983 | 12,683 | 15,533 |
| | 7 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 942 | 942 | 2,664 | 5,023 | 6,151 | 8,699 | 7,534 | 9,227 | 13,049 | 13,841 | 15,982 | 19,574 |
| | 8 | 3,212 | 3,323 | 4,154 | 4,984 | 5,815 | 6,646 | 6,923 | 942 | 1,151 | 3,254 | 6,136 | 7,516 | 10,629 | 9,205 | 11,273 | 15,943 | 16,910 | 19,526 | 23,915 |
| 5/8 | 3 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 1,002 | NP | NP | 1,422 | 1,742 | 2,464 | 2,134 | 2,613 | 3,696 | 3,920 | 4,526 | 5,544 |
| | 4 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 1,061 | NP | 1,230 | 2,320 | 2,841 | 4,018 | 3,480 | 4,262 | 6,027 | 6,393 | 7,381 | 9,040 |
| | 5 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 1,110 | NP | 1,798 | 3,390 | 4,152 | 5,872 | 5,085 | 6,228 | 8,807 | 9,342 | 10,787 | 13,211 |
| | 6 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 1,110 | NP | 2,363 | 4,456 | 5,458 | 7,718 | 6,684 | 8,187 | 11,578 | 12,280 | 14,180 | 17,366 |
| | 7 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 1,110 | NP | 2,978 | 5,615 | 6,878 | 9,726 | 8,423 | 10,316 | 14,589 | 15,474 | 17,868 | 21,884 |
| | 8 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 1,110 | 1,286 | 3,638 | 6,861 | 8,403 | 11,883 | 10,291 | 12,604 | 17,825 | 18,906 | 21,831 | 26,737 |
| | 9 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 1,110 | 1,535 | 4,342 | 8,187 | 10,026 | 14,180 | 12,280 | 15,040 | 21,269 | 22,560 | 26,050 | 31,904 |
| | 10 | 5,112 | 5,288 | 6,611 | 7,933 | 9,255 | 10,577 | 11,018 | 1,110 | 1,798 | 5,085 | 9,588 | 11,743 | 16,607 | 14,382 | 17,615 | 24,911 | 26,422 | 30,510 | 37,366 |
| 3/4 | 4 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 1,180 | NP | 1,299 | 2,450 | 3,001 | 4,244 | 3,675 | 4,501 | 6,366 | 6,752 | 7,796 | 9,549 |
| | 5 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 1,233 | NP | 1,899 | 3,581 | 4,385 | 6,202 | 5,371 | 6,578 | 9,303 | 9,867 | 11,393 | 13,954 |
| | 6 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 1,279 | NP | 2,589 | 4,882 | 5,979 | 8,455 | 7,322 | 8,968 | 12,683 | 13,452 | 15,533 | 19,024 |
| | 7 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 1,279 | NP | 3,262 | 6,151 | 7,534 | 10,655 | 9,227 | 11,301 | 15,982 | 16,951 | 19,574 | 23,973 |
| | 8 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 1,279 | 1,409 | 3,986 | 7,516 | 9,205 | 13,017 | 11,273 | 13,807 | 19,526 | 20,711 | 23,915 | 29,289 |
| | 9 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 1,279 | 1,681 | 4,756 | 8,968 | 10,983 | 15,533 | 13,452 | 16,475 | 23,299 | 24,713 | 28,536 | 34,949 |
| | 10 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 1,279 | 1,969 | 5,570 | 10,503 | 12,864 | 18,192 | 15,755 | 19,296 | 27,289 | 28,944 | 33,422 | 40,933 |
| | 12 | 7,555 | 7,816 | 9,770 | 11,723 | 13,677 | 15,631 | 16,283 | 1,279 | 2,589 | 7,322 | 13,807 | 16,910 | 23,915 | 20,711 | 25,365 | 35,872 | 38,048 | 43,934 | 53,808 |
| 7/8 | 4 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 1,298 | NP | 1,361 | 2,566 | 3,143 | 4,445 | 3,849 | 4,714 | 6,667 | 7,072 | 8,165 | 10,001 |
| | 6 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 1,407 | NP | 2,711 | 5,113 | 6,262 | 8,855 | 7,669 | 9,392 | 13,283 | 14,089 | 16,268 | 19,924 |
| | 8 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 1,451 | 1,522 | 4,305 | 8,118 | 9,942 | 14,060 | 12,177 | 14,913 | 21,091 | 22,370 | 25,831 | 31,636 |
| | 12 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 1,451 | 2,796 | 7,909 | 14,913 | 18,265 | 25,831 | 22,370 | 27,398 | 38,746 | 41,096 | 47,454 | 58,119 |
| | 15 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 1,451 | 3,908 | 11,053 | 20,842 | 25,526 | 36,099 | 31,263 | 38,289 | 54,149 | 57,434 | 66,319 | [illegible] |
| | 18 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 1,451 | 5,137 | 14,530 | 27,398 | 33,555 | 47,454 | 41,096 | 50,332 | 71,181 | 75,499 | 87,178 | 106,771 |
| | 25 | 10,450 | 10,811 | 13,514 | 16,216 | 18,919 | 21,622 | 22,523 | 1,451 | 8,408 | 23,783 | 44,845 | 54,923 | 77,674 | 67,267 | 82,385 | 116,510 | 123,578 | [illegible] | [illegible] |

## Table 34-6C. Design Strengths for Single Cast-In Anchors Subject to Shear Loads ($f'_c$ = 6000 psi)[1, 2, 3, 5] (cont'd.)

Notes pertaining to this table are given on Page 34-17

| $d_o$ in. | $h_{ef}$ in. | $\phi V_s$ - Shear Strength of Anchor: $f_{ut}$ - for design purposes[4] - psi 58,000 | 60,000 | 75,000 | 90,000 | 105,000 | 120,000 | 125,000 | $\phi V_{cb}$ - Shear Breakout: $h = h_{ef}$[11] and $c_{a1}$ =[11] 1-1/2-in. cover | $0.25h_{ef}$ | $0.5h_{ef}$ | $h_{ef}$ | $1.5h_{ef}$ | $3h_{ef}$ | $h = 1.5h_{ef}$ and $c_{a1}$ = $h_{ef}$ | $1.5h_{ef}$ | $3h_{ef}$ | $h = 2.25h_{ef}$ and $c_{a1}$ = $1.5h_{ef}$ | $2h_{ef}$ | $3h_{ef}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,536 | NP | 2,822 | 5,322 | 6,518 | 9,217 | 7,982 | 9,776 | 13,826 | 14,664 | 16,933 | 20,739 |
| | 9 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,627 | 1,942 | 5,492 | 10,355 | 12,683 | 17,936 | 15,533 | 19,024 | 26,904 | 28,536 | 32,950 | 40,356 |
| | 12 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,627 | 2,989 | 8,455 | 15,943 | 19,526 | 27,614 | 23,915 | 29,289 | 41,421 | 43,934 | 50,730 | 62,132 |
| | 15 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,627 | 4,178 | 11,816 | 22,281 | 27,289 | 38,592 | 33,422 | 40,933 | 57,888 | 61,399 | 70,898 | 86,832 |
| | 18 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,627 | 5,492 | 15,533 | 29,289 | 35,872 | 50,730 | 43,934 | 53,808 | 76,096 | 80,711 | 93,198 | 114,143 |
| | 21 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,627 | 6,920 | 19,574 | 36,909 | 45,204 | 63,928 | 55,363 | 67,805 | 95,891 | 101,708 | 117,442 | 143,837 |
| | 25 | 13,708 | 14,180 | 17,726 | 21,271 | 24,816 | 28,361 | 29,543 | 1,627 | 8,989 | 25,425 | 47,941 | 58,716 | 83,037 | 71,912 | 88,074 | 124,555 | 132,110 | 152,548 | 186,832 |
| 1-1/8 | 6 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,667 | NP | 2,924 | 5,513 | 6,752 | 9,549 | 8,269 | 10,128 | 14,323 | 15,192 | 17,542 | 21,485 |
| | 9 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,807 | 2,059 | 5,825 | 10,983 | 13,452 | 19,024 | 16,475 | 20,178 | 28,536 | 30,267 | 34,949 | 42,804 |
| | 12 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,807 | 3,171 | 8,968 | 16,910 | 20,711 | 29,289 | 25,365 | 31,066 | 43,934 | 46,599 | 53,808 | 65,901 |
| | 15 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,807 | 4,431 | 12,533 | 23,633 | 28,944 | 40,933 | 35,449 | 43,416 | 61,399 | 65,124 | 75,198 | 92,099 |
| | 18 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,807 | 5,825 | 16,475 | 31,066 | 38,048 | 53,808 | 46,599 | 57,072 | 80,711 | 85,607 | 98,851 | 121,067 |
| | 21 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,807 | 7,340 | 20,761 | 39,147 | 47,946 | 67,805 | 58,721 | 71,918 | 101,708 | 107,878 | 124,566 | 152,562 |
| | 25 | 17,259 | 17,854 | 22,318 | 26,781 | 31,245 | 35,708 | 37,196 | 1,807 | 9,534 | 26,967 | 50,849 | 62,277 | 88,074 | 76,274 | 93,416 | 132,110 | 140,124 | 161,801 | 198,165 |
| 1-1/4 | 6 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,799 | NP | 3,018 | 5,690 | 6,969 | 9,855 | 8,535 | 10,453 | 14,783 | 15,680 | 18,105 | 22,174 |
| | 9 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,951 | 2,126 | 6,012 | 11,336 | 13,884 | 19,635 | 17,004 | 20,826 | 29,452 | 31,239 | 36,071 | 44,178 |
| | 12 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,992 | 3,342 | 9,453 | 17,825 | 21,831 | 30,874 | 26,737 | 32,746 | 46,310 | 49,119 | 56,718 | 69,465 |
| | 15 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,992 | 4,671 | 13,211 | 24,911 | 30,510 | 43,147 | 37,366 | 45,764 | 64,721 | 68,647 | 79,266 | 97,081 |
| | 18 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,992 | 6,140 | 17,366 | 32,746 | 40,106 | 56,718 | 49,119 | 60,159 | 85,077 | 90,238 | 104,198 | 127,616 |
| | 21 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,992 | 7,737 | 21,884 | 41,265 | 50,539 | 71,473 | 61,898 | 75,809 | 107,210 | 113,713 | 131,305 | 160,815 |
| | 25 | 21,919 | 22,675 | 28,343 | 34,012 | 39,681 | 45,349 | 47,239 | 1,992 | 10,050 | 28,426 | 53,600 | 65,646 | 92,838 | 80,400 | 98,469 | 139,256 | 147,704 | 170,554 | 208,885 |
| 1-3/8 | 6 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 1,933 | NP | 3,105 | 5,855 | 7,171 | 10,141 | 8,783 | 10,756 | 15,212 | 16,135 | 18,631 | 22,818 |
| | 9 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 2,097 | 2,187 | 6,186 | 11,665 | 14,287 | 20,204 | 17,497 | 21,430 | 30,306 | 32,145 | 37,118 | 45,460 |
| | 12 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 2,183 | 3,505 | 9,914 | 18,695 | 22,896 | 32,380 | 28,042 | 34,345 | 48,571 | 51,517 | 59,487 | 72,856 |
| | 15 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 2,183 | 4,899 | 13,856 | 26,127 | 31,999 | 45,253 | 39,190 | 47,998 | 67,879 | 71,997 | 83,135 | 101,819 |
| | 18 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 2,183 | 6,440 | 18,214 | 34,345 | 42,063 | 59,487 | 51,517 | 63,095 | 89,230 | 94,643 | 109,284 | 133,845 |
| | 21 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 2,183 | 8,115 | 22,952 | 43,279 | 53,006 | 74,962 | 64,919 | 79,509 | 112,443 | 119,263 | 137,713 | 168,664 |
| | 25 | 26,239 | 27,144 | 33,930 | 40,716 | 47,502 | 54,288 | 56,550 | 2,183 | 10,540 | 29,813 | 56,216 | 68,850 | 97,369 | 84,324 | 103,275 | 146,053 | 154,913 | 178,878 | 219,080 |
| 1-1/2 | 12 | 31,894 | 32,994 | 41,243 | 49,491 | 57,740 | 65,988 | 68,738 | 2,378 | 3,661 | 10,355 | 19,526 | 23,915 | 33,820 | 29,289 | 35,872 | 50,730 | 53,808 | 62,132 | 76,096 |
| | 15 | 31,894 | 32,994 | 41,243 | 49,491 | 57,740 | 65,988 | 68,738 | 2,378 | 5,117 | 14,472 | 27,289 | 33,422 | 47,265 | 40,933 | 50,132 | 70,898 | 75,198 | 86,832 | 106,347 |
| | 18 | 31,894 | 32,994 | 41,243 | 49,491 | 57,740 | 65,988 | 68,738 | 2,378 | 6,726 | 19,024 | 35,872 | 43,934 | 62,132 | 53,808 | 65,901 | 93,198 | 98,851 | 114,143 | 139,796 |
| | 21 | 31,894 | 32,994 | 41,243 | 49,491 | 57,740 | 65,988 | 68,738 | 2,378 | 8,476 | 23,973 | 45,204 | 55,363 | 78,295 | 67,805 | 83,044 | 117,442 | 124,566 | 143,837 | 176,164 |
| | 25 | 31,894 | 32,994 | 41,243 | 49,491 | 57,740 | 65,988 | 68,738 | 2,378 | 11,009 | 31,139 | 58,716 | 71,912 | 101,699 | 88,074 | 107,868 | 152,548 | 161,801 | 186,832 | 228,822 |
| 1-3/4 | 12 | 42,978 | 44,460 | 55,575 | 66,690 | 77,805 | 88,920 | 92,625 | 2,701 | 3,834 | 10,845 | 20,450 | 25,046 | 35,421 | 30,675 | 37,570 | 53,131 | 56,354 | 65,073 | 79,697 |
| | 15 | 42,978 | 44,460 | 55,575 | 66,690 | 77,805 | 88,920 | 92,625 | 2,786 | 5,527 | 15,631 | 29,475 | 36,099 | 51,052 | 44,213 | 54,149 | 76,578 | 81,224 | 93,789 | 114,868 |
| | 18 | 42,978 | 44,460 | 55,575 | 66,690 | 77,805 | 88,920 | 92,625 | 2,786 | 7,265 | 20,548 | 38,746 | 47,454 | 67,110 | 58,119 | 71,181 | 100,665 | 106,771 | 123,289 | 150,997 |
| | 21 | 42,978 | 44,460 | 55,575 | 66,690 | 77,805 | 88,920 | 92,625 | 2,786 | 9,155 | 25,894 | 48,825 | 59,799 | 84,568 | 73,238 | 89,698 | 126,852 | 134,547 | 155,362 | 190,278 |
| | 25 | 42,978 | 44,460 | 55,575 | 66,690 | 77,805 | 88,920 | 92,625 | 2,786 | 11,891 | 33,634 | 63,420 | 77,674 | 109,847 | 95,130 | 116,510 | 164,770 | 174,765 | 201,802 | 247,156 |
| | 12 | 56,550 | 58,500 | 73,125 | 87,750 | 102,375 | 117,000 | 121,875 | 3,036 | 3,991 | 11,289 | 21,286 | 26,070 | 36,869 | 31,929 | 39,105 | 55,303 | 58,658 | 67,732 | 82,955 |
| | 15 | 56,550 | 58,500 | 73,125 | 87,750 | 102,375 | 117,000 | 121,875 | 3,175 | 5,832 | 16,496 | 31,106 | 38,097 | 53,877 | 46,659 | 57,145 | 80,816 | 85,718 | 98,979 | 121,224 |