USP STRUCTURAL CONNECTORS®
A MiTek® Company

DUCTILE UNDERCUT ANCHORS

WHAT THE PROFESSIONALS USE

DUCTILITY • SAFETY • PERFORMANCE

How it Works

The DUC Undercut Anchor consists of an ASTM A36 or A193 Grade B7 threaded stud, a thick-walled expansion sleeve, an expander coupling and a nut and washer (316 stainless steel is also available).

The DUC Undercut Anchor is installed into a pre-drilled hole which has been enlarged at the bottom in the shape of a reversed cone. The reverse cone is created using the USP DUC Undercutting Bit. The DUC Undercutting Bit fits into SDS or SDS Max rotary hammer drills and guarantees the correct angle of the reverse cone. The anchor is expanded into the reverse cone when the expansion sleeve is driven over the expander coupling.

The result is an anchor which transfers load mainly through bearing, and unlike a typical expansion anchor (sleeve, heavy duty sleeve, wedge and drop-ins), the DUC is not dependent upon friction between the expansion sleeve and the concrete. Due to the use of a thick walled expansion sleeve, the load is distributed to a large area which ensures ductile behavior of the anchor even at relatively shallow embedments.

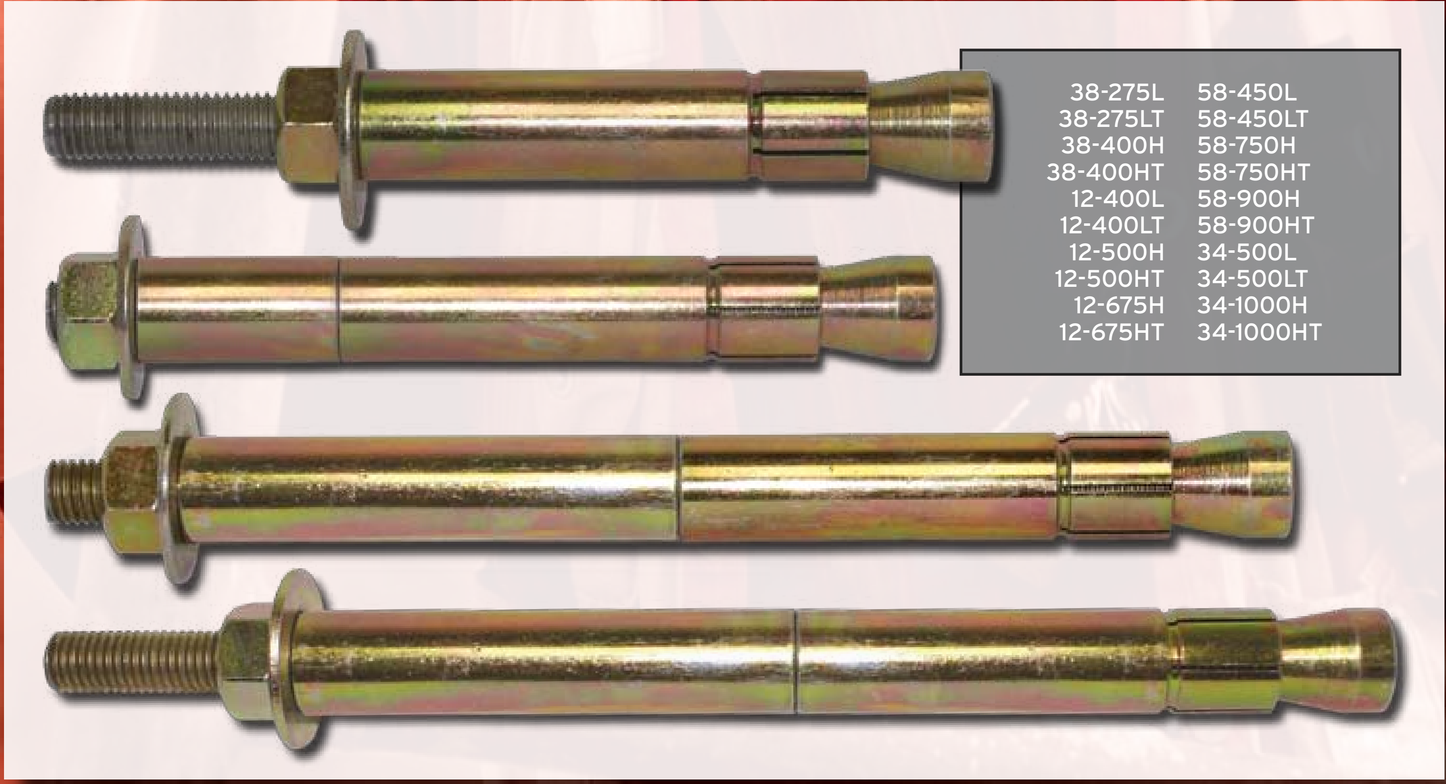
DUC Undercut Anchor Advantages

Compared with heavy capacity sleeve and expansion anchors and other undercut systems:

- DUC Undercut design provides consistent expansion and is easy to set. Stress risers have been eliminated to prevent tearing.
- Large bearing area provides exceptional performance even in low strength concrete.
- Load transfers mainly through bearing, not expansion forces. They are not dependent upon friction which can be lost when cracks occur.
- Thick walled sleeves transfer load over a larger area which insures predictable ductile performance.
- ASTM A36 or A193 grade B7 rods are used. Full ultimate steel strength is developed at listed embedment and spacing. Stainless steel also available.
- Installation is simple. It is similar to installing a typical expansion anchor; no coring drills are necessary. Creation of proper undercut is correctly done and easily verified using DUC Undercut Bits. Creation of undercut takes only seconds.

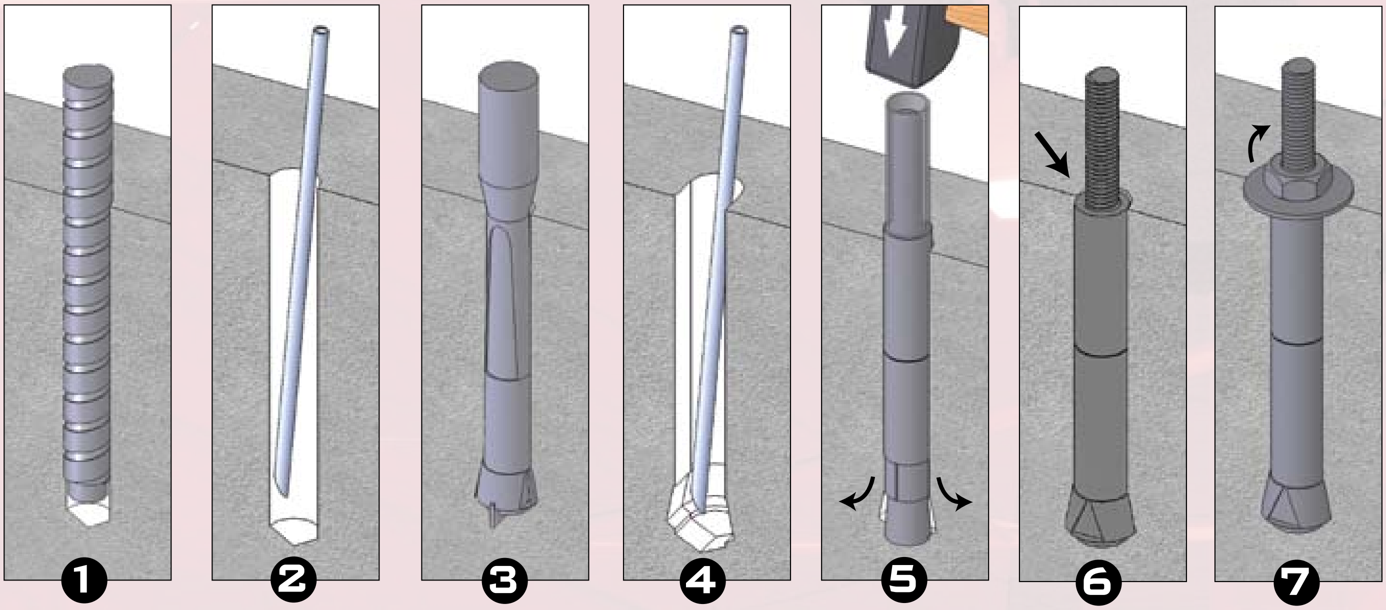
The DUC Undercut Anchors have been tested in accordance with ACI 355.2 to be qualified for use with the design methods of ACI 318 appendix D, including recognition in cracked concrete.

Available Anchor Sizes



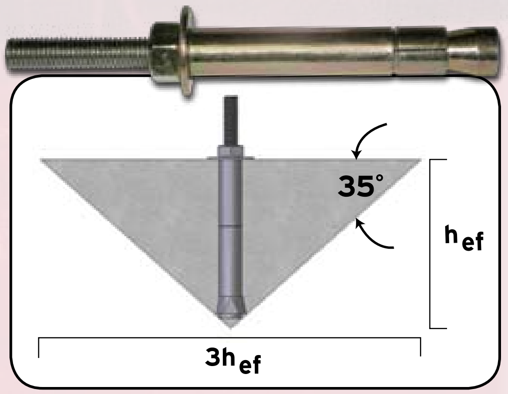
38-275L	58-450L
38-275LT	58-450LT
38-400H	58-750H
38-400HT	58-750HT
12-400L	58-900H
12-400LT	58-900HT
12-500H	34-500L
12-500HT	34-500LT
12-675H	34-1000H
12-675HT	34-1000HT

Ductile Undercut (DUC) Undercut Anchor Installation Instructions



1. Drill the hole to proper depth and diameter per specifications using rotohammer and stop drill.
2. Clean the hole using a blow-out bulb or compressed air.
3. Insert the undercut bit and start the rotohammer. Undercutting is complete when the stopper sleeve is fully compressed (gap closed).
4. Clean the hole again using a blow-out bulb or compressed air.
5. Insert anchor into hole. Place setting sleeve over anchor and drive the expansion sleeve over the expansion coupling.
6. Verify that the setting mark is visible on the threaded rod above the sleeve.
7. Apply proper torque.

**Images not at equal scale*



The DUC Undercut Anchor behaves nearly identically to a cast-in-place bolt. The standard embedments listed ensure that the capacity of the concrete exceeds that of the steel at the listed spacings and edge distances.

The capacity of DUC anchors can be calculated using Section 1923 of the 1997 UBC or Appendix D of ACI 318 for the IBC. Capacities for close spacing, edge conditions, and cracked concrete can be calculated using the provisions of ACI 318 Appendix D.

Stop Drill Bit

Stop Drill Bit Dimensions

Stop Drill Bit Designation	Corresponding Anchor Catalog Number	Maximum Drilling Depth, t (inches)	dbit (inches)	Shank Type
DUCSB38-275	DUC38-275	3-1/4	5/8	SDS
DUCSB38-400	DUC38-400	4-1/2	5/8	SDS
DUCSB12-400	DUC12-400	4-9/16	3/4	SDS
DUCSB12-500	DUC12-500	5-9/16	3/4	SDS
DUCSB12-675	DUC12-675	7-5/16	3/4	SDS
DUCSB58-450	DUC58-450	5-7/16	1	SDS-Max
DUCSB58-750	DUC58-750	8-7/16	1	SDS-Max
DUCSB58-900	DUC58-900	9-9/16	1	SDS-Max
DUCSB34-500	DUC34-500	6	1-1/8	SDS-Max
DUCSB34-1000	DUC34-1000	11	1-1/8	SDS-Max

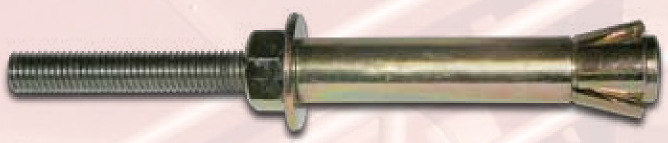
For SI: 1 inch = 25.4 mm.

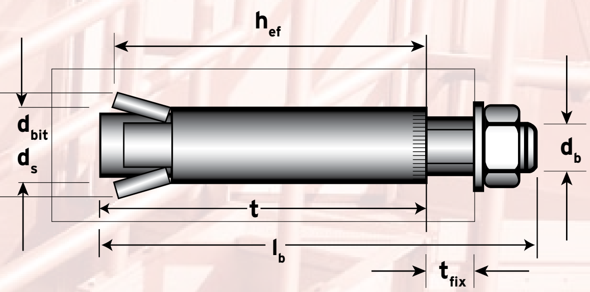
Installation Details and Allowable Loads for DUC Undercut Anchors

Catalog No.	Stud dia. d_b	Sleeve dia. d_s	Drill hole dia. d_{bit}	Drill hole depth t	effective embed. h_{ef}	Max fastening thickness t_{fix}	Overall Length, l_b	Sleeve length l_s	Allowable Tensile Capacity, N_s	Allowable shear capacity V_s
38-275L	3/8	5/8	5/8	3-1/8	2 3/4	1-3/4	6	2-3/4	2087	1043
38-275LT	3/8	5/8	5/8	3-1/8	2 3/4	1-3/4	6	4-1/2	2087	1043
38-400H	3/8	5/8	5/8	4-3/8	4	1-3/4	7-1/2	4	4497	2254
38-400HT	3/8	5/8	5/8	4-3/8	4	1-3/4	7-1/2	5-3/4	4497	2254
12-400L	1/2	3/4	3/4	4-3/8	4	1-3/4	7-1/2	4	3821	1909
12-400LT	1/2	3/4	3/4	4-3/8	4	1-3/4	7-1/2	5-3/4	3821	1909
12-500H	1/2	3/4	3/4	5-3/8	5	1-3/4	8-1/2	5	8235	4111
12-500HT	1/2	3/4	3/4	5-3/8	5	1-3/4	8-1/2	6-3/4	8235	4111
12-675H	1/2	3/4	3/4	7-1/8	6 3/4	1-3/4	10-1/4	6-3/4	8235	4111
12-675HT	1/2	3/4	3/4	7-1/8	6 3/4	1-3/4	10-1/4	8-1/2	8235	4111
58-450L	5/8	1	1	5-1/8	4 1/2	1-3/4	8-3/8	4-1/2	6086	3047
58-450LT	5/8	1	1	5-1/8	4 1/2	1-3/4	8-3/8	6-1/4	6086	3047
58-750H	5/8	1	1	8-1/8	7 1/2	1-3/4	11-3/8	7-1/2	13116	6552
58-750HT	5/8	1	1	8-1/8	7 1/2	1-3/4	11-3/8	9-1/4	13116	6552
58-900H	5/8	1	1	9-5/8	9	1-3/4	13	9	13116	6552
58-900HT	5/8	1	1	9-5/8	9	1-3/4	13	10-3/4	13116	6552
34-500L	3/4	1-1/8	1-1/8	5-5/8	5	1-3/4	9	5	9007	4497
34-500LT	3/4	1-1/8	1-1/8	5-5/8	5	1-3/4	9	6-3/4	9007	4497
34-1000H	3/4	1-1/8	1-1/8	10-5/8	10	1-3/4	14	10	19411	9692
34-1000HT	3/4	1-1/8	1-1/8	10-5/8	10	1-3/4	14	11-3/4	19411	9692

NOTES:
1. The tabulated values are for anchors installed at the specified spacing (s) and edge (c) distances. Spacing and edge distances may be reduced using the provisions of Section 1923 of the Uniform Building Code, or ACI 318 Appendix D for the 2003 and 2006 IBC and IRC.

6. Contact USP for custom lengths and stainless steel options.





UBC Series Undercut Drill Bits

Undercutter Bits for DUC Undercut Anchors

Catalog Number	Use With Anchors	Diam. (inches)	Shank Type	Max. Drilling Depth (inches)	Require Drill Impact Energy (ft. lbs)
UCB58	DUC38-275L DUCB38-400H	5/8	SDS	9	1.6
UCB34	DUCB12-400L DUC12-500H	3/4	SDS	10-1/4	2.5
UCB100	DUC58-450L DUC58-750H DUC58-900H	1	SDS	12-1/4	3.2
UCB118	DUC34-500L DUC34-1000H	1-1/8	SDS-Max	13-1/2	4.0
UCB118L	DUC34-500L DUC34-1000H	1-1/8	SDS-Max	29-1/2	4.0

Replacement Parts for DUC Undercutter Bit

Undercutter Drill Bit	Replacement Bow Jaw	Replacement Cutterblade
UCB12	BJ12	CB12
UCB58	BJ58	CB58
UCB34	BJ34	CB34
UCB78	BJ78	CB78
UCB100	BJ100	CB100
UCB118	BJ118	CB118
UCB118L	BJ118L	CB118

To change the cutter blade or bow jaw, do not loosen the set screw on the stopper sleeve. Push the detent pin through the stopper sleeve from the side opposite the set screw until it stops. The bow jaw can now be pulled out. Reverse for reassembly.

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COVERT OPERATIONS
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4.0 DUC Undercut Anchors

4.1 Product Information

4.1.1 Description
4.1.2 Product Features
4.1.3 Code Reports/Listings/Test Standards
4.1.4 Suggested Specification
4.1.5 DUC Anchor Component Material Specifications

4.2 Performance Parameters

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4.2.2 Anchor Working Principals
4.2.3 DUC Undercut Anchor Testing and Performance Evaluation

4.3 Specification and Installation Details

4.3.1 DUC Anchor Dimensional Information
4.3.2 DUC Anchor Installation Details
4.3.3 DUC Anchor Installation Procedures

4.4 2003/06 IBC (ACI 318-02/05, Appendix D) Anchor Design

4.4.1 Introduction
4.4.2 Strength Design
4.4.3 Allowable Stress Design

4.1 Product Details - DUC Undercut Anchors

4.1.1 Description

The USP Structural Connectors DUC Ductile Undercut Anchor is a high strength mechanical undercut anchor that is installed into a hole that has been undercut at the bottom using a secondary undercut drilling operation. During installation, the DUC Anchor is expanded into the undercut substrate, allowing tensile loads to be transferred through bearing on the undercut portion of concrete. The DUC anchors are available in 3/8-inch, 1/2-inch, 5/8-inch and 3/4-inch stud diameters manufactured with ASTM A36 (L series for low strength), ASTM A193 Gr. B7 (H series for high strength), or SS 316 stainless threaded rod. Additionally, stock anchors are available in standard and Through-bolted versions (T designated) which provide an additional length of sleeve for anchoring through various attachments (See Table 1 for anchor dimensions). The main components of the DUC Anchor include: an expansion coupling, an expansion sleeve, a threaded rod, a nut and washer, and a spacer sleeve when required. The primary hole is drilled into the substrate using a carbide tipped rotary hammer stop drill bit. The primary hole is then undercut using the corresponding diameter DUC undercut drillbit.

The USP Structural Connectors DUC Anchors are classified as heavy duty Type 2 displacement controlled undercut anchors per ACI 355.2. A displacement controlled undercut anchor is set in a predrilled undercut by driving the expansion sleeve over the expansion coupling (See Figure 1). The DUC undercut anchor derives its name from the fact that its sleeve expands into an undercut created by a special drilling operation performed on the primary hole drilled into the concrete. Upon setting, the sleeve expands into the undercut creating a mechanical interlock. The expanded portion of the anchor sleeve, bearing on the undercut portion of the hole, effectively transfers load into the concrete structural member. The bearing area of the DUC undercut anchor in contact with the concrete is 2 1/2 to 4 times larger than the tensile area of the anchor rod, depending on the specific anchor geometry. This large contact bearing area allows for ductile steel failure of the anchor rod in tension, a mechanism not typically possible with friction-only type expansion anchors.

4.1.2 Product Features

- Load transfers to concrete through bearing, not friction
- Predictable ductile steel performance
- Behaves like a cast in place headed bolt
- DUC Anchor capacities can be calculated in accordance with ACI 318-02
- Tested to rigorous ACI 355.2 cracked concrete and seismic requirements
- ASTM A 36, A 193 Grade B7, and Stainless options
- Bearing load transfer allows for closer spacing and edge distances
- Excellent performance in tension zones and cracked concrete
- Undercut created in seconds with durable tool
- Easy verification of complete undercut using DUC Undercutter Drillbits
- Replacement carbide cutter blades for Undercut Drillbits install easily

4.1.3 Code Reports/ Listings/ Test Standards (See section 8.0 for further information)

ICC (ICBO) ES ESR 1970 – ICC Evaluation Service, Inc
RR25753 – City of Los Angeles Research Report
FL 4928 – Florida Statewide Building Code product Approval
Meets ACI 318-02/05 Appendix D – Anchoring to Concrete
Evaluated under ACI 355.2 - Performance of Post Installed Mechanical Anchors in Concrete
Evaluated under ICC ES AC 193- Mechanical Anchors in Concrete Elements

4.1.4 Suggested Specification

Anchors installed into hardened concrete shall be DUC Ductile Undercut Anchors, manufactured by USP Structural Connectors, Burnsville, MN, per ICC ES ESR 1970. Anchors shall have been qualified for use in cracked concrete and for seismic applications in accordance with ACI 355.2, meeting the requirements for Category 1 classification. See structural details for diameter, embedment, spacing and edge distance or follow manufacturers' recommendations if not shown in details. Follow all manufacturers' installation instructions.

4.1.5 DUC Anchor component material specifications

Component	Material Spec.	fy (psi)	fu (psi)
L Series Threaded Rod	ASTM A 36	36000	58000
H Series Threaded Rod	ASTM A 193 Gr. B7	105000	125000
Expansion Coupling	ASTM A 108 12L14	70000	78000
Expansion Sleeve	ASTM A 513 Type 5	70000	80000
Spacer Sleeve	ASTM A 513 Type 5	70000	80000
Hex Nut	ASTM A 563, Gr. C	--	--
Washer	ASTM F 844	--	--

4.2 Performance Parameters

4.2.1 Behavior of Anchors in Concrete

The strength and serviceability of anchors in concrete are affected by many factors. Some of these factors are under the control of the anchor manufacturer such as the mechanical strength and corrosion resistance properties of a specifically selected anchor material, or the design of the geometry of the anchors' load transfer mechanism to the concrete. Other factors are not under the control of the manufacturer, including installation in corrosive environments, subjection to seismic, long term, or shock loading conditions, installation with drill bits that are out of the specified diameter range, installation into tension zones in concrete subject to cracking, close spacing and edge conditions, etc. Although the manufacturer cannot control where and how an anchor is installed and loaded when in service, the manufacturer can design and test the anchor for proper performance in most of these conditions.

One anchor installation condition that has been shown to have a marked effect on the tensile strength and serviceability of anchors is installation in areas where there is a likelihood of the concrete cracking. Reinforced concrete design is largely based upon the principle that concrete has low strength in tension, and steel reinforcement is provided to carry the tensile loads in concrete members, even at the service load level in many cases. In order for the structural element to properly transfer the tensile loads into the steel reinforcement, the concrete must crack. These cracks are a result of flexure in beams and slabs, moments in columns, walls, and other members, shrinkage, creep, settlement, thermal expansion and contraction, loading due to seismic and impact conditions, as well as stresses on the anchors themselves.

It has been shown that anchors under load located in the tension zone of a member will have a tendency to cause the formation of cracks towards itself due to stress concentrations in the concrete. The strength and serviceability of reinforced concrete members is well understood, and details such as reinforcing bar deformation requirements and bar development lengths have been established with acknowledgment that cracking in the concrete will occur. As indicated previously, it is also now recognized that cracking at or near an anchor can have a significant effect on its performance. This recognition is noticeably evident in ACI 318 Appendix D – Anchoring to Concrete, which references ACI 355.2 - Evaluating the Performance of Post-Installed Mechanical Anchors in Concrete. These documents contain specific provisions to address the effect of cracks on anchors, including test methods and criteria used to establish whether an anchor is acceptable for use in cracked concrete. There is a wide difference in the effect that a crack will have on an anchor depending on that anchors specific design and manufacture. Certain types or classes of anchors that have been used widely in the past may not be suitable for cracked concrete applications under these new design criteria.

4.2.2 Anchor working principals

The DUC undercut anchor transfers tensile loads applied to the anchor stud into bearing between the attached expansion coupling and the expansion sleeve. The expansion sleeve in turn bears on the surface of the concrete, which has been undercut to a matching geometry which allows a large area of bearing contact. This undercut geometry allows the tensile load to be transferred into the concrete similar to a cast in place bolt, as opposed to traditional expansion anchors which rely on friction on the side of the cylindrical hole to resist pullout.

The unit bearing compressive stress on the surrounding concrete for a DUC undercut anchor is relatively small when compared to the unit-compressive stresses created by other types of expansion anchors which helps reduce deflection and creep at all load levels. The bearing load transfer mechanism also exerts less expansion force in the concrete when compared to traditional mechanical anchors, which allows for closer spacing and edge distances. Bearing in the undercut hole results in the anchor performing exceptionally well in cracked concrete when evaluated under the requirements of ACI 355.2. **Perhaps most importantly, the low stress in the concrete provided by the large bearing area allows the DUC anchors to achieve full ductile steel failure in tension, even for the 125,000 psi H-designated anchor rods.**

The thick sleeve of the USP DUC undercut anchor also transfers lateral load into the concrete without the crushing of the concrete generally associated with other types of anchors. Again, this is because of the lower unit compressive stress on the concrete generated by a sleeve with a much larger circumference than other types of concrete anchors. Additionally, the through-bolted version of the anchors, designated by a T suffix on the anchor catalog number, are provided with an additional length of high strength spacer sleeve designed to transfer lateral load from the attachment into the concrete more effectively.

4.2.3 DUC Undercut Anchor Testing and Performance Evaluation

Over the last decade, the design of anchors in concrete has become increasingly complicated. This increase recognizes that there are many installation and service conditions that affect anchor performance that had not been adequately addressed in previous test and design methods. The latest design and test methods now address this deficiency, and as a result we have a better understanding of anchor performance in many installation conditions, both for cast in place anchors as well as post installed anchors. New test requirements examine an anchors performance in many possible adverse service conditions, and apply appropriate strength reduction factors to the capacities based on the results of this testing.

In the past, proprietary anchoring products were typically tested in accordance with a standard such as ASTM E-488, Strength of Anchors in Concrete and Masonry Elements. Additionally, companies such as ICBO Evaluation Services, now ICC ES, published additional test and acceptance criteria which typically specified a safety factor to the average ultimate test load of a series of 5 tests. These Acceptance Criteria (AC) also covered several service conditions including seismic loading, edge and group effects, etc. Undercut anchor testing has been covered under AC 01 and AC 193 in the past. Results of testing in accordance with these criteria have been published in ICBO/ICC ES Reports, which have served to bridge the gap between proprietary products and the building codes. Building officials have generally relied upon these Evaluation Report findings to determine a products suitability and compliance with the building code.

This process has changed somewhat beginning with publication of the 2002 ACI 318 Building Code. In ACI 318-02 (and continuing in 318-05 and 318-08), the strength design of anchors in concrete is covered in Appendix D. Appendix D contains design methods to calculate the capacity of cast in place headed anchors, but also contains provisions to recognize proprietary anchor products directly. In order for proprietary anchors to be recognized, they must be tested in accordance with ACI 355.2, Evaluating the Performance of Post Installed Mechanical Anchors in Concrete.

ACI 355.2 is an extremely comprehensive test and evaluation program. In addition to the service conditions listed above, ACI 355.2 contains methods for evaluation of anchors for use in cracked concrete. This is especially important in areas determined as high seismic zones by building codes such as the 2003 and 2006 International Building Code (IBC). Design of anchorage to concrete members in high seismic areas will require the use of anchors that are recognized for use in cracked concrete. The USP DUC Ductile Undercut anchor capacities for use with the 2003 and 2006 IBC, and ACI 318-02/05 are found in Section 4.4 of this Guide. The anchor design information in Section 4.5 is a result of tests in accordance with ACI 355.2 conducted at the University of Stuttgart and ICC ES Evaluation Service Report ESR 1970.

4.3 Specification and Installation Details

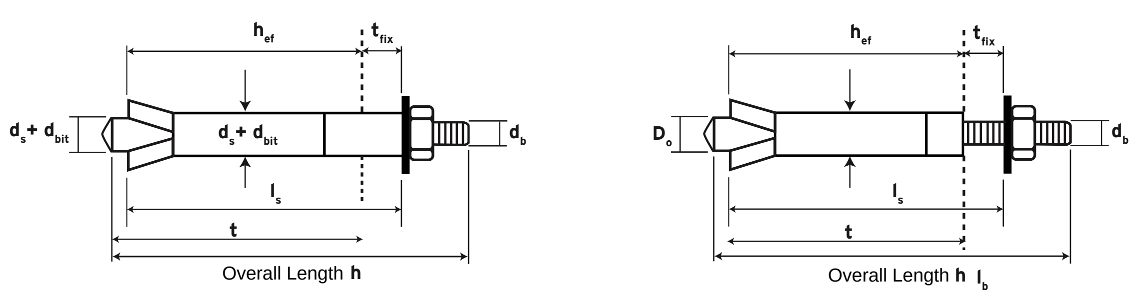
4.3.1 DUC Anchor Dimensional Information

Table 1 Standard Anchor Dimensional Characteristics

Anchor Designation	d_b (in.)	d_s (in.)	d_c (in.)	l_b (in.)	Length code letter	h_{ef} (in.)	l_s (in.)	t_{fix} (in.)
38-275L	3/8	5/8	5/8	6 1/4	J	2 3/4	2 3/4	1 3/4
38-275LT	3/8	5/8	5/8	6 1/4	J	2 3/4	4 1/2	1 3/4
38-400H	3/8	5/8	5/8	7 1/2	L	4	4	1 3/4
38-400HT	3/8	5/8	5/8	7 1/2	L	4	5 3/4	1 3/4
12-400L	1/2	3/4	3/4	7 1/2	L	4	4	1 3/4
12-400LT	1/2	3/4	3/4	7 1/2	L	4	5 3/4	1 3/4
12-500H	1/2	3/4	3/4	8 1/2	N	5	5	1 3/4
12-500HT	1/2	3/4	3/4	8 1/2	N	5	6 3/4	1 3/4
12-675H	1/2	3/4	3/4	10 1/4	R	6 3/4	6 3/4	1 3/4
12-675HT	1/2	3/4	3/4	10 1/4	R	6 3/4	8 1/2	1 3/4
58-450L	5/8	1	1	8 3/8	N	4 1/2	4 1/2	1 3/4
58-450LT	5/8	1	1	8 3/8	N	4 1/2	6 1/4	1 3/4
58-750H	5/8	1	1	11 3/8	S	7 1/2	7 1/2	1 3/4
58-750HT	5/8	1	1	11 3/8	S	7 1/2	9 1/4	1 3/4
58-900H	5/8	1	1	12 7/8	T	9	9	1 3/4
58-900HT	5/8	1	1	12 7/8	T	9	10 3/4	1 3/4
34-500L	3/4	1 1/8	1 1/8	8 7/8	O	5	5	1 3/4
34-500LT	3/4	1 1/8	1 1/8	8 7/8	O	5	7	1 3/4
34-1000H	3/4	1 1/8	1 1/8	13 7/8	U	10	10	1 3/4
34-1000HT	3/4	1 1/8	1 1/8	13 7/8	U	10	11 3/4	1 3/4

T_{fix} = Maximum thickness of fastened part

Figure 1 - Anchor installation configurations, standard and through bolted (T designation)



ANCHOR INSTALLED THROUGH ATTACHMENT

ATTACHMENT ADDED AFTER ANCHOR IS INSTALLED

Table 2 - Setting Information for DUC Undercut Anchors

Anchor Type		38-		12-			58-			34-	
		275L	400H	400L	500H	675H	450L	750H	900H	500L	1000H
Stud Diameter	d_b (in.)	3/8		1/2			5/8			3/4	
Nominal drill bit diameter	d_o (in.)	5/8		3/4			1			1 1/8	
Undercut Bit for Anchor Installation		UCB58		UCB34			UCB100			UCB118 UCB118L	
Undercut Bit Shank Type		SDS		SDS			SDS-Max			SDS-Max	
Undercut Bit Max. Drilling Depth	(in.)	9		10 1/4			12 1/4			13 1/2 29 1/2	
Required Impact Drill Energy	ft. – lbs.	1.6		2.5			3.2			4	
Recommended Setting Sleeve		SSL38		SSL12			SSL58			SSL34	
Embedment depth	h_{ef} (in.)	2 3/4	4	4	5	6 3/4	4 1/2	7 1/2	9	5	10
Hole Depth	t (in.)	3 1/8	4 3/8	4 1/4	5 1/4	7	5	8	9 1/2	5 13/16	10 13/16
Hole diameter of attached part	d_1 (in.)	5/16		9/16			11/16			15/16	
Min. attachment thickness	Min.t_{fix} (in.)	0		0			0			0	
Maximum Torque	T_{inst}(ft.lbs.)	35		60			90			180	

Actual hole depth for through-bolted anchors is given by hole depth (t) + (t_{fix} – t_{pl}) where t_{fix} is given in Table 1 and t_{pl} is the thickness of the parts being fastened.

Table 3 – Stop Drill Bit Dimensions

DUC Anchor Catalog Number	USP Stop Drill Bit Designation	Max. drilling depth t (in.)	d_{bit} (in.)	Shank Type
DUC 38-275L	DUCSB38-275	3 1/8	5/8	SDS
DUC 38-400H	DUCSB38-400	4 3/8	5/8	SDS
DUC 12-400L	DUCSB12-400	4 1/4	3/4	SDS
DUC 12-500H	DUCSB12-500	5 1/4	3/4	SDS
DUC 12-675H	DUCSB12-675	7	3/4	SDS
DUC 58-450L	DUCSB58-450	5	1	SDS-Max
DUC 58-750H	DUCSB58-750	8	1	SDS-Max
DUC 58-900H	DUCSB58-900	9 1/2	1	SDS-Max
DUC 34-500L	DUCSB34-500	5 13/16	1 1/8	SDS-Max
DUC 34-1000H	DUCSB34-1000	10 13/16	1 1/8	SDS-Max

Figure 2 – DUC Stop Drill Bit

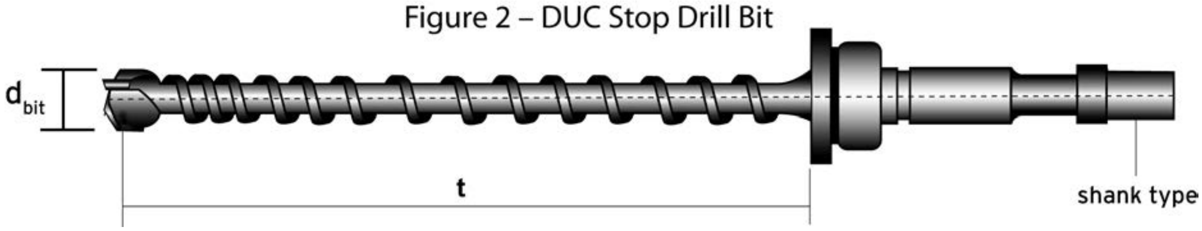
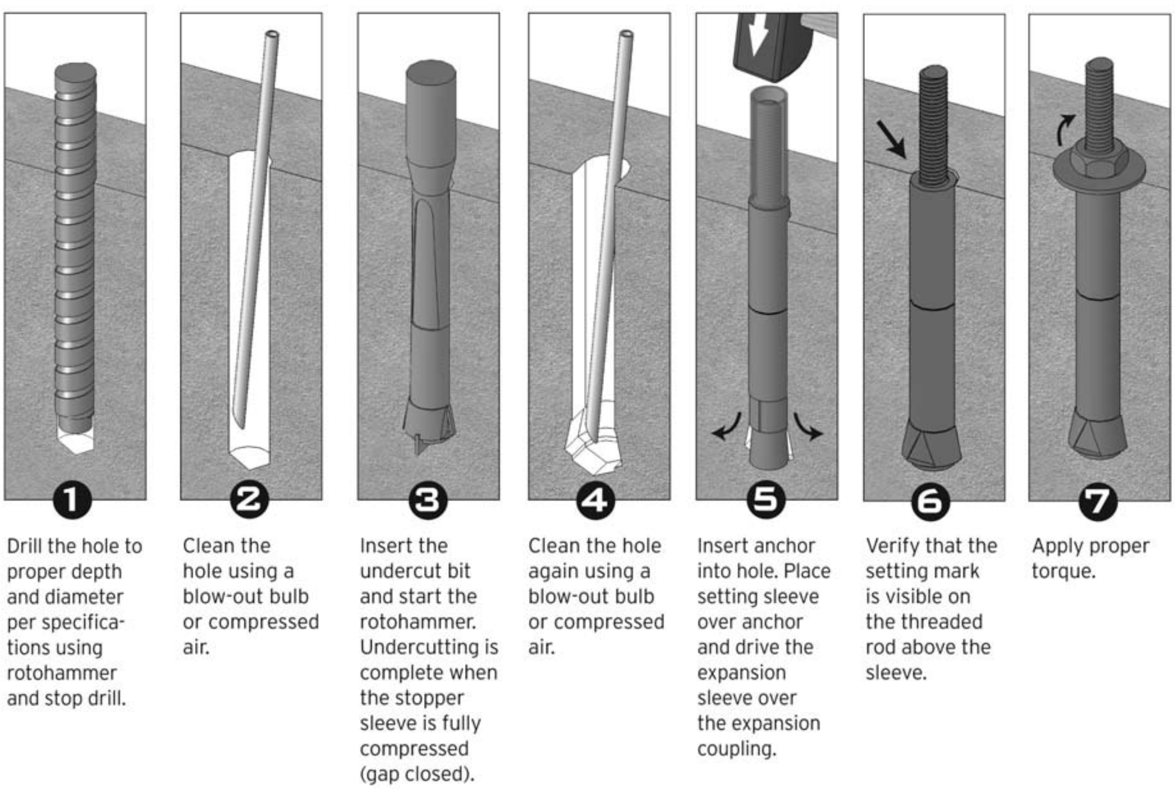


Table 4- Replacement Parts for DUC Undercutter Drill Bits

Undercutter drill bit	Replacement Cutter Blade	Replacement Bow Jaw
UCB 58	CB 58	BJ 58
UCB 34	CB 34	BJ 34
UCB 100	CB 100	BJ 100
UCB 118	CB 118	BJ 118
UCB 118L	CB 118	BJ 118L

Figure 3-UCB Undercut Bit (expanded).

4.3.3 DUC Ductile Undercut Anchor Installation Procedures



4.4 2003/06 IBC Anchor Design (ACI 318-02/05, Appendix D)

4.4.1 Introduction

Design of the DUC Ductile Undercut Anchors in accordance with the 2003 and 2006 IBC is based on extensive testing and calculations conforming to state of the art standards. As described in Section 4.2.3 of this guide, the DUC anchor capacities listed in the following sections have been derived based on the requirements of ACI 318-05 Appendix D, ACI 355.2, and ICC ES AC 193. These tests include static and seismic tests, in tension and shear, in cracked and uncracked concrete, conducted in multiple concrete strengths. Additional testing included moving crack (opening and closing), group, spacing, edge, base thickness, and reduced setting effort tests. The result of this testing and evaluation is the basis for the design in the following sections.

4.4.2 Strength Design (LRFD) in accordance with the 2003/06 IBC

As noted previously, design strength of the DUC Undercut Anchors in accordance with the 2003/06 IBC is based primarily on the concepts found in ACI 318 Appendix D. The Appendix D method for concrete breakout design has been developed from the European Concrete Capacity Design (CCD) method, which was an adaptation of the Kappa (κ) Method, also from Europe. The concrete breakout method is based around a prism breakout angle of 35 degrees.

In accordance with Appendix D Section D.4.1.2, the strength of an anchor or group of anchors shall be based on the lowest design strength determined from all appropriate failure modes. ϕN_n is the lowest design strength in tension, and ϕV_n is the lowest design strength in shear. The information in Table 5 shall be used where required by Appendix D to complete anchor strength calculations in accordance with the code.

The strength reduction factor ϕ for anchors in concrete shall be in accordance with ACI 318 D.4.4 when using the load combinations found in section 9.2, or D.4.5 when using the load combinations found in Appendix C. Also, note that when anchor design includes seismic loads, the requirements of D.3.3 shall apply.

4.4.3 Allowable Stress Design in accordance with ACI 318-02/05

Allowable Strength Design (ASD) capacities for the DUC Ductile Undercut Anchors are derived by applying the appropriate α factor to the limiting strength found when using the Strength Design Method (LRFD) calculations of the previous section. The ASD capacities for use in accordance with IBC Section 1605.3 are calculated using the following:

$$T_{allowable,\ ASD} = \phi N_n / \alpha$$

and

$$V_{allowable,\ ASD} = \phi V_n / \alpha$$

where:

$T_{allowable,\ ASD}$ = Allowable tension load (lbf or kN)

$V_{allowable,\ ASD}$ = Allowable shear load (lbf or kN)

ϕN_n = Lowest design strength of an anchor or anchor group in tension as determined in accordance with ACI 318 Appendix D and 2006 IBC Section 1908.1.16.

ϕV_n = Lowest design strength of an anchor or anchor group in shear as determined in accordance with ACI 318 Appendix D and 2006 IBC Section 1908.1.16.

α = Conversion factor calculated as a weighted average of the load factors for the controlling load combination. In addition, α shall include all applicable factors to account for non-ductile failure modes and required over-strength.

Interaction shall be calculated consistent with ACI 318 Appendix D Section D.7 as follows:

For shear loads $V \leq 0.2\ V_{allowable,\ ASD}$, the full allowable load in tension shall be permitted.

For tension loads $T \leq 0.2\ T_{allowable,\ ASD}$, the full allowable load in shear shall be permitted.

For all other cases: $T / T_{allowable,\ ASD} + V / V_{allowable,\ ASD} \leq 1.2$

Table 5 – DUC Anchor Design Information

Design Parameter	Symbol	Anchor Designation 38- 275L	38- 400H	12- 400L	12- 500H	12- 675H	58- 450L	58- 750H	58- 900H	34- 500L	34- 1000H
Stud Diameter	d (in.)	3/8		1/2			5/8			3/4	
Anchor O.D.	d_o (in.)	5/8		3/4			1			1 1/8	
Min. Embedment depth	$h_{ef,\ min}$ (in.)	2 3/4	4	4	5	6 3/4	4 1/2	7 1/2	9	5	10
Maximum Torque	T_{inst} (ft.lbs.)	35		60			90			180	
Yield strength of anchor steel	f_y (Ksi)	36	105	36	105	105	36	105	105	36	105
Ultimate strength of anchor steel	f_{ut} (Ksi)	58	125	58	125	125	58	125	125	58	125
Anchor Category[1]	1,2, or 3	1		1			1			1	
Strength Reduction Factor for Tension Steel failure modes[2]	ϕ	0.75									
Strength Reduction Factor for Shear Steel failure modes[2]	ϕ	0.65									
Strength Reduction Factor for Tension Concrete failure modes[2]	ϕ Cond. A	0.75									
	ϕ Cond. B	0.65									
Strength Reduction Factor for Shear Concrete failure modes[2]	ϕ Cond. A	0.75									
	ϕ Cond. B	0.7									
Tensile stress Area	A_{se} (in^2)	0.0775		0.1418			0.226			0.334	
Effectiveness Factor Uncracked Concrete	$K_{c,uncr}$ (in-lb)	30		30			30			30	
Effectiveness Factor Cracked Concrete[3]	$K_{c,cr}$	24		24			24			24	
$K_{c,uncr}/K_{c,cr}$	$\psi_{c,N}$	1.25		1.25			1.25			1.25	
Steel Resistance - Static Tension	$N_{sa,\ static}$ (lbs)	4494	9685	8225	17730	17730	13101	28247	28247	19371	41730
Steel Resistance- Static Shear	$V_{s,static}$ (lbs)	2247	4854	4112	8854	8854	6562	14112	14112	9685	20876
Steel Resistance- Sesimic Tension	$N_{sa,seismic}$ (lbs)	4494	9685	8225	17730	17730	12292	26494	26494	16067	34607
Steel Resistance- Seismic Shear	$V_{s,seismic}$ (lbs)	2247	4854	4112	8854	8854	6562	14112	14112	9685	20876
Pullout Resistance cracked concrete[5]	$N_{p,cr}$ (lbs)	9000		11500			15000			22000	
Pullout Resistance Seismic Tension	$N_{p,seismic}$ (lbs)	11888		17730			28247			41753	
Axial Stiffness in service load range uncracked concrete	βmin (10^3lb/in)	131									
	βm (10^3lb/in)	930									
	βmax (10^3lb/in)	1444									
Axial Stiffness in the service load range in cracked concrete	βmin (10^3lb/in)	91									
	βm (10^3lb/in)	394									
	βmax (10^3lb/in)	1724									

1) Anchor Category is used in ACI 318 Section D.4.4
2) For use with the load combinations of ACI 318 9.2. Condition A applies where the potential concrete failure surfaces are crossed by supplementary reinforcement proportioned to tie the potential concrete failure prism into the structural member. Condition B applies where such supplementary reinforcement is not provided, or where pullout or pryout strength governs.
3) Values must be used in accordance with ACI 318 D 5.2.2 and Section 4.1.3 of ESR 1970.
4) Values must be used in accordance with ACI 318 D 5.2.6 and Section 4.1.3 of ESR 1970.
5) Values must be used in accordance with Section 4.1.5 of ESR 1970.
6) Values must be used in accordance with Section 4.1.10 of ESR 1970.
7) Values must be used in accordance with Section 4.1.4 of ESR 1970.

Table 6 – Spacing, Edge Distance and Concrete Thickness Requirements for DUC Undercut Anchors

Design Parameter	Symbol	Nominal Anchor Diameter									
		3/8		1/2			5/8			3/4	
		275L	400H	400L	500H	675H	450L	750H	900H	500L	100H
Anchor O.D.	d_o (in.)	5/8		3/4			1			1 1/8	
Min. Embedment depth	$h_{ef,\,min}$ (in.)	2 3/4	4	4	5	6 3/4	4 1/2	7 1/2	9	5	10
Drill hole depth	t (in.)	3 1/8	4 3/8	4 1/4	5 1/4	7	5	8	9 1/2	5 13/16	10 13/16
Minimum Concrete Thickness 1											
Min. Concrete Thickness 1	h_{min1}	5 1/2	8	8	10	13 1/2	9	15	18	10	20
Critical edge distance	c_{ac}	4 1/8	6	6	7 1/2	10 1/8	6 3/4	11 1/4	13 1/2	7 1/2	15
Min. edge distance	c_{min}	2 1/4	3 1/4	3 1/4	4	5 3/8	3 5/8	6	7 1/4	4	8
Min. anchor spacing	s_{min}	2 3/4	4	4	5	6 3/4	4 1/2	7 1/2	9	5	10
Minimum Concrete Thickness 2											
Min. Concrete Thickness 2	h_{min2}	4 1/2	6	6	7 1/2	10 1/8	6 7/8	11 1/4	13 1/2	7 1/2	15
Critical edge distance	c_{cr}	4 1/8	6	6	7 1/2	10 1/8	6 3/4	11 1/4	13 1/2	7 1/2	15
Critical corner edge distance	c_{ac}	5 1/2	10 3/8	9 3/16	13	20 1/4	9 7/16	21	27	10 1/2	30
Min. edge distance	c_{min}	2 1/4	3 1/4	3 1/4	4	5 3/8	3 5/8	6	7 1/4	4	8
Min. anchor spacing	s_{min}	2 3/4	4	4	5	6 3/4	4 1/2	7 1/2	9	5	10

THE DESIGN REQUIREMENTS FOR ANCHORS IN TENSION SHALL BE BASED ON THE FOLLOWING:

N_{sa}, the nominal steel design strength of an anchor or group of anchors in tension shall not exceed the following (See Table 5 for the N_{sa} strengths based on this calculation for the DUC Undercut Anchors):

$N_{sa} = nA_{se}f_{uta}$ (ACI 318 D.5.1.2)

N_{cb}, the nominal concrete breakout strength of an anchor in tension shall be calculated as follows:
For a single anchor:

$N_{cb} = (A_{Nc}/A_{Nco})\ \Psi_{ed,N}\Psi_{c,N}\Psi_{cp,N}\ N_b$ (ACI 318 D.5.2.1)

For a group of anchors:

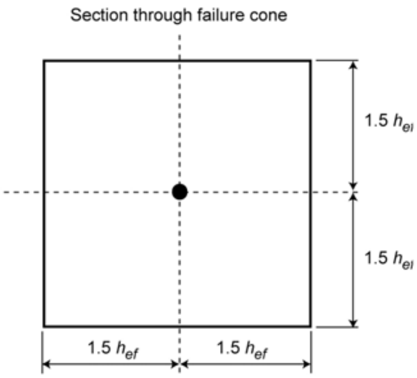
$N_{cbg} = (A_{Nc}/A_{Nco})\ \Psi_{ec,N}\ \Psi_{ed,N}\Psi_{c,N}\Psi_{cp,N}\ N_b$ (ACI 318 D.5.2.1)

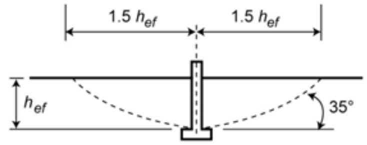
A_{Nc} is the projected area of the failure surface for the anchor or anchor group, which is approximated by extending the surface out $1.5h_{ef}$ from the centerline of the anchor or group of anchors. A_{Nco} is the projected area for a single anchor away from the edge (See D.5.2.1).

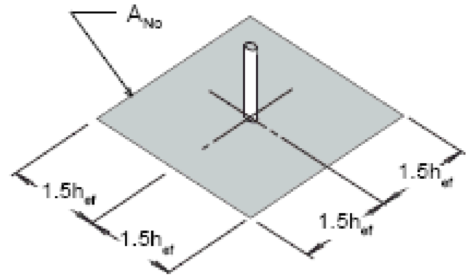
$A_{Nco} = 9h_{ef}^2$ (ACI 318 D.5.2.1)

$N_b = k_c\ (f'_c)^{1/2}\ h_{ef}^{1.5}$ (ACI 318 D.5.2.2)

k_c for the DUC anchors is listed in Table 5 for cracked & uncracked concrete ($k_{c,cr}$ and $k_{c,uncr}$).
$\Psi_{ec,N}$ is the modification factor for eccentrically loaded anchor groups per D.5.2.4.
$\Psi_{ed,N}$ is the modification factor for edge effects per D.5.2.5. Edge distance must be greater than c_{min} in Table 11
$\Psi_{c,N}$ is the modification factor for uncracked concrete ($f_t < f_r$) per D.5.2.6 and Table 5. For cracked concrete, $\Psi_{c,N} = 1.0$.
$\Psi_{cp,N}$ is the modification factor for post installed anchors per D.5.2.7.







$A_{Nco} = (1.5h_{ef} + 1.5h_{ef})(1.5h_{ef} + 1.5h_{ef})$

$A_{Nco} = 9h_{ef}^2$

N_{pn} is the nominal pullout strength of the DUC Undercut Anchor in tension and shall not exceed:

$N_{pn} = \Psi_{c,P} N_p$ (ACI 318 D.5.3.1)

N_p for the DUC Undercut Anchors is listed in Table 10 for seismic and cracked concrete conditions. In uncracked concrete, N_p will not be the governing design strength and need not be considered.

$\Psi_{c,P}$ = 1.4 for uncracked concrete. Otherwise, $\Psi_{c,P}$ shall be taken as 1.0. (ACI 318 D.5.3.6)

N_{sb}, concrete side face blowout strength per ACI 381 D.5.4.1 need not be considered. ACI 355.2 setting tests to preclude splitting have been accounted for in the minimum and critical edge distances, spacing, and base thicknesses listed in Table 6.

THE DESIGN REQUIREMENTS FOR ANCHORS IN SHEAR SHALL BE BASED ON THE FOLLOWING:

V_{sa}, the nominal steel design strength of a DUC Undercut Anchor or group of DUC anchors in shear, is listed in Table 5. V_{sa} is based on the following:

$V_{sa} = n0.6A_{se}f_{uta}$ (ACI 318 D.6.1.2(b))

V_{cb} or V_{cbg} the nominal concrete breakout strength of an anchor or group of anchors in shear shall be calculated as follows:
For a single anchor with the load applied perpendicular to the edge of the concrete:

$V_{cb} = (A_{Vc}/A_{Vco})\ \Psi_{ed,V}\Psi_{c,V}V_b$ (ACI 318 D.6.2.1(a))

For a group of anchors with the load applied perpendicular to the edge of the concrete:

$V_{cbg} = (A_{Vc}/A_{Vco})\ \Psi_{ec,V}\ \Psi_{ed,V}\Psi_{c,V}V_b$ (ACI 318 D.6.2.1(b))

For a shear force parallel to an edge, V_{cb} and V_{cbg} shall be twice the value calculated above respectively, with $\Psi_{ed,V} = 1.0$.

A_{Vc} is the projected area of the failure surface on the side of a concrete member in the direction of the load for the anchor or anchor group. A_{Vc} shall be the area of the base of a truncated half pyramid projected on the side face of the member (See D.6.2.1). A_{Vco} is the projected area for a single anchor in a deep member away from the edge. A_{Vco} shall be the area of the base of a half pyramid with a side length parallel to the edge of $3c_{a1}$ and a depth of $1.5c_{a1}$ (See D.6.2.1)

$A_{Vco} = 4.5c_{a1}^2$ (ACI 318 D.6.2.1)

V_b is the basic concrete breakout strength of a single anchor in cracked concrete.

$V_b = 7(l/d_o)^{0.2}(d_o)^{1/2}\,(f'_c)^{1/2}\,c^{1.5}$ (ACI 318 D.6.2.2)

$\Psi_{ec,V}$ is the modification factor for eccentrically loaded anchor groups per D.6.2.5.
$\Psi_{ed,V}$ is the modification factor for edge effects per D.6.2.6. Edge distance must be greater than c_{min} in Table 6.
$\Psi_{c,V}$ is the modification factor for cracked/uncracked concrete and supplementary reinforcement per D.6.2.7. For cracked concrete, $\Psi_{c,V} = 1.0$.

V_{cp} is the nominal pryout strength of an anchor in shear and shall not exceed:

$V_{cp} = k_{cp}\,N_{cb}$ (ACI 318 D.6.3.1)

where

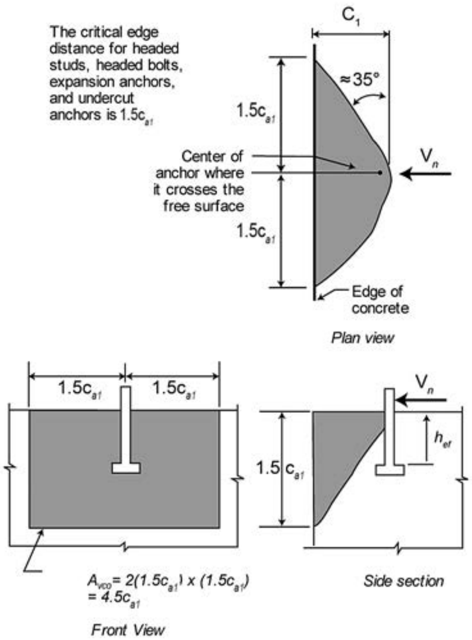
$k_{cp} = 1.0$ for $h_{ef} < 2.5$ in.
$k_{cp} = 2.0$ for $h_{ef} \geq 2.5$ in.

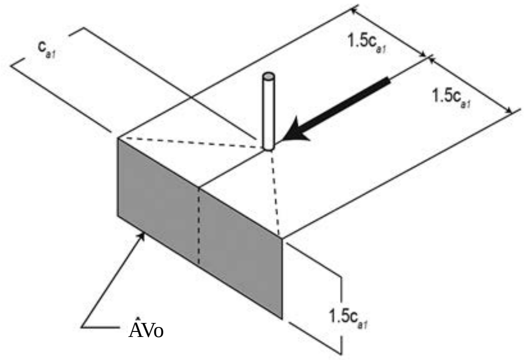
For combined loads, the following may be used when an anchor or group of anchors is simultaneously subjected to both shear and tension loading:

If $V_{ua} \leq 0.2\phi V_n$, then full strength in tension shall be permitted: $\phi N_n \geq N_{ua}$.
If $N_{ua} \leq 0.2\phi N_n$, then full strength in shear shall be permitted: $\phi V_n \geq V_{ua}$.
If $V_{ua} \geq 0.2\phi V_n$ and $N_u \geq 0.2\phi N_n$, then:

$(N_{ua}/\phi N_n) + (V_{ua}/\phi V_n) \leq 1.2$ (ACI 318 D.7.3)

ACI 355.2 setting tests to preclude splitting have been accounted for in the minimum and critical edge distances, spacing, and base thicknesses listed in Table 6.



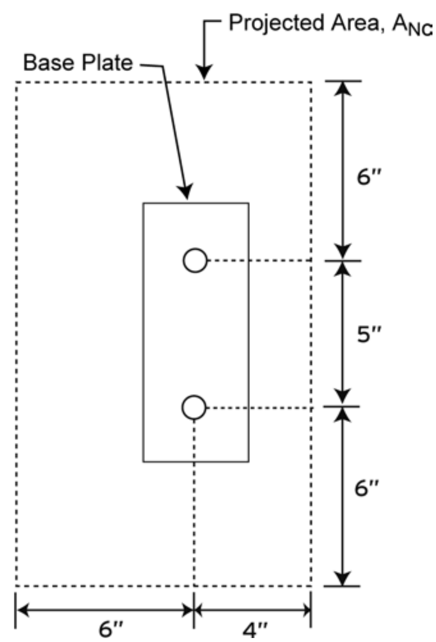


$$AVo = (1.5c_{a1} + 1.5c_{a1})(1.5c_{a1})$$

$$AVo = 4.5\ c_{a1}{}^2$$

Example:

Verify the tensile and shear adequacy of a two anchor group consisting of 2 - DUC 38-400H anchors with a 4 inch embedment in 3000 psi concrete spaced at 5 inches on center with a 4 inch edge distance as shown. No supplementary reinforcement is provided. Load combinations from ACI 310-05 Section 9.2 will be applied. Loading is concentric (no eccentricity). Shear load of 1000 lbs applied toward 4 inch edge, tensile load of 4000 lbs. Concrete thickness h = 9 inches and is uncracked. Load comprises of 80% dead load and 20% live load.



Calculation	ACI 318-05 Appendix D Section	ESR 1970 Section
Steel strength in tension: $N_{sa} = nA_{se}f_{uta}$ = (2)(.0775)(125000) = 19375 lb	D.5.1.2	Table 5
Steel capacity in tension: ϕN_{sa} = (0.75)(19375) = <u>14531 lb</u> (ϕ for steel tension failure modes)	D.4.4	Table 5
Concrete breakout in tension: $N_{cbg} = (A_{Nc}/A_{Nco})\ \Psi_{ec,N}\ \Psi_{ed,N}\Psi_{c,N}\Psi_{cp,N}\ N_b$ $\Psi_{ec,N}$ =1.0 (no eccentricity) $\Psi_{ed,N} = 0.7 + 0.3(c/1.5h_{ef}) = 0.7 + 0.3(4/1.5(4)) = 0.90$ $\Psi_{c,N}$ = 1.25 (uncracked concrete) $\Psi_{cp,N} = (1.5)(4)/6 = 1.0$ $A_{No} = 9h_{ef}^2 = (9)(4)^2 = 144$ in^2 $A_N = (1.5h_{ef} + s + 1.5h_{ef})(1.5\ h_{ef} + c) = (6+5+6)(6+4) = 170$ in^2 $k_{c,uncr} = 30$ $N_b = k_{c,uncr}\ (f'_c)^{1/2}\ h_{ef}^{1.5} = (30)(3000)^{1/2}(4)^{1.5} = 13145$ lb N_{cbg} = (170/144)(1.0)(0.90)(1.25)(1.0)(13145) = 17458 lb $\phi\ N_{cbg}$ = (0.65)(17458) = <u>11,348 lb</u> (ϕ for concrete failure mode, no supplementary reinforcement)	D.5.2.1 D.5.2.4 D.5.2.5 D.5.2.6 D.5.2.7 D.5.2.1 RD.5.2.1 D.5.2.2 D.5.2.2 D.4.4	Table 5 Table 5 Table 5
Concrete pullout in tension: $N_{pn} = \Psi_{c,P}N_p$ N/A – pullout does not govern in uncracked concrete.	D.5.3.1	Table 5
Controlling tensile strength $\phi N_n = \phi\ N_{cbg}$ = <u>11348 lb for the 2 anchor group</u>		
Steel strength in shear: nV_{sa} = (2)(4854) = <u>9708 lb</u> (loaded through anchor stud only, non-T anchor)		Table 5
Steel capacity in shear: ϕV_{sa} = (0.65)(9708) = <u>6310 lb</u> (ϕ for ductile steel shear failure modes)		Table 5

Concrete breakout in shear: $V_{cbg} = (A_{Vc}/A_{Vco})\ \Psi_{ec,V}\ \Psi_{ed,V}\Psi_{c,V}V_b$ $\Psi_{ec,V}$ = 1.0 (no eccentricity) $\Psi_{ed,V}$ = 1.0 $\Psi_{c,V}$ = 1.4 (uncracked concrete) $A_{Vco} = 4.5c_{a1}^2 \quad = (4.5)(4)^2 = 72$ in^2 $A_{Vc} = (1.5c_{a1} + s + 1.5c_{a1})(1.5c_{a1}) = (6 + 6 + 6)(6) = 108$ in^2 $V_b = 7(l/d_o)^{0.2}(d_o)^{1/2}\ (f'_c)^{1/2}\ c_{a1}^{1.5}$ l = lesser of h_{ef} or $8(d_o) = (8)(3/8) = 3$" Note that for through bolted anchors (T), $d_o = d_s$ (sleeve dia) $V_b = 7(3/(3/8))^{0.2}(3/8)^{1/2}\ (3000)^{1/2}\ (4)^{1.5} = 2847$ lb $V_{cbg} = (108/72)(1.0)(1.0)(1.4)(2847) = 5979$ lb $\phi\ V_{cbg} = (0.70)(5979) =$ <u>4185 lb</u> (ϕ for concrete failure mode, no supplementary reinforcement)	D.6.2.1(b) D.6.2.5 D.6.2.6 D.6.2.7 D.6.2.1 D.6.2.2 D.6.2.2	Table 5
Concrete Pryout: $V_{cp} = k_{cp}\ N_{cbg} = (2.0)(17458) = 34916$ lb $\phi V_{cpg} = (0.70)(34916) =$ <u>24441 lb</u>	D.6.3.1	
Controlling shear strength $\phi V_n = \phi\ V_{cbg}$ = <u>4185 lb for the 2 anchor group</u>		
Combined loading: Given 80% D + 20% L loading, ACI 318-05, 9.2, 9-2 governs. U = 1.2D + 1.6L. $N_{ua} = (1.2)(.8)(4000) + (1.6)(.2)(4000) = 5120$ lb $V_{ua} = (1.2)(.8)(1000) + (1.6)(.2)(1000) = 1280$ lb Verify that the applied factored loads N_{ua} and V_{ua} comply with the following: $N_{ua}/\phi N_n + V_{ua}/\phi V_n < 1.2 = 5120/11348 + 1280/4185 = 0.76 < 1.2$ ok	D.7.3	
Or, for ASD, determine α based on ACI 318-05 9.2 load combinations. Given 80% D + 20%L loading, 9-2 governs. U = 1.2D + 1.6L. $\alpha = 1.2(0.8) + 1.6(0.2) = 1.28$	9.2.1	4.2
Allowable tensile strength: $N_{allowable\ ASD} = \phi N_n / \alpha = (11348)/1.28 =$ <u>8865 lb for the 2 anchor group</u>		4.2
Allowable shear strength: $V_{allowable\ ASD} = \phi Vn / \alpha = (4185)/1.28 =$ <u>3270 lb for the 2 anchor group</u>		4.2
Interaction: $T/T_{allowable\ ASD} = V/V_{allowable\ ASD} \leq 1.2 = (4000/8865) + (1000/3270) = 0.76 \leq 1.2\ \therefore$ ok		4.2

ICC-ES Report

ESR-1970

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DIVISION: 03 00 00—CONCRETE
SECTION: 03 16 00—CONCRETE ANCHORS
DIVISION: 05 00 00—METALS
SECTION: 05 05 19—POST-INSTALLED CONCRETE ANCHORS

REPORT HOLDER:

USP STRUCTURAL CONNECTORS, *MiTek*® USA, INC.

14305 SOUTHCROSS DRIVE, SUITE 200
BURNSVILLE, MINNESOTA 55306

EVALUATION SUBJECT:

DUC UNDERCUT ANCHORS

ICC-ES Evaluation Report

ESR-1970*

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Section: 03 16 00—Concrete Anchors

DIVISION: 05 00 00—METALS
Section: 05 05 19—Post-installed Concrete Anchors

REPORT HOLDER:

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EVALUATION SUBJECT:

DUC UNDERCUT ANCHORS

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2015, 2012, 2009, and 2006 *International Building Code®* (IBC)
- 2015, 2012, 2009, and 2006 *International Residential Code®* (IRC)

Property evaluated:

Structural

2.0 USES

The USP Structural Connectors DUC Undercut Anchor is used to resist static, wind, and seismic tension and shear loads in cracked and uncracked normal-weight and sand-lightweight concrete having a specified compressive strength, f'_c, of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa). The DUC anchors comply as anchors installed in hardened concrete as described in Section 1901.3 of the 2015 IBC, Section 1909 of the 2012 IBC, and Section 1912 of the 2009 and 2006 IBC. The anchors are an alternative to cast-in-place anchors described in Section 1908 of the 2012 IBC, and Section 1911 of the 2009 and 2006 IBC. The anchors may also be used where an engineered design is submitted in accordance with Section R301.1.3 of the IRC.

3.0 DESCRIPTION

3.1 General:

The USP Structural Connectors DUC Undercut Anchors are displacement controlled undercut anchors. The DUC Undercut Anchors are comprised of five components as shown in Figure 1. The expanded anchor sleeve creates a mechanical interlock with the surrounding concrete. The DUC Undercut Anchors are available in standard (L and H designations) and through-bolted (LT and HT designations) versions with component dimensions as listed in Table 1. Sizes available include $^3/_8$-inch (9.5 mm), $^1/_2$-inch (12.7 mm), $^5/_8$-inch (15.9 mm), and $^3/_4$-inch (19.1 mm) diameters and various lengths. Table 1 shows anchor dimensions.

3.2 Anchor Materials:

3.2.1 Threaded Rods: The steel threaded rods used with the low-strength (L designation) anchors are ASTM A36 (F1554 Grade 36) low carbon steel and have a minimum 0.0002-inch (5 μm) zinc plating in accordance with ASTM B633, Type I. The steel threaded rods used with the high-strength (H designation) anchors comply with ASTM A193 Grade B7 and have a minimum 0.0002-inch (5 μm) yellow zinc plating in accordance with ASTM B633, Type II. A painted red setting mark (used for visual setting control) is provided on the threaded rod of both the low- and high-strength anchors.

3.2.2 Sleeves: The steel expansion sleeves comply with ASTM A513 Type 5 ERW DOM, with a minimum yield strength of 70,000 psi (483 MPa) and a minimum tensile strength of 80,000 psi (552 MPa). The sleeves have a minimum 0.0002-inch-thick (5 μm) yellow zinc plating in accordance with ASTM B633, Type II.

3.2.3 Coupling: The steel expansion couplings comply with ASTM A108 Type 12L14.

3.2.4 Nut and Washer: The hex nuts comply with ASTM A563, Grade A. The washers comply with ASTM F844.

3.3 Concrete:

Normal-weight and sand-lightweight concrete must conform to Sections 1903 and 1905 of the IBC, as applicable.

4.0 DESIGN AND INSTALLATION

4.1 Strength Design:

4.1.1 Design Strength of anchors complying with the 2015 IBC and Section R301.1.3 of the 2015 IRC must be determined in accordance with ACI 318-14 Chapter 17 and this report.

Design strength of anchors complying with the 2012 IBC and Section R301.1.3 of the 2012 IRC, must be determined in accordance with ACI 318-11 Appendix D and this report.

Design strength of anchors complying with the 2009 IBC and Section R301.1.3 of 2009 IRC must be in accordance with ACI 318-08 Appendix D and this report.

***Revised August 2015**

Design strength of anchors complying with the 2006 IBC and Section R301.1.3 of 2006 IRC must be in accordance with ACI 318-05 Appendix D and this report.

Design examples according to the 2015 IBC and 2012 IBC are given in Figures 5, 6, and 7 of this report. Design parameters are described in Tables 4 and 5 of this report and are based on the 2015 IBC (ACI 318-14) and 2012 IBC (ACI 318-11) unless noted otherwise in Sections 4.1.1 through 4.1.12. The strength design of anchors must comply with ACI 318-14 17.3.1 or ACI 318-11 D.4.1, except as required in ACI 318-14 17.2.3 or ACI 318-11 D.3.3, as applicable.

Strength reduction factors, ϕ, as given in ACI 318-14 17.3.3 or ACI 318-11 D.4.3, as applicable, and Table 4 must be used for load combinations calculated in accordance with Section 1605.2 of the IBC and Section 5.3 of ACI 318-14 or Section 9.2 of ACI 318-11, as applicalbe. Strength reduction factors, ϕ, as given in ACI 318-11 D.4.4 must be used for load combinations calculated in accordance with ACI 318-11 Appendix C.

The value of f'_c used in the calculations must be limited to a maximum of 8,000 psi (55.2 MPa), in accordance with ACI 318-14 17.2.7 or ACI 318-11 D.3.7.

4.1.2 Requirements for Static Steel Strength in Tension, N_{sa}: The nominal steel strength of a single anchor in tension, N_{sa}, must be calculated in accordance with ACI 318-14 17.4.1.2 or ACI 318-11 D.5.1.2, as applicable. The resulting values of N_{sa} are described in Table 4 of this report. Strength reduction factors, ϕ, corresponding to ductile steel elements may be used.

4.1.3 Requirements for Static Concrete Breakout Strength in Tension, N_{cb} or N_{cbg}: The nominal concrete breakout strength of a single anchor or group of anchors in tension, N_{cb} and N_{cbg}, respectively, must be calculated in accordance with ACI 318-14 17.4.2 or ACI 318-11 D.5.2, as applicable, and modifications as described in this section. The basic concrete breakout strength of a single anchor in tension in regions where analysis indicates cracking, N_b, must be calculated according to ACI 318-14 17.4.2.2 or ACI 318-11 D.5.2.2, as applicable, using the values of h_{ef} and k_{cr} as described in Table 4 of this report. Concrete breakout strength in tension in regions where analysis indicates no cracking in accordance with ACI 318-14 17.4.2.6 or ACI 318-11 D.5.2.6, as applicable, must be calculated with $\Psi_{c,N}$ = 1.0 and using the value of k_{uncr} as given in Table 4 of this report.

4.1.4 Requirements for Static Pullout Strength in Tension, N_{pn}: The nominal pullout strength of a single anchor or a group of anchors in tension, in accordance with ACI 318-14 17.4.3 or ACI 318-11 D.5.3, as applicable, in cracked concrete, $N_{p,cr}$, is given in Table 4 of this report. For all design cases, $\Psi_{c,P}$ =1.0. In accordance with ACI 318-14 17.4.3.2 or ACI 318-11 D.5.3.2, as applicable, the nominal pullout strength in cracked concrete must be adjusted by calculation according to Eq-1:

$$N_{pn,f'c} = N_{p,cr}\sqrt{\frac{f'_c}{2{,}500}} \quad \text{(lb, psi)} \qquad \text{(Eq-1)}$$

$$N_{pn,f'c} = N_{p,cr}\sqrt{\frac{f'_c}{17.2}} \quad \text{(N, MPa)}$$

In uncracked concrete, pullout strength does not control and therefore need not be evaluated.

4.1.5 Requirements for Static Steel Strength in Shear, V_{sa}: The nominal steel strength in shear, V_{sa}, of a single anchor in accordance with ACI 318-14 17.5.1.2 or ACI 318-11 D.6.1.2, as applicable, is given in Table 4 for the standard type and through-bolt type anchors and must be used in lieu of the values derived by calculation from ACI 318-14 Eq. 17.5.1.2b or ACI 318-11 Eq. D-29, as applicable. Strength reduction factors, ϕ, corresponding to ductile steel elements must be used.

4.1.6 Requirements for Static Concrete Breakout Strength in Shear, V_{cb} or V_{cbg}: The nominal static concrete breakout strength of a single anchor or a group of anchors in shear, V_{cb} or V_{cbg}, respectively, must be calculated in accordance with ACI 318-14 17.5.2 or ACI 318-11 D.6.2, as applicable, with modifications as described in this section. The basic concrete breakout strength of a single anchor in shear must be calculated in accordance with ACI 318-14 17.5.2.2 or ACI 318-11 D.6.2.2, as applicable, where the value of l_e used in ACI 318-14 Eq. 17.5.2.2a or ACI 318-11 Eq. D-33 must be taken as h_{ef}, but no greater than $8d_a$, for the anchors with one tubular shell over full length of the embedment depth; or the value of l_e used in ACI 318-14 Eq. 17.5.2.2a or ACI 318-11 Eq. D-33 must be taken as $2d_o$ for the anchors with a distance sleeve separated from the expansion sleeve.

4.1.7 Requirements for Static Concrete Pryout Strength in Shear, V_{cp} or V_{cpg}: The nominal static concrete pryout strength of a single anchor or a group of anchors in shear, V_{cp} or V_{cpg}, respectively, must be calculated in accordance with ACI 318-14 17.5.3 or ACI 318-11 D.6.3, as applicable, modified by using the value k_{cp} provided in Table 4 and the value N_{cb} and N_{cbg} as calculated in Section 4.1.3 of this report.

4.1.8 Requirements for Seismic Design: General: For load combinations including seismic, the design must be performed in accordance with ACI 318-14 17.2.3 or ACI 318-11 D.3.3, as applicable. Modifications to ACI 318-14 17.2.3 shall be applied under Section 1905.1.8 of the 2015 IBC. For the 2012 IBC, Section 1905.1.9 shall be omitted. Modifications to ACI 318 (-08, -05) D.3.3 must be applied under Section 1908.1.9 of the 2009 IBC or Section 1908.1.16 of the 2006 IBC, as applicable.

The L, LT, H, and HT designated anchors comply with ACI 318-14 2.3 or ACI 318-11 D.1, as applicable, as ductile steel elements and must be designed in accordance with ACI 318-14, 17.2.3.4, 17.2.3.5, 17.2.3.6 or 17.2.3.7; ACI 318-11 D.3.3.4, D.3.3.5, D.3.3.6, and D.3.3.7; ACI 318-08 D.3.3.4, D.3.3.5, or D.3.3.6; or ACI 318-05 D.3.3.4 or D.3.3.5, as applicable.

4.1.8.1 Seismic Tension: The nominal steel strength and nominal concrete breakout strength for anchors in tension must be calculated in accordance with ACI 318-14 17.4.1 and 17.4.2 or ACI 318-11 D.5.1 and D.5.2, respectively, as applicable, as described in Sections 4.1.2 and 4.1.3 of this report. In accordance with ACI 318-14 17.4.3.2 or ACI 318-11 D.5.3.2, as applicable, the appropriate value for pullout strength in tension for seismic loads, $N_{p,eq}$, described in Table 4 of this report must be used in lieu of N_p. $N_{p,eq}$ may be adjusted by calculations for concrete compressive strength in accordance with Eq-1 of this report.

4.1.8.2 Seismic Shear: The nominal concrete breakout strength and pryout strength for anchors in shear must be calculated according to ACI 318-14 17.5.2 and 17.5.3 or ACI 318-11 D.6.2 and D.6.3, respectively, as applicable, as described in Sections 4.1.6 and 4.1.7 of this report. In accordance with ACI 318-14 17.5.1.2 or ACI 318-11 D.6.1.2, as applicable, the appropriate value for nominal steel strength in shear for seismic loads $V_{sa,eq}$, described in Table 4 must be used in lieu of V_{sa}.

4.1.9 Requirements for Interaction of Tensile and Shear Forces: The effects of combined tensile and shear forces must be determined in accordance with ACI 318-14 17.6 or ACI 318-11 D.7, as applicable.

4.1.10 Requirements for Critical Edge Distance: In applications where $c < c_{ac}$ and supplemental reinforcement to control splitting of the concrete is not present, the concrete breakout strength in tension for uncracked concrete, calculated according to ACI 318-14 17.4.2 or ACI 318-11 D.5.2, as applicable, must be further multiplied by the factor $\psi_{cp,N}$ given in the following equation:

$$\psi_{cp,N} = \frac{c}{c_{ac}} \qquad \text{(Eq-2)}$$

whereby the factor $\psi_{cp,N}$ need not be taken as less than $\frac{1.5h_{ef}}{c_{ac}}$. For all other cases $\psi_{cp,N}$ = 1.0. In lieu of ACI 318-14 17.7.6 or ACI 318-11 D.8.6, as applicable, values of c_{ac} critical edge distance must be in accordance with Table 4 of this report.

4.1.11 Requirements for Minimum Member Thickness, Minimum Anchor Spacing and Minimum Edge Distance: In lieu of ACI 318-14 17.7.1 and 17.7.3 or ACI 318-11 D.8.1 and D.8.3, respectively, as applicable, values of s_{min} and c_{min} provided in Table 4 of this report must be used. In lieu of ACI 318-14 17.7.5 or ACI 318-11 D.8.5, as applicable, minimum member thickness, h_{min}, must be in accordance with Table 4 of this report.

4.1.12 Requirements for Sand-lightweight Concrete: For ACI 318-14 (2015 IBC), ACI 318-11 (2012 IBC) and ACI 318-08 (2009 IBC), when anchors are used in sand-lightweight concrete, the modification factor λ_a or λ, respectively, for concrete breakout strength must be taken as 0.6 in lieu of ACI 318-14 17.2.6, ACI 318-11 D.3.6 (2012 IBC) and ACI 318-08 D.3.4 (2009 IBC). In addition, the pullout strength $N_{p,cr}$ and $N_{p,eq}$ must be multiplied by 0.6, as applicable.

For ACI 318-05 (2006 IBC), the values N_b, $N_{p,eq}$, $N_{p,cr}$, *and* V_b determined in accordance with this report must be multiplied by 0.60, in lieu of ACI 318-05 D.3.4.

4.2 Allowable Stress Design:

4.2.1 General: For anchors designed using load combinations in accordance with IBC Section 1605.3 (Allowable Stress Design), allowable loads must be established using the equations below:

$$T_{allowable,ASD} = \frac{\phi N_n}{\alpha} \qquad \text{(Eq-3)}$$

$$V_{allowable,ASD} = \frac{\phi V_n}{\alpha} \qquad \text{(Eq-4)}$$

where:

$T_{allowable,ASD}$ = Allowable tension load (lb or N).

$V_{allowable,ASD}$ = Allowable shear load (lb or N).

ϕN_n = Lowest design strength of an anchor or anchor group in tension as determined in accordance with ACI 318-14 Chapter 17 and 2015 IBC Section 1905.1.8, ACI 318-11 Appendix D, ACI 318-08 Appendix D and2009 IBC Section 1908.1.9, ACI 318-05 Appendix D and 2006 IBC Section 1908.1.16, and Section 4.1 of this report, as applicable (lb or N).

ϕV_n = Lowest design strength of an anchor or anchor group in shear as determined in accordance with ACI 318-14 Chapter 17 and 2015 IBC Section 1905.1.8, ACI 318-11 Appendix D, ACI 318-08 Appendix D and 2009 IBC Section 1908.1.9, ACI 318-05 Appendix D and 2006 IBC Section 1908.1.16, and Section 4.1 of this report, as applicable (lb or N).

α = Conversion factor calculated as a weighted average of the load factors for the controlling load combination. In addition, α must include all applicable factors to account for non-ductile failure modes and required over-strength.

Limits on edge distance, anchor spacing, and member thickness as given in Table 4 must apply. An example of Allowable Stress Design tension values is given in Table 5.

4.2.2 Interaction of Tensile and Shear Forces: The interaction must be calculated and consistent with ACI 318-14 17.6 or ACI 318 (-11, -08, -05) D.7 as follows:

For shear loads $V \le 0.2\ V_{allowable,\ ASD}$, the full allowable load in tension must be permitted.

For tension loads $T \le 0.2\ T_{allowable,ASD}$, the full allowable load in shear must be permitted.

For all other cases:

$$\frac{T}{T_{allowable}} + \frac{V}{V_{allowable}} \le 1.2 \qquad \text{(Eq-5)}$$

4.3 Installation:

Installation parameters are described in Tables 1 through 4 and Figures 2 through 5 of this report. Anchor locations must comply with the plans and specifications approved by the code official and this report. Anchors must be installed in accordance with USP Structural Connectors instructions and this report. Holes must be drilled normal to the concrete surface using carbide-tipped masonry stop drill bits complying with ANSI B212.15-1994 supplied by USP Structural Connectors. The holes must be cleaned using a hand pump or compressed air. The undercut drill bit must then be inserted into the hole and drilled until the stopper sleeve is fully compressed and the gap is closed. The holes must be cleaned again using a hand pump or compressed air. The DUC anchors must be inserted into the holes without nut and washer and the setting sleeve must be placed on the anchor and hammered to drive the expansion sleeve over the expansion coupling. Proper setting requires the red setting mark on the threaded rod to be visible above the expansion sleeve. The setting sleeve must be removed and the attachment must then be placed over the threaded rod and secured by the nut and washer. The maximum applied torque, T_{max}, must not exceed the values given in Table 3. Undercut drill bits and setting tools used are provided by USP Structural Connectors.

4.4 Special Inspection:

Periodic special inspection is required, in accordance with Section 1705.1.1 and Table 1705.3 of the 2015 IBC and 2012 IBC; Section 1704.15 and Table 1704.4 of the 2009 IBC; or Section 1704.13 of the 2006 IBC, as applicable. The special inspector must make periodic inspections during anchor installation to verify anchor type, anchor dimensions, concrete type, concrete compressive strength, hole dimensions, hole cleaning procedure, anchor spacing, edge distances, concrete thickness, anchor embedment, tightening torque and adherence to the manufacturer's printed installation instructions. The special inspector must be present as often as required in accordance with the "statement of special inspection." Under the IBC, additional requirements as set forth in Chapter 17 must be observed, where applicable.

5.0 CONDITIONS OF USE

The USP DUC Undercut Anchors described in this report comply with, or are suitable alternatives to what is specified in, those codes listed in Section 1.0 of this report, subject to the following conditions:

5.1 Anchor sizes, dimensions, and minimum embedment depths are as set forth in the tables of this report.

5.2 The anchors must be installed in accordance with the manufacturer's published installation instructions and this report. In cases of a conflict, this report governs.

5.3 Anchors must be limited to use in concrete with a specified strength, f'_c, from 2,500 to 8,500 psi (17.2 to 58.6 MPa).

5.4 The values of f'_c used for calculation purposes must not exceed 8,000 psi (55.1 MPa).

5.5 Strength design values must be established in accordance with Section 4.1 of this report.

5.6 Allowable stress design values must be established in accordance with Section 4.2 of this report.

5.7 Anchor spacing and edge distance, as well as minimum member thickness, must comply with Table 4 of this report.

5.8 Prior to installation, calculations and details demonstrating compliance with this report must be submitted to the code official for approval. The calculations and details must be prepared by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed.

5.9 Since an ICC-ES acceptance criteria for evaluating data to determine the performance of undercut anchors subjected to fatigue or shock loading is unavailable at this time, the use of these anchors under these conditions is beyond the scope of the report.

5.10 Anchors may be installed in regions of concrete where cracking has occurred or where analysis indicates cracking may occur ($f_t > f_r$), subject to the conditions of this report.

5.11 Anchors may be used to resist short-term loading due to wind or seismic forces, subject to the conditions of this report.

5.12 Where not otherwise prohibited in the code, anchors are permitted for installation in fire-resistance rated construction provided that at least one of the following conditions is fulfilled:

- Anchors are used to resist wind or seismic forces only.
- Anchors that support a fire-resistance-rated envelope or a fire-resistance-rated membrane are protected by approved fire-resistance-rated materials, or have been evaluated for resistance to fire exposure in accordance with recognized standards.
- Anchors are used to support nonstructural elements.

5.13 Use of zinc-coated carbon steel anchors must be limited to dry, interior locations.

5.14 Special inspection must be provided in accordance with Section 4.4.

5.15 Anchors are manufactured under an approved quality control program with inspections by ICC-ES.

5.16 Axial Stiffness values are shown in Table A.

6.0 EVIDENCE SUBMITTED

Data in accordance with the ICC-ES Acceptance Criteria for Mechanical Anchors in Concrete Elements (AC193), dated June 2012, (editorially revised April 2015), which incorporates requirements in ACI 355.2-07 / 355.2-04, for use in cracked and uncracked concrete; including optional suitability tests for seismic tension and shear; and quality control documentation.

7.0 IDENTIFICATION

The anchors are identified by a length letter code head marking stamped on the exposed end of the rod, and packaging labeled with the company name (USP Structural Connectors, *MiTek*® USA, Inc., or USP Structural Connectors, a *MiTek*® Company) and address, anchor name, anchor size, evaluation report number (ESR-1970).

TABLE A—AXIAL STIFFNESS VALUES, β, FOR USP DUC UNDERCUT ANCHORS IN NORMAL-WEIGHT CONCRETE[1]

Concrete State	Notation	Units	Nominal Anchor Size / Rod Diameter (inch)			
			$^3/_8$	$^1/_2$	$^5/_8$	$^3/_4$
Uncracked concrete	β_{min}	10^3 lbf/in. (kN/mm)	131 (23)			
	β_m	10^3 lbf/in. (kN/mm)	930 (163)			
	β_{max}	10^3 lbf/in. (kN/mm)	1,444 (253)			
Cracked concrete	β_{min}	10^3 lbf/in. (kN/mm)	91 (16)			
	β_m	10^3 lbf/in. (kN/mm)	394 (69)			
	β_{max}	10^3 lbf/in. (kN/mm)	1,724 (302)			

[1]Valid for anchors with high strength threaded rod (A193 Grade B7). For anchors with low strength threaded rod (A36) values must be multiplied by 0.7.

TABLE 1—USP DUC UNDERCUT ANCHOR DIMENSIONAL CHARACTERISTICS[1]

Anchor Designation	Anchor Type	Anchor Rod ASTM Designation	Rod Diameter, d_b (inch)	Anchor Length, l_b (inches)	Sleeve Length, l_s (inches)	Sleeve Diameter, d_s (inch)	Expansion Coupling Dia., d_c (inch)	Max. Fixture Thickness, t (inches)
DUC38-275L	Standard	A36	$^3/_8$	$5^1/_2$	$2^3/_4$	$^5/_8$	$^5/_8$	$1^3/_4$
DUC38-275LT	Through bolt (TB)	A36	$^3/_8$	$5^1/_2$	$4^1/_2$	$^5/_8$	$^5/_8$	$1^3/_4$
DUC38-400H	Standard	A193, Grade B7	$^3/_8$	$6^3/_4$	4	$^5/_8$	$^5/_8$	$1^3/_4$
DUC38-400HT	Through bolt (TB)	A193, Grade B7	$^3/_8$	$6^3/_4$	$5^3/_4$	$^5/_8$	$^5/_8$	$1^3/_4$
DUC12-400L	Standard	A36	$^1/_2$	7	4	$^3/_4$	$^3/_4$	$1^3/_4$
DUC12-400LT	Through bolt (TB)	A36	$^1/_2$	7	$5^3/_4$	$^3/_4$	$^3/_4$	$1^3/_4$
DUC12-500H	Standard	A193, Grade B7	$^1/_2$	8	5	$^3/_4$	$^3/_4$	$1^3/_4$
DUC12-500HT	Through bolt (TB)	A193, Grade B7	$^1/_2$	8	$6^3/_4$	$^3/_4$	$^3/_4$	$1^3/_4$
DUC12-675H	Standard	A193, Grade B7	$^1/_2$	$9^3/_4$	$6^3/_4$	$^3/_4$	$^3/_4$	$1^3/_4$
DUC12-675HT	Through bolt (TB)	A193, Grade B7	$^1/_2$	$9^3/_4$	$8^1/_2$	$^3/_4$	$^3/_4$	$1^3/_4$
DUC58-450L	Standard	A36	$^5/_8$	$7^3/_4$	$4^1/_2$	1	1	$1^3/_4$
DUC58-450LT	Through bolt (TB)	A36	$^5/_8$	$7^3/_4$	$6^1/_4$	1	1	$1^3/_4$
DUC58-750H	Standard	A193, Grade B7	$^5/_8$	$10^3/_4$	$7^1/_2$	1	1	$1^3/_4$
DUC58-750HT	Through bolt (TB)	A193, Grade B7	$^5/_8$	$10^3/_4$	$9^1/_4$	1	1	$1^3/_4$
DUC58-900H	Standard	A193, Grade B7	$^5/_8$	$12^1/_4$	9	1	1	$1^3/_4$
DUC58-900HT	Through bolt (TB)	A193, Grade B7	$^5/_8$	$12^1/_4$	$10^3/_4$	1	1	$1^3/_4$
DUC34-500L	Standard	A36	$^3/_4$	$8^3/_8$	5	$1^1/_8$	$1^1/_8$	$1^3/_4$
DUC34-500LT	Through bolt (TB)	A36	$^3/_4$	$8^3/_8$	$6^3/_4$	$1^1/_8$	$1^1/_8$	$1^3/_4$
DUC34-1000H	Standard	A193, Grade B7	$^3/_4$	$13^3/_8$	10	$1^1/_8$	$1^1/_8$	$1^3/_4$
DUC34-1000HT	Through bolt (TB)	A193, Grade B7	$^3/_4$	$13^3/_8$	$11^3/_4$	$1^1/_8$	$1^1/_8$	$1^3/_4$

For SI: 1 inch = 25.4 mm.

[1]Threaded anchor rod conforming to ASTM F1554, Grade 36 is equivalent to threaded anchor rod with ASTM A36 designation.

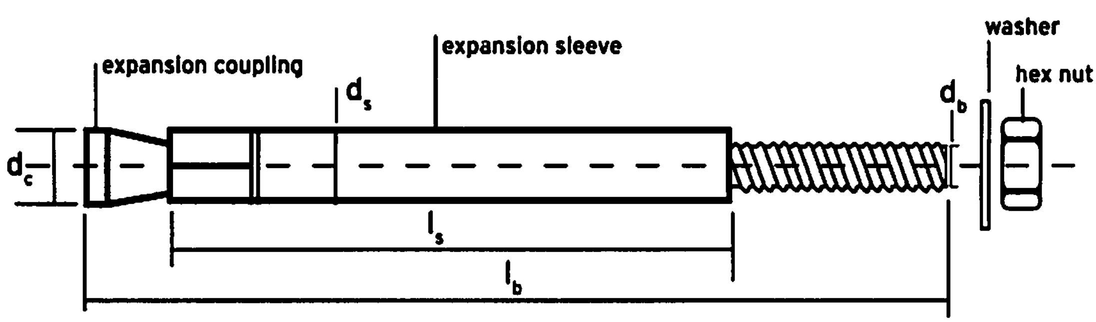
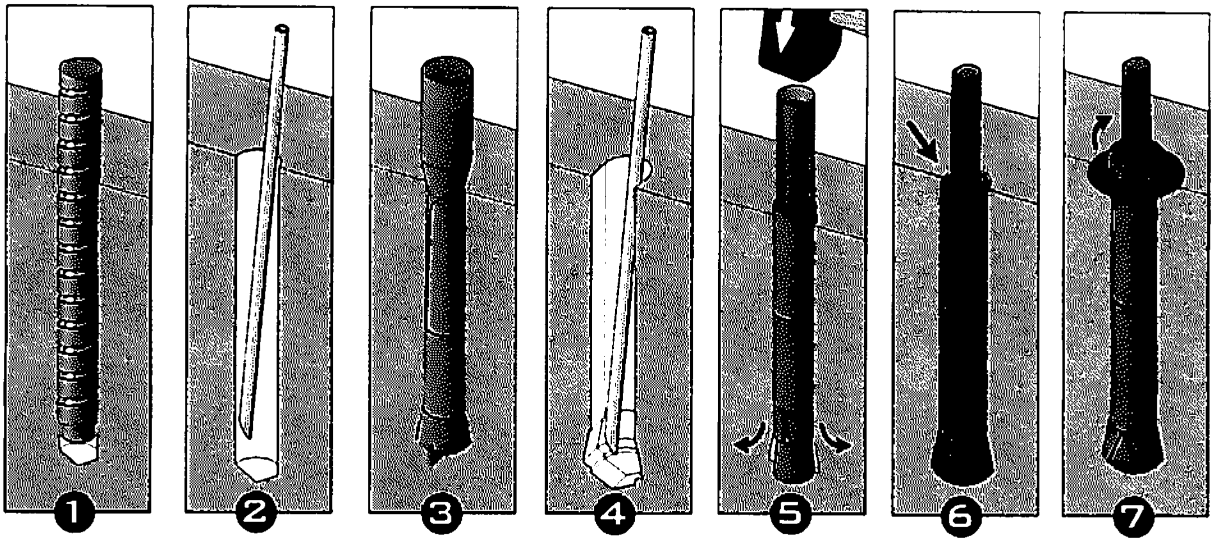


FIGURE 1—USP DUC UNDERCUT ANCHOR ASSEMBLY

TABLE 2—ANCHOR LENGTH CODE IDENTIFICATION SYSTEM

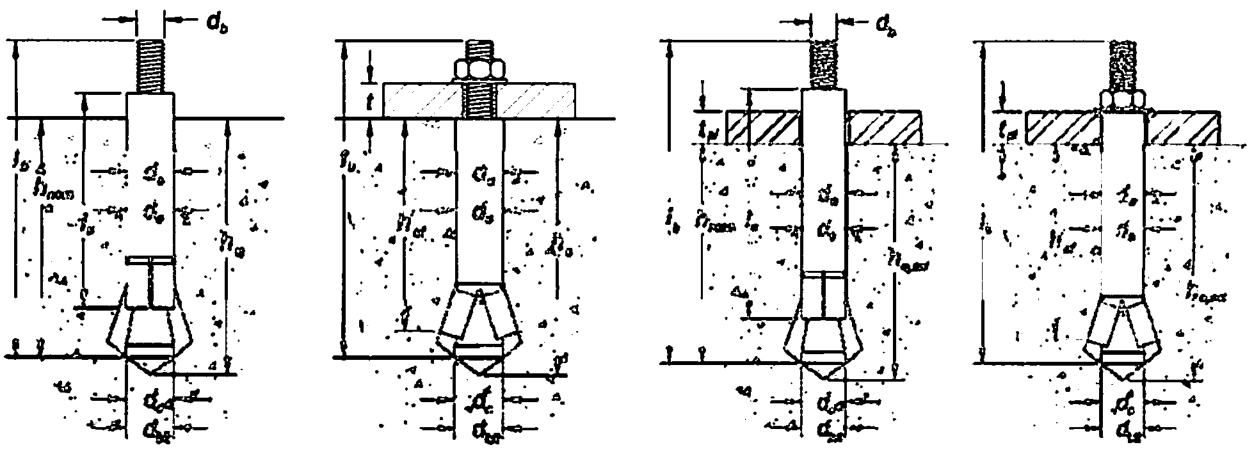
Length ID marking on anchor rod head		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
Anchor length, l_b, (inches)	From	$1^1/_2$	2	$2^1/_2$	3	$3^1/_2$	4	$4^1/_2$	5	$5^1/_2$	6	$6^1/_2$	7	$7^1/_2$	8	$8^1/_2$	9	$9^1/_2$	10	11	12	13
	Up to but not including	2	$2^1/_2$	3	$3^1/_2$	4	$4^1/_2$	5	$5^1/_2$	6	$6^1/_2$	7	$7^1/_2$	8	$8^1/_2$	9	$9^1/_2$	10	11	12	13	14

For SI: 1 inch = 25.4 mm.



1. Drill the hole to proper depth and diameter per specifications using rotohammer and stop drill.
2. Clean the hole using a blow-out bulb or compressed air.
3. Insert the undercut bit and start the rotohammer. Undercutting is complete when the stopper sleeve is fully compressed (gap closed).
4. Clean the hole again using a blow-out bulb or compressed air.
5. Insert anchor into hole. Place setting sleeve over anchor and drive the expansion sleeve over the expansion coupling.
6. Verify that the setting mark is visible on the threaded rod above the sleeve.
7. Apply proper torque.

FIGURE 2—INSTALLATION OF USP DUC UNDERCUT ANCHOR



Before After
Standard Type (Pre-set Version)

Before After
Through Bolt Type

FIGURE 3—USP DUC UNDERCUT ANCHOR DETAIL
Before and After Application of Setting Sleeve and Attachment

TABLE 3—USP DUC UNDERCUT ANCHOR INSTALLATION SPECIFICATIONS

Anchor Property / Setting Information	Notation	Units	Nominal Anchor Size / Rod Diameter (inch)									
			3/8		1/2			5/8			3/4	
Outside anchor diameter	d_a [d_o][3]	in. (mm)	0.625 (15.9)		0.750 (19.1)			1.000 (25.4)			1.125 (28.6)	
Nominal embedment depth	h_{nom}	in. (mm)	3 1/8 (79)	4 3/8 (111)	4 1/4 (108)	5 1/4 (133)	7 (178)	5 (127)	8 (203)	9 1/2 (241)	5 7/8 (149)	10 7/8 (276)
Effective embedment depth	h_{ef}	in. (mm)	2 3/4 (70)	4 (102)	4 (102)	5 (127)	6 3/4 (171)	4 1/2 (114)	7 1/2 (190)	9 (229)	5 (127)	10 (254)
Minimum hole depth[1]	h_o	in. (mm)	3 1/8 (79)	4 3/8 (111)	4 1/4 (108)	5 1/4 (133)	7 (178)	5 (127)	8 (203)	9 1/2 (241)	5 7/8 (149)	10 7/8 (276)
Minimum diameter of hole clearance in fixture[2]	d_h	in. (mm)	7/16 (11.1)		9/16 (14.3)			11/16 (17.5)			13/16 (20.6)	
Maximum thickness of fixture	t	in. (mm)	1 3/4 (44)		1 3/4 (44)			1 3/4 (44)			1 3/4 (44)	
Maximum torque	T_{max}	ft.-lbf.	26		44			60			133	
Torque wrench / socket size	-	in.	9/16		3/4			15/16			1 1/8	
Nut height	-	in.	21/64		7/16			35/64			41/64	
Stop Drill Bit												
Nominal stop drill bit diameter	d_{bd}	in.	5/8 ANSI		3/4 ANSI			1 ANSI			1 1/8 ANSI	
Stop drill bit for anchor installation	-	-	DUCSB 38-275	DUCSB 38-400	DUCSB 12-400	DUCSB 12-500	DUCSB 12-675	DUCSB 58-450	DUCSB 58-750	DUCSB 58-900	DUCSB 34-500	DUCSB 34-1000
Drilled hole depth of stop bit[1]	-	in. (mm)	3 1/8 (79)	4 3/8 (111)	4 1/4 (108)	5 1/4 (133)	7 (178)	5 (127)	8 (203)	9 1/2 (241)	5 7/8 (149)	10 7/8 (276)
Stop drill bit shank type	-	-	SDS		SDS			SDS-Max			SDS-Max	
Undercut Drill Bit												
Nominal undercut drill bit diameter	d_{uc}	in.	5/8		3/4			1			1 1/8	
Undercut drill bit designation	-	-	UCB58		UCB34			UCB100			UCB118	
Maximum depth of hole for undercut drill bit	-	in. (mm)	9 (229)		10 1/4 (260)			12 1/4 (311)			13 1/2 (343)	
Undercut drill bit shank type	-	-	SDS		SDS			SDS-Max			SDS-Max	
Required impact drill energy	-	ft.-lbf.	1.6		2.5			3.2			4	
Setting Sleeve												
Recommended setting sleeve	-	-	SSL38		SSL12			SSL58			SSL34	

For SI: 1 inch = 25.4 mm, 1 ft-lbf = 1.356 N-m.

[1]For through bolt applications the actual hole depth is given by the minimum hole depth plus the maximum thickness of fixture less the thickness of the actual part(s) being fastened to the base material ($h_{o,act} = h_o + t - t_{pl}$). See Figure 3.
[2]For through bolt applications the minimum diameter of hole clearance in fixture is 1/16-inch larger than the nominal outside anchor diameter.
[3]The notation in brackets is for the 2006 IBC.

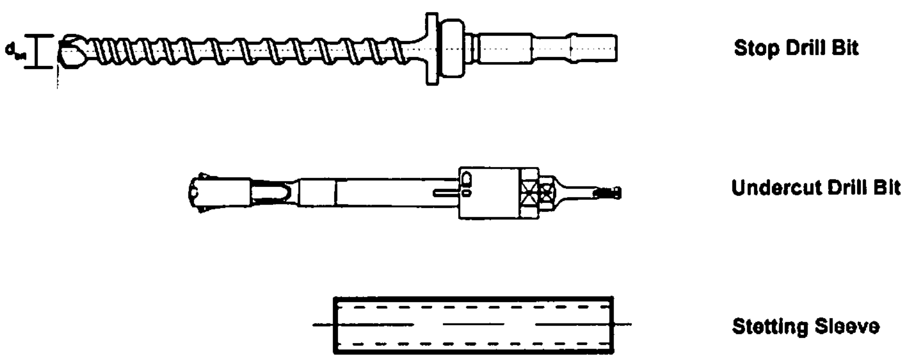


FIGURE 4—STOP DRILL BIT, UNDERCUT DRILL BIT AND SETTING SLEEVE

TABLE 4—USP DUC UNDERCUT ANCHOR DESIGN INFORMATION
(For use with load combinations taken from ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2)[1]

Anchor Property / Setting Information	Notation	Units	Nominal Anchor Size / Rod Diameter (inch)									
			3/8		1/2			5/8			3/4	
Anchor category	1, 2, or 3	-	1		1			1			1	
Outside diameter of anchor	d_a [d_o][8]	in. (mm)	0.625 (15.9)		0.750 (19.1)			1.000 (25.4)			1.125 (28.6)	
Effective embedment depth	h_{ef}	in. (mm)	2-3/4 (70)	4 (102)	4 (102)	5 (127)	6-3/4 (171)	4-1/2 (114)	7-1/2 (190)	9 (229)	5 (127)	10 (254)
Minimum concrete member thickness	h_{min}	in. (mm)	5-1/2 (140)	8 (203)	8 (203)	10 (254)	13-1/2 (343)	9 (229)	15 (381)	18 (457)	10 (254)	20 (508)
	for c_{ac} ≥	in. (mm)	4-1/8 (105)	6 (152)	6 (152)	7-1/2 (190)	10-1/8 (257)	6-3/4 (171)	11-1/4 (286)	13-1/2 (343)	7-1/2 (190)	15 (381)
	h_{min}	in. (mm)	4-1/8 (105)	6 (152)	6 (152)	7-1/2 (190)	10-1/8 (257)	6-3/4 (171)	11-1/4 (286)	13-1/2 (343)	7-1/2 (190)	15 (381)
	for c_{ac} ≥	in. (mm)	5-1/2 (140)	10-1/4 (260)	9-1/4 (235)	13 (330)	20-1/4 (514)	9-1/2 (241)	21 (533)	27 (686)	10-1/2 (267)	30 (762)
Minimum edge distance	c_{min}	in. (mm)	2-1/4 (57)	3-1/4 (82)	3-1/4 (82)	4 (102)	5-3/8 (137)	3-5/8 (92)	6 (152)	7-1/4 (184)	4 (102)	8 (203)
Minimum spacing distance	s_{min}	in. (mm)	2-3/4 (70)	4 (102)	4 (102)	5 (127)	6-3/4 (171)	4-1/2 (114)	7-1/2 (190)	9 (229)	5 (127)	10 (254)
STEEL STRENGTH IN TENSION AND SHEAR[3]												
Minimum specified yield strength of anchor rod	f_y	ksi (N/mm²)	36 (248)	105 (723)	36 (248)	105 (723)	105 (723)	36 (248)	105 (723)	105 (723)	36 (248)	105 (723)
Minimum specified ultimate tensile strength of anchor rod	f_{uta}	ksi (N/mm²)	58 (400)	125 (860)	58 (400)	125 (860)	125 (860)	58 (400)	125 (860)	125 (860)	58 (400)	125 (860)
Tensile stress area of anchor rod steel	$A_{se,N}$ [A_{se}][8]	in.² (mm²)	0.0775 (50)		0.1419 (91)			0.2260 (146)			0.3345 (245)	
Steel strength in tension, static	N_{sa}	lb. (kN)	4,495 (20.1)	9,685 (43.2)	8,230 (36.7)	17,735 (79.1)	17,735 (79.1)	13,100 (58.5)	28,250 (126.1)	28,250 (126.1)	19,400 (86.3)	41,810 (186.0)
Steel strength in shear, static[9]	V_{sa}	lb. (kN)	2,245 (10.0)	4,855 (21.7)	4,110 (18.4)	8,855 (39.5)	8,855 (39.5)	6,560 (29.3)	14,110 (63.0)	14,110 (63.0)	9,685 (43.2)	20,875 (93.2)
Steel strength in shear, seismic[9]	$V_{sa,eq}$	lb. (kN)	2,245 (10)	4,855 (21.7)	4,110 (18.4)	8,855 (39.5)	8,855 (39.5)	6,560 (29.3)	14,110 (63)	14,110 (63)	9,685 (43.2)	20,875 (93.1)
Reduction factor for steel strength in tension[2]	ϕ	-	0.75									
Reduction factor for steel strength in shear[2]	ϕ	-	0.65									
CONCRETE BREAKOUT STRENGTH IN TENSION[7]												
Effectiveness factor uncracked concrete	k_{uncr}	-	30		30			30			30	
Effectiveness factor cracked concrete	k_{cr}	-	24		24			24			24	
Modification factor for cracked and uncracked concrete[4]	$\Psi_{c,N}$	-	1.0 (see note 4)		1.0 (see note 4)			1.0 (see note 4)			1.0 (see note 4)	
Reduction factor for concrete breakout strength in tension[2]	ϕ	-	0.65 (Condition B)									
Reduction factor for concrete breakout strength in shear[2]	ϕ	-	0.70 (Condition B)									
PULLOUT STRENGTH IN TENSION[7]												
Characteristic pullout strength, uncracked concrete (2,500 psi)	$N_{p,uncr}$	lb. (kN)	See note 6		See note 6			See note 6			See note 6	
Characteristic pullout strength, cracked concrete (2,500 psi)[5]	$N_{p,cr}$	lb. (kN)	See note 6	9,000 (40.2)	See note 6	11,500 (51.3)		See note 6	15,000 (67.0)		See note 6	22,000 (98.2)
Characteristic pullout strength, seismic (2,500 psi)[5]	$N_{p,eq}$	lb. (kN)	See note 6	9,000 (40.2)	See note 6	11,500 (51.3)		See note 6	15,000 (67.0)		See note 6	22,000 (98.2)
Reduction factor for pullout strength in tension[2]	ϕ	-	0.65 (Condition B)									
PRYOUT STRENGTH IN SHEAR[7]												
Coefficient for pryout strength	k_{cp}	-	2.0		2.0			2.0			2.0	
Reduction factor for pryout strength in shear[2]	ϕ	-	0.70 (Condition B)									

For SI: 1 inch = 25.4 mm, 1 ksi = 6.895 MPa (N/mm²), 1 lbf = 0.0044 kN, 1 in² = 645 mm².

[1]The data in this table is intended to be used with the design provisions of ACI 318-14 Chapter 17 or ACI 318-11 Appendix D, as applicable; for anchors resisting seismic load combinations the additional requirements of ACI 318-14 17.2.3 or ACI 318-11 D.3.3, as applicable, shall apply.
[2]All values of ϕ were determined from the load combinations of IBC Section 1605.2, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2, as applicable. If the load combinations of ACI 318-11 Appendix C are used, then the appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.4. For reinforcement that meets ACI 318-14 Chapter 17 or ACI 318-11 Appendix D requirements for Condition A, see ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for the appropriate ϕ factor when the load combinations of IBC Section 1605.2, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used, as applicable.
[3]Anchors are considered a ductile steel element as defined by ACI 318-14 2.3 or ACI 318-11 D.1, as applicable.
[4]For all design cases $\Psi_{c,N}$=1.0. The appropriate effectiveness factor for cracked concrete (k_{cr}) or uncracked concrete (k_{uncr}) must be used.
[5]For all design cases $\Psi_{c,P}$=1.0. For the calculation of N_{pn}, see Section 4.1.4 of this report.
[6]Pullout strength does not control design of indicated anchors. Do not calculate pullout strength for indicated anchor size and embedment.
[7]Anchors are permitted to be used in sand-lightweight concrete in accordance with Section 4.1.12 of this report.
[8]The notation in brackets is for the 2006 IBC.
[9]Shear strength values are based on standard (pre-set) installation, and must be used for both standard (pre-set) and through-bolt installations.

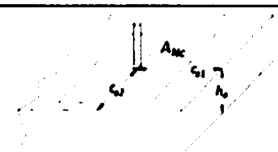
TABLE 5—EXAMPLE ALLOWABLE STRESS DESIGN VALUES FOR ILLUSTRATIVE PURPOSES[1,2,3,4,5,6,7,8,9]

Nominal Anchor Size (inch)	Nominal Embedment Depth (inches)	Effective Embedment (inches)	Anchor Rod Designation (ASTM)	Allowable Tension Load (pounds)
$^3/_8$	$3^1/_8$	$2^3/_4$	A36	2,280
	$4^3/_8$	4	A193, Grade B7	4,910
$^1/_2$	$4^1/_4$	4	A36	4,170
	$5^1/_4$	5	A193, Grade B7	7,365
	7	$6^3/_4$	A193, Grade B7	8,990
$^5/_8$	5	$4^1/_2$	A36	6,290
	8	$7^1/_2$	A193, Grade B7	13,530
	$9^1/_2$	9	A193, Grade B7	14,315
$^3/_4$	$5^7/_8$	5	A36	7,365
	$10^7/_8$	10	A193, Grade B7	20,830

For **SI:** 1 inch = 25.4 mm, 1 lbf = 0.0044 kN.

[1] Single anchor with static tension load only.
[2] Concrete determined to remain uncracked for the life of the anchorage.
[3] Load combinations from ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2, as applicable (no seismic loading considered).
[4] 30% dead load and 70% live load, controlling load combination 1.2*D* + 1.6*L*.
[5] Calculation of weighted average for α = 1.2(0.3) + 1.6(0.7) = 1.48.
[6] f'_c = 2,500 psi (normal weight concrete).
[7] $c_{a1} = c_{a2} \geq c_{ac}$.
[8] $h \geq h_{min}$.
[9] Values are for Condition B where supplementary reinforcement in accordance with ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, is not provided.

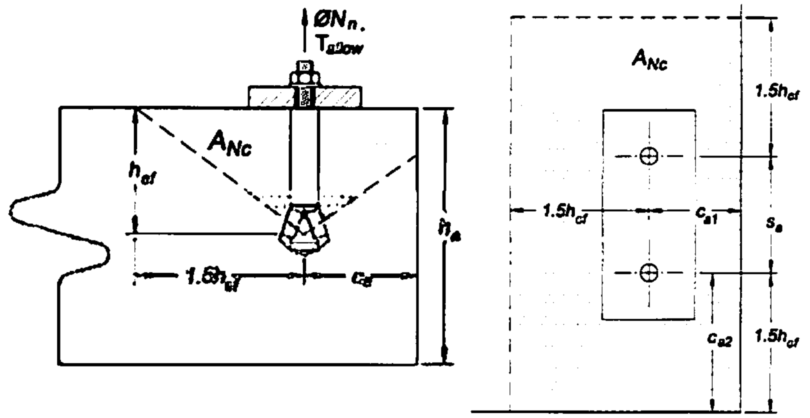
Given: Calculate the factored resistance strength, ϕN_n, and the allowable stress design value, $T_{allowable,ASD}$, for a $^3/_8$-inch undercut anchor with ASTM A193, Grade B7 anchor rod designation assuming the given conditions in Table 5.



Calculation in accordance with ACI 318-14 Chapter 17, ACI 318-11 Appendix D and this report:	**ACI 318-14 Ref.**	**ACI 318-11 Ref.**	**Report Ref.**
Step 1. Calculate steel strength of a single anchor in tension: $\phi N_{sa} = (0.75)(9{,}685) = 7{,}264\ lbs.$	17.4.1.2	D.5.1.2	Table 4
Step 2. Calculate concrete breakout strength of a single anchor in tension: $\phi N_{cb} = \phi \frac{A_{Nc}}{A_{Nc0}} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b$ $N_b = k_c \lambda_a \sqrt{f'_c}(h_{ef})^{1.5}$ $N_b = (30)(1.0)\sqrt{2{,}500}(4.0)^{1.5} = 12{,}000\ lbs.$ $\phi N_{cb} = (0.65)\frac{(144.0)}{(144.0)}(1.0)(1.0)(1.0)(12{,}000) = 7{,}800\ lbs.$	17.4.2.1	D.5.2.1	Table 4
Step 3. Calculate pullout strength of a single anchor: $\phi N_{pn} = \phi N_{p,uncr} \psi_{c,P} \left(\frac{f'_{c,act}}{2{,}500}\right)^{0.5}$ ϕN_{pn} = N/A, pullout strength does not control	17.4.2.2	D.5.2.2	Table 4
Step 4. Determine controlling factored resistance strength in tension: $\phi N_n = \min\lvert \phi N_{sa}, \phi N_{cb}, \phi N_{pn} \rvert = \phi N_{sa} = 7{,}264\ lbs.$	17.3.1.1	D.4.1.1	-
Step 5. Calculate allowable stress design conversion factor for loading condition: Controlling load combination: 1.2*D* + 1.6*L* α = 1.2(30%) + 1.6(70%) = 1.48	5.3	9.2	-
Step 6. Calculate the converted allowable stress design value: $T_{allowable,ASD} = \frac{\phi N_n}{\alpha} = \frac{7{,}264}{1.48} = 4{,}908\ lbs.$	-	-	Section 4.2

FIGURE 5—USP DUC UNDERCUT ANCHOR EXAMPLE STRENGTH DESIGN CALCULATION INCLUDING ASD CONVERSION FOR ILLUSTRATIVE PURPOSES

Given:
Two 3/8" undercut anchors
A 193, Grade B7 designation
Concrete compressive strength:
(f'_c) = 4,000 psi
No supplemental reinforcement:
(Condition B per ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c))
Assume uncracked concrete, no seismic, no loading eccentricity and a rigid plate



h_a = 8.0 in.
h_{ef} = 4.0 in.
s_a = 5.0 in.
$c_{a1} = c_{a,min}$ = 4.0 in.
$c_{a2} \geq 1.5c_{a1}$

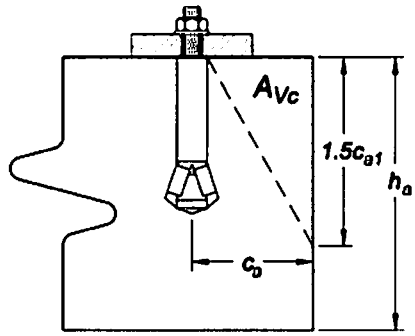
Calculate the factored resistance design strength in tension and equivalent allowable stress design load for the configuration.

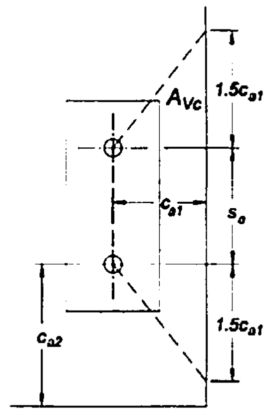
Calculation in accordance with ACI 318-14, ACI 318-11 and this report:	**ACI 318-14 Ref.**	**ACI 318-11 Ref.**	**Report Ref.**
Step 1. Verify minimum member thickness, spacing and edge distance: h_a = 8.0 in. ≥ h_{min} = 8.0 in. ∴ OK s_a = 5.0 in. ≥ s_{min} = 4.0 in. ∴ OK $c_{a,min}$ = 4.0 in. ≥ c_{min} = 3.25 in. ∴ OK	17.7	D.8	Table 4
Step 2. Calculate steel strength of anchor group in tension: $N_{sag} = nN_{sa}$ = (2)(9,685) = 19,370 lbs. Calculate steel capacity: ϕN_{sag} = 0.75 • 19,370 lbs. = **14,525 lbs.**	17.4.1.2	D.5.1.2	Table 4
Step 3. Calculate concrete breakout strength of anchor group in tension: $N_{cbg} = \frac{A_{Nc}}{A_{Nc0}}\psi_{ec,N}\psi_{ed,N}\psi_{c,N}\psi_{cp,N}N_b$	17.4.2.1(b)	D.5.2.1(b)	-
Step 3a. Calculate A_{Nco} and A_{Nc} $A_{Nco} = 9h_{ef}^2 = 9 \cdot (4.0)^2 =$ **144 in.²** $A_{Nc} = (c_{a1} + 1.5h_{ef}) \cdot (3.0\,h_{ef} + s_a) = (4.0 \cdot 6.0)\cdot(3.0 \cdot 4.0 + 5.0) =$ **170 in.²**	17.4.2.1(b)	D.5.2.1(b)	Table 4
Step 3b. Calculate $\psi_{ec,N} = \frac{1}{(1+\frac{2e'_N}{3h_{ef}})} \leq 1.0$; $e'_N = 0 \therefore \psi_{ec,N} = \mathbf{1.0}$	17.4.2.4	D.5.2.4	-
Step 3c. Calculate $\psi_{ed,N} = 1.0$ if $c_{a,min} \geq 1.5h_{ef}$; $\psi_{ed,N} = 0.7 + 0.3\frac{c_{a,min}}{1.5h_{ef}}$ if $c_{a,min} < 1.5h_{ef}$ $c_{a,min}$ =4.0 in. ≥ $1.5h_{ef}$ = 6.0 in. ∴ $\psi_{ed,N} = 0.7 + 0.3\frac{4.0}{6.0} =$ **0.90**	17.4.2.5	D.5.2.5	Table 4
Step 3d. Calculate $\psi_{c,N}$ = **1.0** (uncracked concrete)	17.4.2.6	D.5.2.6	Table 4
Step 3e. Calculate $\psi_{cp,N} = 1.0$ if $c_{a,min} \geq c_{ac}$; $\psi_{cp,N} = \frac{c_{a,min}}{c_{ac}} \geq \frac{1.5h_{ef}}{c_{ac}}$ if $c_{a,min} < c_{ac}$ $c_{a,min}$ = 4.0 in. < c_{ac} = 6.0 in. ∴ $\psi_{cp,N} = \frac{c_{a,min}}{c_{ac}} \geq \frac{1.5h_{ef}}{c_{ac}} = \frac{4.0}{6.0} \geq \frac{6.0}{6.0} =$ **1.0**	17.4.2.7	D.5.2.7	Table 4
Step 3f. Calculate $N_b = k_{cr}\lambda_a\sqrt{f'_c}\,h_{ef}^{1.5} = 30(1.0)\sqrt{4{,}000} \cdot 4.0^{1.5} =$ **15,180 lbs.**	17.4.2.2	D.5.2.2	Table 4
Step 3g. Calculate concrete breakout strength of anchor group in tension: N_{cbg} = (170/144) • 1.0 • 0.90 • 1.0 • 1.0 • 15,180 = 16,125 lbs. Calculate concrete breakout capacity = ϕN_{cbg} = 0.65 • 16,125 = **10,480 lbs.**	17.4.2.1(b)	D.5.2.1(b)	-
Step 4. Calculate nominal pullout strength of a single anchor in tension: $N_{pn} = \psi_{c,P} \cdot N_{pn,f'c}$ – Pullout does not control; therefore it needs not be considered.	17.4.3.1	D.5.3.1	-
Step 5. Determine controlling resistance strength of the anchor group in tension: $\phi N_n = \min\lvert \phi N_{sag}, \phi N_{cbg}, n\phi N_{pn}\rvert = \phi N_{cbg} =$ **10,480 lbs.**	17.3.1.1	D.4.1.1	-
Step 6. Calculate allowable stress design conversion factor for loading condition: Assume controlling load combination: 1.2*D* + 1.6*L* ; 50% Dead Load, 50% Live Load α = 1.2(50%) + 1.6(50%) = **1.40**	5.3	9.2	-
Step 7. Calculate allowable stress design value: $T_{allowable,ASD} = \frac{\phi N_n}{\alpha} = \frac{10{,}480}{1.40} =$ **7,485 lbs.**	5.3	9.2	-

FIGURE 6—EXAMPLE CALCULATION FOR USP DUC UNDERCUT ANCHORS

Given:
Two 3/8" undercut anchors
A 193, Grade B7 designation
Concrete compressive strength:
(f'_c) = 3,000 psi
No supplemental reinforcement:
(Condition B per ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c))
Assume uncracked concrete, no seismic, no loading eccentricity and a rigid plate

h_a = 8.0 in.
h_{ef} = 4.0 in.
s_a = 5.0 in.
$c_{a1} = c_{a,min}$ = 4.0 in.
$c_{a2} \geq 1.5c_{a1}$





Calculate the factored resistance design strength in shear and equivalent allowable stress design load for the configuration.

Calculation in accordance with ACI 318-14, ACI 318-11 and this report:	**ACI 318-14 Ref.**	**ACI 318-11 Ref.**	**Report Ref.**
Step 1. Verify minimum member thickness, spacing and edge distance: h_a = 8.0 in. ≥ h_{min} = 8.0 in. ∴ OK s_a = 5.0 in. ≥ s_{min} = 4.0 in. ∴ OK $c_{a,min}$ = 4.0 in. ≥ c_{min} = 3.25 in. ∴ OK	17.7	D.8	Table 4
Step 2. Calculate steel strength of anchor group in shear: $V_{sag} = n \cdot V_{sa} = 2 \cdot 4{,}855$ lbs. = 9,710 lbs. Calculate steel capacity: ϕV_{sag} = 0.65 • 9,710 lbs. = **6,310 lbs.**	17.5.1.2	D.6.1.2	Table 4
Step 3. Calculate concrete breakout strength of anchor group in shear: $V_{cbg} = \frac{A_{Vc}}{A_{Vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b$	17.5.2.1(b)	D.6.2.1(b)	-
Step 3a. Calculate A_{Vco} and A_{Vc} $A_{Vco} = 4.5\,(c_{a1})^2 = 4.5 \cdot (4.0)^2$ = **72 in.²** $A_{Vc} = (1.5\,c_{a1}) \cdot (1.5\,c_{a1} + s_a + 1.5\,c_{a1})$ = (6.0)(6.0 + 6.0 + 6.0) = **108 in.²**	17.5.2.1	D.6.2.1	Table 4
Step 3b. Calculate $\psi_{ec,V} = \frac{1}{(1+\frac{2e'_N}{3c_{a1}})} \leq 1.0$; $e'_V = 0$ ∴ $\psi_{ec,V}$ = **1.0**	17.5.2.5	D.6.2.5	-
Step 3c. Calculate $\psi_{ed,V}$ = 1.0 if $c_{a2} \geq 1.5c_{a1}$; $\psi_{ed,V} = 0.7 + 0.3\frac{c_{a2}}{1.5c_{a1}}$ if $c_{a2} < 1.5c_{a1}$ $c_{a2} \geq 1.5\,c_{a1}$ ∴ $\psi_{ed,V}$ = **1.0**	17.5.2.6	D.6.2.6	-
Step 3d. Calculate $\psi_{c,V}$ = **1.4** (uncracked concrete)	17.5.2.7	D.6.2.7	-
Step 3e. Calculate $\psi_{h,V} = \sqrt{\frac{1.5c_{a1}}{h_a}}$; for members where $h_a < 1.5c_{a1}$ $h_a = 8.0 \geq 1.5c_{a1} = 6.0$ ∴ $\psi_{h,V}$ = **1.0**	17.5.2.8	D.6.2.8	-
Step 3f. Calculate $V_b = 7\left(\frac{l_e}{d_a}\right)^{0.2} \lambda_\alpha \sqrt{d_a}\sqrt{f'_c}(c_{a1})^{1.5}$ $7\left(\frac{3.0}{0.625}\right)^{0.2}(1.0)\sqrt{0.625}\sqrt{4000}(4.0)^{1.5}$ = **3,830 lbs.**	17.5.2.2	D.6.2.2	Table 4
Step 3g. Calculate concrete breakout strength of anchor group in shear: V_{cbg} = (108/72) • 1.0 • 1.0 • 1.4 • 1.0 • 3,830 = 8,045 lbs. Calculate concrete breakout capacity = ϕV_{cbg} = 0.70 • 8,045 = **5,630 lbs.**	17.5.2.1(b)	D.6.2.1(b)	-
Step 4. Calculate nominal pryout strength of an anchor group in shear: $V_{cpg} = k_{cp} N_{cbg}$ = 2.0 • 17,455 lbs = 34,915 lbs. Calculate pryout capacity: $\phi\, V_{cpg}$ = 0.70 • 34,915 lbs. = **24,440 lbs.**	17.5.3.1(b)	D.6.3.1(b)	Table 4
Step 5. Determine controlling resistance strength in shear: $\phi V_n = \min\lvert \phi V_{sag}, \phi V_{cbg}, \phi V_{cpg} \rvert = \phi V_{cbg}$ = **5,630 lbs.**	17.3.1.1	D.4.1.1	-
Step 6. Calculate allowable stress design conversion factor for loading condition: Controlling load combination: 1.2D + 1.6L ; 50% Dead Load, 50% Live Load α = 1.2(30%) + 1.6(70%) = **1.40**	5.3	9.2	-
Step 7. Calculate allowable stress design value: $V_{allowable,ASD} = \frac{\phi V_n}{\alpha} = \frac{5{,}630}{1.40}$ = **4,020 lbs.**	5.3	9.2	-

FIGURE 7—EXAMPLE CALCULATION FOR USP DUC UNDERCUT ANCHORS