CIA-Gel 7000
Epoxy Anchoring System

Section 2.1: Product Details -CIA-Gel 7000

2.1.1 Description

Covert Injection Adhesive (CIA-Gel 7000) is a structural epoxy designed for anchoring into concrete as well as solid and hollow masonry construction. It is a low odor, solvent free, non-shrink, non-sag anchoring compound which may be used for a wide range of applications. The epoxy is packaged in equal volume side-by-side plastic cartridges. The cartridges are sealed individually with a D-plug which open easily on the jobsite and also allow partially used cartridges to be saved for later use. The epoxy components are completely mixed when dispensed through a spiral motionless mixer attached to the cartridges. The epoxy may be dispensed with either a hand-powered or air-powered injection tool.

2.1.2 Product Features

Excellent Chemical Resistance	Moisture Insensitive
Tested to ASTM E 1512 for Sesimic/Wind Loading	100% solids
Long Working Time, Fast Cure Times	Meets ASTM C-881
Cures and Bonds Underwater	No Odor, Solvent Free, Non shrink

2.1.3 Listings/Approvals (see section 8.0 for complete information)

ICC-ES ESR-1702
FL4928
City of Los Angeles: RR 25113, RR 25029
Caltrans & many other State DOT's
Meets AASHTO M-235
Meets ASTM C 881 Type 1, 2, 4, & 5 - Grade 3 - Class B, C, D, E, & F

2.1.4 Product Specifications

Parameter	Part A	Part B	Mixed
Color:	Black	White	Gray
Product:	Epoxy Resin	Amine Adduct	
Viscosity (Brookfield):	16,000 cps	23,500 cps	Non-sag Epoxy
Shelf Life:	2 year minimum	2 year minimum	
	not sensitive to UV light or heat		

Mixed Epoxy:

Heat Deflection Temperature (ASTM D 648-82) .... 144?F/62?C
Compressive Strength (ASTM D 695) .... 18,530 psi.
Tensile Strength (ASTM D 638) .... 5,500 psi.
Elongation (ASTM D 229) 0.57%
Slant Shear (ASTM C-881) .... 6000 psi.
Hardness (Shore D) 85

2.1.5 Setting Times:

Temperature (°F)	Temperature (°C)	Bolt-up Time (hrs.)	Cure Time (hrs.)
40 - 50	4 -10	12	72
51 - 60	10 -16	8	48
61 - 70	16 - 21	6	36
71 - 80	21 - 27	4	24
>80	>27	4	24

Adhesives cure slower in colder substrate temperatures. The table on the right lists the recommended bolt-up and ultimate curing times. The CIA-Gel 7000 epoxy is not recommended for installation in substrates colder than 40°F/4.4°C or hotter than 125°F/52°C. "Bolt-up time" is the minimum time required for the anchors to remain undisturbed and before the anchors may be bolted-up or torqued. Anchors installed at standard embedments (9 anchor diameters) will achieve approximately 35% of their ultimate holding capacity at the "Bolt-up times". "Cure Time" is the time required for the epoxy to achieve full strength.

2.1.6 Elevated Temperature Sensitivity

The physical properties of adhesives gradually decrease with increasing temperature. This occurs because the modulus of an adhesive is not a constant and is subject to change in changing temperature environments. The heat deflection temperature (HDT) indicates the temperature range in which this modulus change is rather large. Below the heat deflection temperature, adhesive products exhibit a typically rigid behavior; above the heat deflection temperature, adhesive products exhibit typically flexible behavior. A rigid adhesive with a high heat deflection temperature can withstand sustained loads for long periods of time if the structure temperature is sufficiently distant from its HDT temperature. In most practical cases it is unlikely that the temperature of a structure exceeds the range from 100°F/37.7°C to 125°F/52°C.

In addition to determining the HDT, temperature sensitivity tests are also performed on adhesive anchors. For these tests, epoxy anchors are installed in concrete cubes and allowed to cure. The cubes are then heated to various temperatures ranging from 68°F/20°C to 176°F/80°C. When the unit has reached the desired temperature, the anchor is tested to ultimate capacity. Figure 2 tabulates the results of the temperature sensitivity tests performed on the CIA-Gel 7000 epoxy (Ref. 9). The load reduction factors noted in Fig. 2 must be applied to the tension values in Table Nos. IV and VI (see Section 2) when the anchors are installed locations where the concrete temperature may exceed 105 °F.

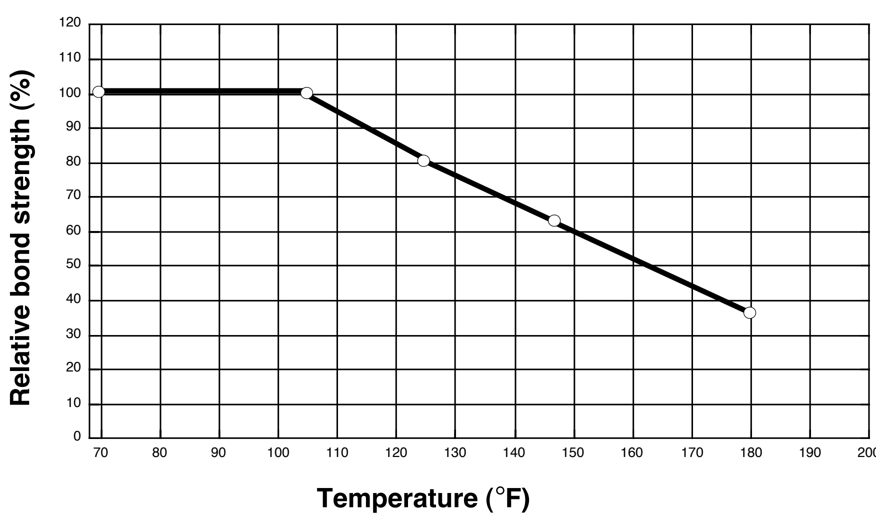


Figure 2: Relative bond strength as a function of temperature

2.1.7 Long-Term Creep Resistance

Epoxies and polyester resins, under sustained (long-term) load, creep because of their visco-elastic properties. The rate of creep is dependent on the magnitude of the load and the prevailing ambient temperature. Long-term behavior of the bond between the concrete and various chemical anchors has been studied and the results indicate that anchor displacement should be expected for long-term loads.

Three CIA-Gel test anchors were installed in nominal 2 ksi concrete test cubes for long-term tests. An independent testing laboratory tested the specimens (Ref. 6) per the requirements of ASTM E 1512, *Methods of Testing Bond Performance of Adhesive-Bonded Anchors*, for long-term loading of chemical (adhesive) anchors.

CIA-Gel 7000 anchors obtained a displacement maximum of 0.006" when subjected to a sustained load of approximately 5700 pounds (approx. $0.4N_u$, where N_u = ultimate capacity) for the full test duration. The resulting load-displacement curve of the long-term tests (see Fig. 3) flattens out with increasing time. This shows that the initial rate of displacement of a CIA-Gel 7000 epoxy anchor under sustained load is greater than the final rate of displacement. The sustained load tests were performed at room temperatures (65-75°F). It is generally accepted that an adhesive anchor which maintains a 120-day load of $0.4N_u$ will be able to sustain adesign load of $0.25N_u$ indefinitely.

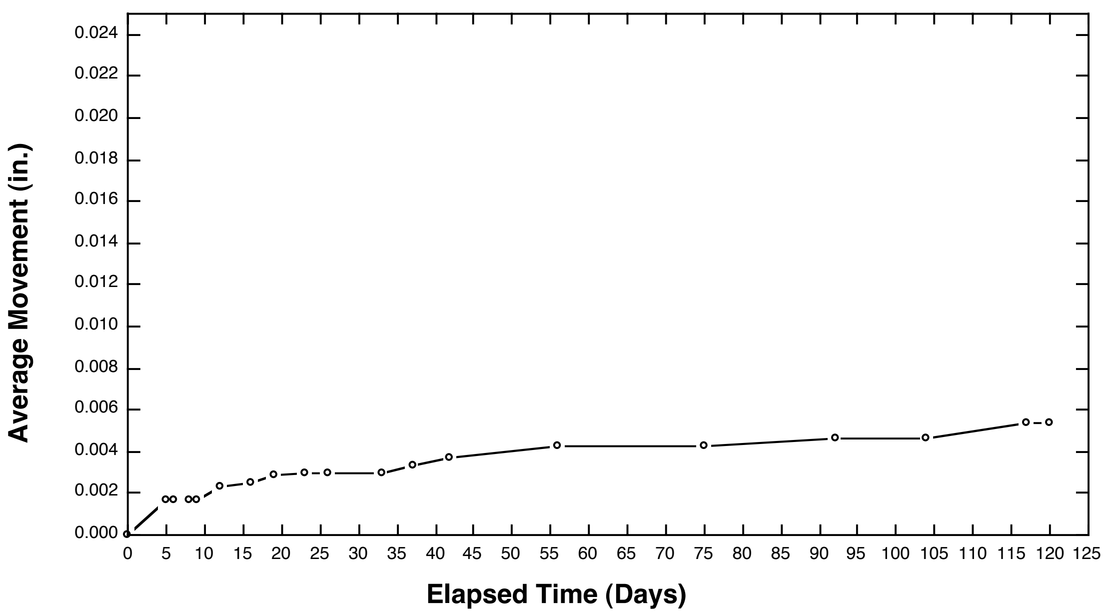


Fig. 3: Long-term tension loading on CIA-Gel 7000 Epoxy anchors.

2.1.8 Elevated Temperature Creep Resistance

Recent research has shown that short-term temperature sensitivity tests and long-term creep tests at room temperature do not provide enough data to indicate an adhesives ability to sustain design loads at higher temperatures (up to 110 °F). Therefore, additional tests were performed to obtain long-term heat sensitivity on CIA-Gel anchors exposed to a constant temperature of

110 °F (43 °C). The long-term (40 day) heat sensitivity tests were performed on 1/2-inch diameter sections of threaded rod installed in unreinforced 2000 psi hardrock concrete blocks using CIA-Gel 7000 epoxy.

Three test specimens were placed in an insulated chamber heated to 115 °F and tested for 46 days (Ref. 10). The tests were performed in accordance with a draft of Test No. 10 - *Caltrans procedure for conducting creep test at elevated temperature*, as well as the applicable requirements of ASTM E 1512, *Methods of Testing Bond Performance of Adhesive-Bonded Anchors*, and ASTM E 488-90, *Standard Test Methods for Strength of Anchors in Concrete and Masonry Elements*. The test specimens were loaded to 3750 pounds ($0.25N_u$). Anchor movement as well as the ambient air and concrete temperature readings were monitored and recorded for 40 days. The results of the long-term tests are graphically presented in Fig. 4. 60 percent of the recorded anchor movement occurred in the first five days. This is not unusual for anchors installed with epoxies which typically require seven days for complete curing. After the initial movement, the amount of movement leveled off. No noticeable anchor movement was observed for any of the test specimens after 33 days. Most importantly, the test results revealed that the CIA-Gel epoxy is suitable for sustaning a design load at ambient air temperatures up to 115 °F.

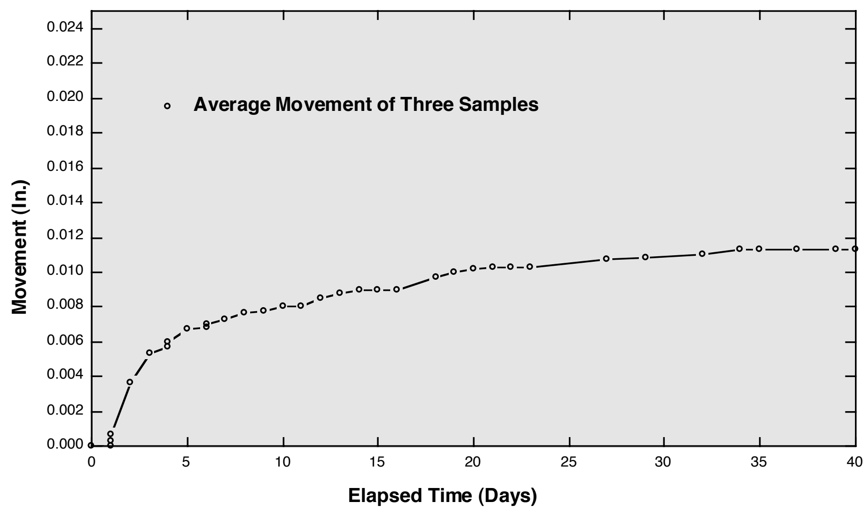


Fig. 4 - Long-term tension loading on CIA-Gel 7000 Epoxy at 110 °F

2.1.9 Fire-resistive Construction

The designer may have to consider the effects of a fire on epoxy anchors. Current research on this subject includes the following variables: length of exposure to fire, effect anchor embedment has on the loss of strength during a fire, and expected temperature levels during a fire.

Construction adhesives, such as epoxies, break down completely if directly exposed to temperatures greater than 350 °F (177 °C). The designer may want to use firestop or insulation around the base material to absorb thermal energy and increase the fire resistance of the adhesive anchors. If possible, deeper anchor embedments ($h_{ef} > 12d$) will also protect the adhesive, since the concrete itself is a very good insulating material. Heat from a fire may have more of an impact on the exposed anchor steel itself than on the epoxy. The exposed anchor steel may also behave as a thermal energy path into the base material (Ref. 5).

General industry practice does allow the use of unprotected adhesive anchors in fire resistive construction if they are used for lateral load resistance (wind/seismic) or other secondary systems.

2.1.10 Sensitivity to Condition of Drilled Holes

The condition of thedrilled hole effects the load carrying capacity of a chemical anchor. The two factors that can be the most important are the type of equipment used to create the hole and how the hole was cleaned. For some types of products, the type of equipment used to drill the hole and determine the degree of roughness of hole surface will effect the tensile pullout capacity of an anchor. The second factor, degree of cleanliness, may determine how well the chemical adhesive bonds to the hole surface. The amount of dust left behind after cleaning the hole effects tensile capacity, especially if the chemical adhesive has poor wetting capability or shrinks after curing. CIA-Gel 7000 epoxy has been formulated to provide excellent wetting and bonding capabilities regardless of drilling equipment used. In addition, CIA-Gel 7000 has the ability to wet through the concrete dust and still attain the design load capacity of the ancho even witththe reduced embedment caused by debris left in the hole.

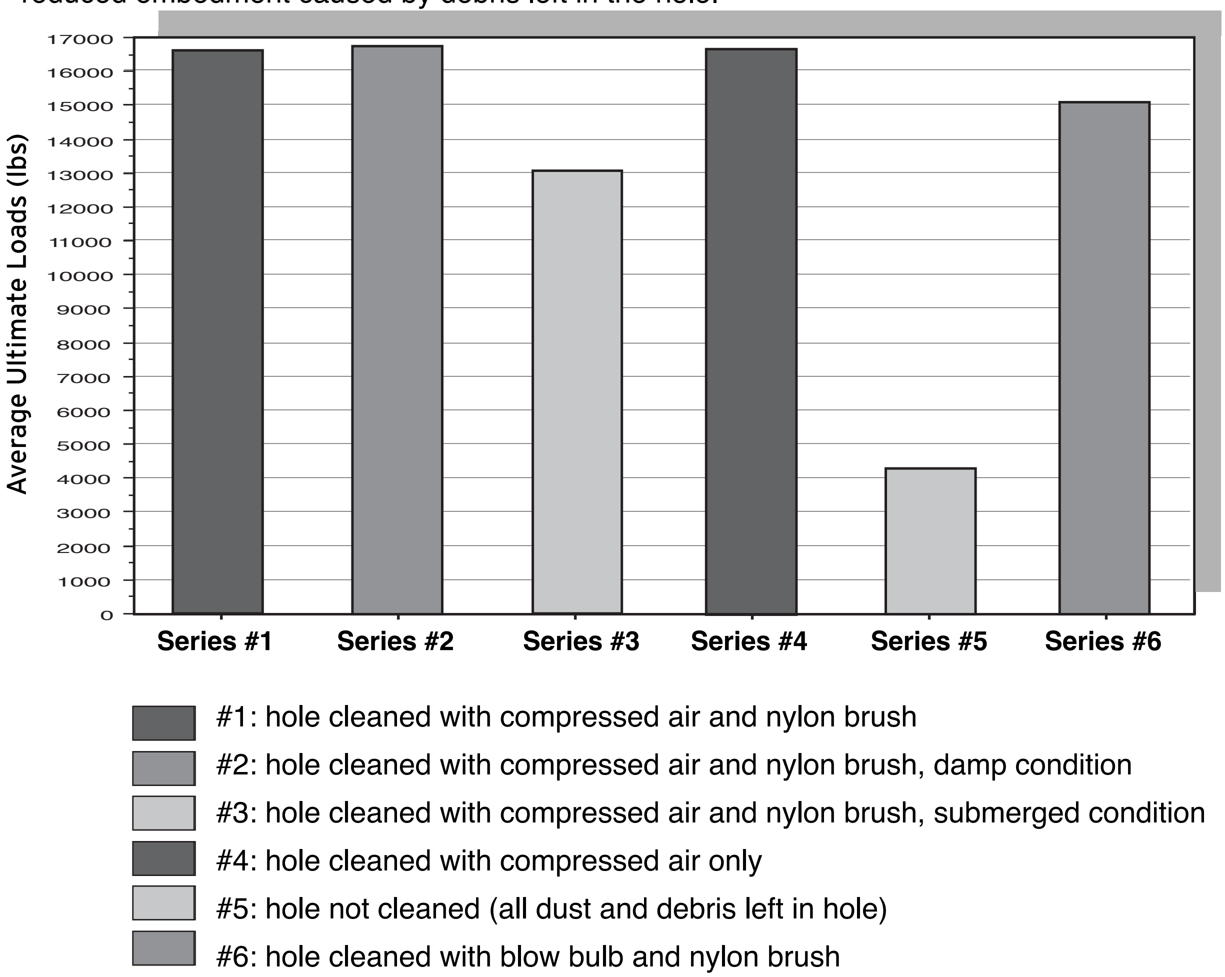


Fig. 5: Average ultimate loads of CIA-Gel anchors installed in holes left in various conditions

Threaded rods, 1/2-inch in diameter, installed with CIA-Gel 7000 epoxy in holes of various conditions (damp, dusty, submerged in water, etc.) were tested for their tension capacity (Ref. 5). Test results are graphically presented in Figure 5. The results demonstrate that variations in installation quality commonly found on the job site (test series nos. 1, 2, 4, and 6) have little effect on the load capacity of CIA-Gel epoxy. The only test series where severe load reductions occurred was when the hole was not cleaned at all (test series no. 5: all dust and debris was left behind in the hole). In the case of test series no. 5, the dust and debris created such a poor condition that proper anchor embedment could not be attained <u>(actual field conditions- installers will not typically drill deeper to try and compensate for the reduced embedment due to the accumulation of debris in the bottom of the hole.)</u>

2.1.11 Dynamic and Seismic Loading

CIA-Gel 7000 adhesive anchors perform very well under dynamic loading. The bond stress transfer mechanism of adhesive anchors is much less likely to fail under dynamic loads than the friction stress mechanism of expansion anchors (example: a wedge anchor). Unlike mechanical anchors which generate very high and concentrated unit stresses, adhesive anchors transfer stress along the entire length of the hole, considerably reducing the unit stress on the concrete itself. The lower unit stresses also allows the designer to place adhesive anchors closer to an edge or in anchor clusters closely spaced together.

The seismic behavior of adhesive anchors depends on the amplitude of the imposed deformation reversals, the direction of application of the deformations (axial, shear, combined), the state of the surrounding structural member (cracked or uncracked), and the presence of reinforcement near the vicinity of the anchors (Ref. 5).

The CIA-Gel 7000 has been tested with threaded rod and rebar for seismic loading in tension and shear in acordance with the ICC ES AC 58 and ASTM E-1512 standards. The CIA-Gel 7000 has passed the requirements of these standards and has earned the use of the short term load increases when applicable by the code.

The behavior of adhesive anchors, installed at embedments of $h_{ef} = 10d$ and large edge distances, subjected to alternate cyclic shear loads and one-direction cyclic tension loads resulted in bolt fractures during the cyclic loading (Ref. 5).

2.1.12 Threaded Anchor Rod Materials

A 307 anchor bolts have been specificed for anchorage to concrete and masonry by the code and by engineers for many years, however the ASTM A 307 specificaly covers headed bolts of relatively short lengths. If A 307 type steel strength is desired, a threaded rod that meets one of the AISI 1000 series such as AISI 1018 is very commonly available. AISI 1018 steel typically has an ultimate tensile strength between 70 ksi and 80 ksi. Yield stress is generally not provided for AISI 1018 steel, therefore if ductile elongation of the threaded rod is required, a material with a more defined separation between yield and ultimate strength should be selected. A 36 steel is also available although typically more expensive because it is usually cut from solid bar rather than roll formed. A 36 steel is a good ductile material with a minimum yield stress of 36 ksi and a minimum ultimate strength of 60 ksi. ASTM A 193, Grade B7 threaded rod is a good high-strength commonly available ductile steel. It has a yield stress of 105 ksi and a ultimate strength of 125 ksi.

2.1.13 Deformed Reinforcing Bar

ASTM A 615 reinforcing bar is commonly available as Grade 40 and Grade 60. Grade 40 rebar typically has an ultimate tensile strength of 70 ksi with a minimum yield stress of 40 ksi. Grade 60 rebar typically has an ultimate tensile strength of 90 ksi with a minimum yield stress of 60 ksi. Both grades of reinforcing bar are very good ductile materials.

2.1.14 Chemical Resistance Chart

EXPOSURE TIME						
Test Medium	**Test Temp. F**	**1 Day**	**7 Days**	**30 Days**	**6 Months**	**12 Months**
Acetic Acid 20 %	77	C	C	C	C	C
	120	C	C	C	C	C
Acetone	77	A	A	B	B	B
Ammonia	77	A	A	A	A	A
	120	A	A	A	A	A
Bleach	77	A	A	A	A	AD
	120	A	A	A	A	AD
Cement Water (Sat.)	77	A	A	A	A	A
	120	A	A	A	A	A
Citric Acid 15 %	77	A	A	A	A	A
	120	A	A	B	B	B
Detergent Soln.	77	A	A	A	A	A
	120	A	A	A	A	A
Distilled Water	77	A	A	A	A	A
	120	A	A	A	A	A
Ethanol	77	A	A	A	A	B
	120	A	A	A	B	B
Ethanol Water (60/40)	77	A	A	A	A	A
Formic Acid 10%	77	A	B	B	B	B
	120	C	C	C	C	C
Fuel Oil	77	A	A	A	A	AD
	120	A	A	A	A	AD
Hydrochloric Acid Concentrated	77	A	A	A	AD	AD
Hydrochloric Acid 10%	77	A	A	A	A	A
	120	A	A	A	A	A
Hydrogen Peroxide 5%	77	A	A	A	A	A
	120	A	A	A	B	BD
Iron (III) Chloride 35%	77	A	A	A	A	AD
	120	A	A	A	AD	AD
Iron (II) Sulfate 35%	77	A	A	A	A	AD
	120	A	A	A	A	AD
Kerosene	77	A	A	A	A	A
	120	A	A	A	A	A
Lactic Acid 20%	77	C	C	C	C	C
	120	C	C	C	C	C
Methyl Ethyl Ketone	77	A	A	B	B	B
Nitric Acid 20%	77	AD	AD	AD	AD	AD
	120	AD	AD	C	C	C
Oxalic Acid 40%	77	A	A	A	A	A
	120	A	A	A	A	A
Phosphoric Acid 40%	77	A	A	A	A	A
	120	A	A	A	A	A
Potassium Permanganate 10%	77	AD	AD	AD	AD	AD
Sodium Chloride Soln. (Sat.)	77	A	A	A	A	A
	120	A	A	A	A	A
Sodium Hydroxide 30%	77	A	A	A	A	A
	120	A	A	A	A	A
Sodium Sulfite 10%	77	A	A	A	A	A
	120	A	A	A	A	A
Styrene	77	A	A	A	A	A
Sulfuric Acid 50%	77	A	A	A	A	A
	120	A	A	A	A	A
Tartaric Acid 20%	77	A	A	A	A	A
	120	A	C	C	C	C
Trichloroethylene	77	A	A	A	A	A

Key :

A= Resistant to Prolonged Contact
B= Swelling and Cracking
C= Disintegration of Sample
D= Discoloration of Sample

2.2 Installation Informaton

2.2.1 Installation Instructions

2.2.1.1 Installation in Concrete and Solid Masonry

A hole is drilled to the specified depth with a hand-held electro-pneumatic rotary hammer drill using carbide tipped drill bits conforming to ANSI Specification B212.15-1994. The holes are cleaned of dust and debris with a nylon brush and a jet of compressed air. The hole diameter, anchor embedment, spacing and edge distances must comply with the Tables herein or in the Code Reports accepted by the Building Official. A mixing nozzle is attached to the adhesive cartridge and the assembly is placed into the hand or pneumatic injection tool. Before placement into the hole, a small amount of epoxy is pumped out of the nozzle until a uniform gray material is achieved. Holes are approximately half filled with the mixed epoxy. The threadedrods or deformed reinforcement bars are inserted with a rotating motion until the anchor contacts the bottom of the hole. The adhesive must be level with the concrete surface after insertion of the rod or bar. Oil, scale, and rust must be removed from the threaded rod or reinforcing bar prior to installation. During anchor installation, the hole and surrounding location may be wet, and any standing water need not be removed from the hole. Anchors shall not be loaded until cure time has passed.

2.2.1.2 Installation in Unreinforced Brick Masonry Walls:

One-inch-diameter (25.4 mm) holes are drilled using standard carbide-tipped masonry drill bits which meet ANSI Specifications B212.15-1994. A rotary drill, or rotary hammer drill set on “rotation only” is used to drill the holes. Holes for the “combination” anchors are drilled 13 inches (330 mm) deep at a 221/2-degree angle. Holes for the “through-bolt” anchors, and the “shear” anchors are drilled perpendicular to the wall. For the “through-bolt” application the holes are drilled completely through the wall. For shear anchors, the holes are drilled 8 inches (203 mm) deep. The holes are cleaned using a nylon brush, and a jet of compressed air. An extension nozzle must be used to reach the back of the hole with compressed air. Screen tubes are completely filled with CIA-Gel 7000 epoxy and then placed into the drilled holes. A 3/4-inch-diameter wall. Drilling is continued until the entire wall is penetrated. The 5/8-inch-diameter (15.9 mm) rod is then inserted and fitted with a plate and nut to complete the through-bolted anchor connection.

2.2.2 Recommended Hole Sizes

TABLE 2.2—SPECIFICATION AND INSTALLATION DETAILS FOR THREADED ROD INSTALLED WITH COVERT CIA-GEL 7000

d ROD DIAMETER (in.)	3/8	1/2	5/8	3/4	7/8	1	1 1/4
d_o NOMINAL BIT DIAMETER HOLE SIZE (in.)	1/2	5/8	3/4	7/8	1	1 1/4	1 1/2
A_s TENSILE STRESS AREA (in.^{2})	0.0775	0.142	0.226	0.334	0.462	0.606	0.969
A_b NOMINAL AREA OF ROD (in.^{2})	0.1042	0.1867	0.2935	0.4246	0.6013	0.7854	1.227
T_{max} MAXIMUM TIGHTENING TORQUE (ft.-lbs.)	15	30	70	150	200	310	375

For **SI**: 1 inch = 25.4 mm, 1 in.^{2} = 645 mm^2, 1 ft-lbf = 1356 N-mm, 1 psi = 6.89 kPa, 1 lbf = 4.45 N

Section 2.3 Allowable Stress Method Information

2.3.1 Allowable Loads

Allowable loads are based on actual tests performed on anchors installed in concrete (tests performed in accordance with appropriate standards). The design capacity of an anchor or group of anchors is determined by applying appropriate safety factors to the average ultimate test loads. Design capacity of anchors or anchor groups installed at reduced spacing or edge distance is determined by applying reduction factors (derived from tests) to the design allowables.

The tables tabulate recommended tension capacities and shear capacities for single threaded studs installed with CIA-Gel epoxy. The tabulated design values were obtained by applying a safety factor of 4 to 1 to the average ultimate shear and tensile capacity determined from tests.

The listed edge and spacing requirements in the table may be reduced using the reduction factors listed in the Reduction Factor Tables.

Two design equations, the straight-line and elliptical curve methods, may be used when an anchor or group of anchors is simultaneously subjected to both shear and tension loading. The straight-line method, represented by eq. 3, is the most conservative approach. Tests have shown that eq. 4 is more accurate than eq. 3. It is therefore recommended that eq. 4 is used for applications involving combined loads.

Straight line method

$$(T/T_c) + (V/V_c) \leq 1.0 \qquad (3)$$

Elliptical curve method

$$(T/T_c)^{5/3} + (V/V_c)^{5/3} \leq 1.0 \qquad (4)$$

where T = applied tensile load
V = applied shear load
T_c = allowable anchor tension capacity
V_c = allowable anchor shear capacity

Notation - Working Stress Method

- A_s = tensile stress area of threaded anchor, in^2.
- d = rod diameter, in.
- h_{ef} = anchor embedment, in.
- h = minimum base thickness, in.
- f'_c = concrete compressive strength, psi.
- f_{ut} = minimum specified tensile strength of anchor steel, psi.
- f_y = minimum specified yield strength of anchor steel, psi.
- F_t = tension reduction factor, dimensionless
- F_v = shear reduction factor, dimensionless
- T = anchor tension capacity, lbs.
- T_c = allowable anchor tension capacity, bond or concrete failure, lbs.
- T_s = allowable anchor tension capacity, steel failure, lbs.
- N = shear strength factor, dimensionless
- c = edge distance or side cover distance measured from the center line of the anchor to edge, in.
- c_{min} = minimum required anchor edge distance, in.
- V = anchor shear capacity, lbs.
- V_c = allowable anchor capacity) bond or concrete failure), lbs.
- V_s = allowable anchor capacity (steel failure), lbs.
- s = anchor spacing, in.
- s_{min} = minimum anchor spacing, in.

TABLE 2.3—SPECIFICATION AND INSTALLATION DETAILS FOR REINFORCING BAR (REBAR) INSTALLED WITH COVERT INJECTION ADHESIVE CIA-GEL 7000

d_r REBAR SIZE	#3	#4	#5	#6	#7	#8	#9	#10	#11
A_{br} NOMINAL AREA OF REBAR (in.^{2})	0.11	0.20	0.31	0.44	0.60	0.79	1.0	1.27	1.56
d_o NOMINAL BIT DIAMETER HOLE SIZE (in.)	1/2	5/8	3/4	1	1 1/8	1 1/4	1 3/8	1 1/2	1 3/4

2.3.1 Allowable Load Tables

TABLE 2.4 – ALLOWABLE TENSILE LOADS FOR THREADED ROD INSTALLED IN NORMAL WEIGHT CONCRETE USING CIA-GEL 7000[123]

STUD DIAMETER (inch)	MINIMUM EMBED. DEPTH, h_{ef} (inches)	SPACING, *s* (inches)	EDGE DISTANCE, *c* (inches)	BASED ON BOND STRENGTH		BASED ON STEEL STRENGTH		
				f'_c = 2,000 psi	f'_c = 4,000 psi	A307 (SAE 1018)	A193 Gr. B7 (SAE 4140)	F593 SS 304
3/8	1 7/8	2 7/8	1 1/2	1190	1190	2185	4580	2732
	3 3/8	5	2 1/2	2150	2590			
1/2	2 1/2	3 3/4	1 7/8	1940	1940	3885	8210	4860
	4 1/2	6 3/4	3 3/8	3495	3780			
5/8	3 1/8	4 3/4	2 3/8	2600	2600	6070	12910	7590
	5 5/8	8 1/2	41/4	5400	5625			
3/4	3 3/4	5 5/8	2 7/8	3915	3915	8740	18680	10925
	6 3/4	10	5	6685	7840			
	7 1/2	11 1/4	5 5/8	6685	9505			
7/8	7 7/8	11 7/8	6	8492	9725	11900	25520	14875
1	9	13 1/2	6 3/4	12330	12700	15540	33390	19428
	11	13 1/2	8 1/4	12330	16740			

For **SI:** 1ºC = 0.555(tºF - 32).

[1]Allowable load must be the lesser of bond or steel strength.

[2]Values are for anchors installed at the specified spacing (*s*) and edge (*c*) distances. Apply appropriate factors for reduced spacing.

[3]Bond strength values are based on a safety factor of 4.0.

TABLE 2.5 – ALLOWABLE SHEAR LOADS FOR THREADED ROD INSTALLED IN NORMAL WEIGHT CONCRETE USING CIA-GEL 7000[123]

STUD DIAMETER (inch)	MINIMUM EMBED. DEPTH, h_{ef} (inches)	SPACING, *s* (inches)	EDGE DISTANCE, *c* (inches)	BASED ON BOND STRENGTH	BASED ON STEEL STRENGTH		
				f'_c = 2000 psi	A307 (SAE 1018)	A193 Gr. B7 (SAE 4140)	F593 SS 304
3/8	3 3/8	5	5	1470	1125	2350	1400
1/2	4 1/2	6 3/4	6 3/4	3555	2000	4170	2500
5/8	5 1/2	6 1/2	6 1/2	4765	3125	6520	3900
3/4	6 3/4	10	10	6905	4500	9390	5610
7/8	7 7/8	11 7/8	11 7/8	8687	6130	12775	8687
1	8 3/4	13 1/2	13 1/2	11180	8000	16700	10000

[1]Allowable load must be the lesser of bond or steel strength.

[2]Values are for anchors installed at the specified spacing (*s*) and edge (*c*) distances. Apply appropriate factors for reduced spacing.

[3]Bond strength values are based on a safety factor of 4.0.

TABLE 2.6—ALLOWABLE TENSILE LOADS FOR ASTM A 615 GRADE 60 REINFORCING BAR (REBAR) INSTALLED IN NORMAL-WEIGHT CONCRETE USING CIA-GEL 7000 (pounds) [1,2,3]

BAR SIZE	DRILL BIT DIAMETER, d_o (inches)	MINIMUM EMBEDMENT, h_{ef} (inches)	SPACING, *s* (inches)	EDGE DISTANCE, *c* (inches)	BASED ON BOND STRENGTH	BASED ON BOND STRENGTH	BASED ON STEEL STRENGTH
					f'_c = 2,000 psi	f'_c = 4,000 psi	ASTM A 615 Grade 60
#3	1/2	4	6	3	1925	1925	2650
#4	5/8	$4^1/_2$	$6^3/_4$	$3^3/_8$	3700	3700	4710
#5	3/4	$5^5/_8$	$8^1/_2$	$4^1/_4$	4870	4870	7365
#6	1	$6^3/_4$	$10^1/_8$	5	7270	7270	10605
#6	1	$7^1/_2$	$11^1/_4$	$5^5/_8$	----	9705	10605
#7	1 1/8	$7^7/_8$	12	6	8720	8720	14430
#8	1 1/4	9	$13^1/_2$	$6^3/_4$	12265	12265	18850
#8	1 1/4	10	15	$7^1/_2$	----	14610	18850
#10	1 1/2	11	$16^1/_2$	$8^1/_4$	14085	14085	30480

[1]Allowable load must be the lesser of bond or steel strength.

[2]Values are for anchors installed at the specified spacing (*s*) and edge (*c*) distances. Apply appropriate factors for reduced spacing.

[3]Bond strength values are based on a safety factor of 4.0.

TABLE 2.7—ALLOWABLE SHEAR LOADS FOR ASTM A 615 GRADE 60 REINFORCING BAR (REBAR) INSTALLED IN NORMAL-WEIGHT CONCRETE USING CIA-GEL 7000 (pounds) [1,2,3]

BAR SIZE	DRILL BIT DIAMETER, d_o (inches)	MINIMUM EMBEDMENT, h_{ef} (inches)	SPACING, *s* (inches)	EDGE DISTANCE, *c* (inches)	BASED ON CONCRETE f'_c =2000 psi	BASED ON STEEL STRENGTH
						ASTM A 615 Grade 60
#3	1/2	4	6	6	2090	1700
#4	5/8	$4^1/_2$	$6^3/_4$	$6^3/_4$	3795	3030
#5	3/4	$5^5/_8$	$8^1/_2$	$8^1/_2$	5885	5150
#6	1	$6^3/_4$	$10^1/_8$	$10^1/_8$	8350	7530
#7	1 1/8	$7^7/_8$	12	12	11390	8800
#8	1 1/4	9	$13^1/_2$	$13^1/_2$	11580	9620
#10	1 1/2	11	$16^1/_2$	$16^1/_2$	13275	18200

[1]Allowable load must be the lesser of bond or steel strength.

[2]Values are for anchors installed at the specified spacing (*s*) and edge (*c*) distances. Apply appropriate factors for reduced spacing.

[3]Bond strength values are based on a safety factor of 4.0.

Table 2.8–ALLOWABLE TENSILE LOADS FOR THREADED ROD INSTALLED IN NORMAL WEIGHT CONCRETE USING CIA-GEL 7000 FOR SILL PLATE AND OTHER CLOSE EDGE DISTANCE APPLICATIONS [123]

STUD DIAMETER	MINIMUM EMBED. DEPTH, h_{ef} (inches)	SPACING, *s* (inches)	EDGE DISTANCE, *c* (inches)	BASED ON BOND STRENGTH	BASED ON STEEL STRENGTH		
				f'_c = 2,000 psi	A307 (SAE 1018)	A193 Gr. B7 (SAE 4140)	F593 SS 304
3/8	1 7/8	2 7/8	1 1/2	1190	2185	4580	2732
	3 3/8	5	1 3/4	1957			
1/2	2 1/2	3 3/4	1 3/4	1901	3885	8210	4860
	4 1/2	6 3/4	1 3/4	2790			
5/8	3 1/8	4 3/4	1 3/4	2395	6070	12910	7590
	5 1/2	8 1/4	1 3/4	3603			
	9	13 1/2	1 3/4	5040			
3/4	3 3/4	5 5/8	1 3/4	3454	8740	18680	10925
	6 3/4	10 1/8	1 3/4	4485			
7/8	7 3/4	11 5/8	1 3/4	6853	11900	25520	14875
	13	19 1/2	1 3/4	8775			
1	9	13 1/2	1 3/4	8725	15540	33390	19428
	15	22 1/2	1 3/4	10480			

[1]Allowable load must be the lesser of bond or steel strength.

[2] Values are for anchors installed at the specified spacing (*s*) and edge distances(*c*). Apply appropriate factors for reduced spacing.

[3]Bond values are based on a factor of safety of 4.

TABLE 2.9–ALLOWABLE SHEAR LOADS FOR THREADED ROD INSTALLED IN NORMAL WEIGHT CONCRETE USING CIA-GEL 7000 FOR SILL PLATE AND OTHER CLOSE EDGE DISTANCE APPLICATIONS [123]

STUD DIAMETER	MINIMUM EMBED. DEPTH, h_{ef} (inches)	SPACING, *s* (inches)	EDGE DISTANCE, *c* (inches)	BASED ON BOND STRENGTH	BASED ON STEEL STRENGTH		
				f'_c = 2000 psi	A307 (SAE 1018)	A193 Gr. B7 (SAE 4140)	F593 SS 304
3/8	3 3/8	5	1 3/4	706	1125	2350	1400
1/2	4 1/2	6 3/4	1 3/4	1448	2000	4170	2500
5/8	5 3/4	8 1/2	1 3/4	2700	3125	6520	3900
3/4	5 3/4	8 1/2	1 3/4	2700	4500	9390	5610
7/8	5 3/4	8 1/2	1 3/4	2700	6130	12775	7650
1	5 3/4	8 1/2	1 3/4	2700	8000	16700	10000

[1]Allowable load must be the lesser of bond or steel strength. Loads based on bond strength are for anchors loaded parallel to the edge.

[2]Values are for anchors installed at the specified spacing (*s*) and edge distances (*c*). Apply appropriate factors for reduced spacing.

[3]Bond values are based on a factor of safety of 4.

TABLE 2.10—ALLOWABLE TENSION AND SHEAR LOADS FOR THREADED ROD INSTALLED IN GROUT-FILLED NORMAL-WEIGHT 2300 psi CONCRETE MASONRY UNITS USING CIA-GEL 7000 (pounds) [1,2,3]

STUD DIAMETER (inch)	DRILL DIAMETER (inch)	EMBEDMENT, h_{ef} (inches)	SPACING, *s* (inches)	EDGE DISTANCE, *c* (inches)	TENSION		SHEAR
					CELL (lbs)	JOINT (lbs)	CELL (lbs)
$^3/_8$	$^1/_2$	$3^1/_2$	$6^3/_4$	$3^3/_8$	1255	790	1170
$^1/_2$	$^5/_8$	$4^1/_4$	9	$4^1/_2$	1610	1060	1880
$^5/_8$	$^3/_4$	$4^7/_8$	$11^1/_4$	$5^5/_8$	1980	1360	2270
$^3/_4$	$^7/_8$	$6^1/_2$	$13^1/_2$	$6^3/_4$	1910	2495	2975

[1]Allowable load must be the lesser of bond or steel strength.

[2]Values are for anchors installed at the specified spacing (*s*) and edge (*c*) distances. Apply appropriate factors for reduced spacing.

[3]The allowable loads are based on a factor of safety of 5. The tabulated allowable loads may be increased by 25 percent for installations under the UBC.

TABLE 2.11-ALLOWABLE TENSILE LOADS FOR THREADED ROD INSTALLED IN THE TOP F 2000 psi GROUTED CONCRETE MASONRY UNIT (CMU) WALLS USING CIA-GEL 7000 FOR SILL PLATE AND OTHER CLOSE EDGE DISTANCE APPLICATIONS123

STUD DIAMETER	MINIMUM EMBED. DEPTH, h_{ef} (inches)	SPACING, s (INCHES)	EDGE DISTANCE c (inches)	BASED ON BOND STRENGTH	BASED ON STEEL STRENGTH		
				f'm=2000 psi	A307 (SAE 1018)	A193 Gr. B7 (SAE 4140)	F593 SS 304
1/2	5	10	1-3/4	1075	2185	4580	2732
5/8	12	16	1-3/4	2555	3885	8210	4860
	18	16	1-3/4	3985			

1Allowable load must be the lesser of bond or steel strength.
2Values are for anchors installed at the specified spacing (s) and edge distances (c). Apply appropriate factors for reduced spacing.
3Bond values are based on a factor safety of 5. The tabulated allowable loads may be increased by 25 percent for installations under the UBC.

TABLE 2.12-ALLOWABLE SHEAR LOADS FOR THREADED ROD INSTALLED IN THE TOP OF 2000PSI GROUTED CONCRETE MASONRY UNIT (CMU) WALLS USING CIA-GEL 7000 FOR SILL PLATE AND OTHER CLOSE EDGE DISTANCE APPLICATIONS

STUD DIAMETER	MINIMUM EMBED. DEPTH, h_{ef} (inches)	SPACING, s (INCHES)	EDGE DISTANCE c (inches)	LOAD DIRECTION	BASED ON BOND STRENGTH	BASED ON STEEL STRENGTH		
					f'm=2000 psi	A307 (SAE 1018)	A193 Gr. B7 (SAE 4140)	F593 SS 304
1/2	5	10	1-3/4	parallel	944	1125	2350	1400
1/2	5	8	1-3/4	perpendicular	420	2000	4170	2500

[1]Allowable load must be the lesser of bond or steel strength.
[2]Values are for anchors installed at the specified spacing (s) and edge distances (c). Apply appropriate factors for reduced spacing.
[3]Bond values are based on a factor safety of 5. The tabulated allowable loads may be increased by 25 percent for installations under the UBC.

TABLE 2.13—ALLOWABLE TENSION AND SHEAR VALUES IN 1300 psi CLAY BRICK MASONRY FOR THREADED RODS USING CIA-GEL 7000 (pounds) [1,2,3,4]

STUD DIAMETER (inch)	DRILL DIAMETER (inch)	EMBEDMENT, h_{ef} (inches)	SPACING, *s* (inches)	EDGE DISTANCE, *c* (inches)	TENSION BASED ON BOND STRENGTH (lbs.)	SHEAR BASED ON BOND STRENGTH (lbs.)
1/2	5/8	6	12	6	3090	2385
3/4	7/8	$7^3/_4$	15	$7^3/_4$	4485	3790

[1]Allowable load must be the lesser of bond or steel strength.
[2]Values are for anchors installed at the specified spacing (*s*) and edge (*c*) distances. Apply appropriate factors for reduced spacing.
[3]Anchors may be installed in the brick face or the mortar joint.
[4]The allowable loads are based on a factor of safety of 5 and may be increased by 25 percent for applications under the UBC.

TABLE 2.14-ALLOWABLE TENSILE LOADS FOR THREADED ROD INSTALLED IN LIGHTWEIGHT AGGREGATE CONCRETE USING CIA-GEL 7000 (pounds) [123]

STUD DIAMETER, *d* (inch)	MINIMUM EMBEDMENT DEPTH, h_{ef} (inches)	SPACING, *s* (inches)	EDGE DISTANCE, *c* (inches)	BASED ON BOND STRENGTH	BASED ON BOND OR CONCRETE STRENGTH f'_c = 2,500 psi (minimum)		
				f'_c = 3,000 psi	A 307	A 193, Gr. B7	SS 304
3/8	1 3/4	5	2 3/4	820	2185	4580	2732
3/8	3 3/8	8	4	2020			
1/2	2 1/2	5	2 3/8	1077	3885	8210	4860
1/2	4 1/2	9	4 1/2	2245			
5/8	5 5/8	11	6	2545	6070	12910	7290

[1]Allowable load must be the lesser of bond or steel strength.

[2]Values are for anchors installed at the specified spacing (*s*) and edge (*c*) distances. Apply appropriate factors for reduced spacing.

[3]Bond strength values are based on a safety factor of 4.0.

TABLE 2.15-ALLOWABLE SHEAR LOADS FOR THREADED ROD INSTALLED IN LIGHTWEIGHT AGGREGATE CONCRETE USING CIA-GEL 7000 (pounds) [123]

STUD DIAMETER, *d* (inch)	MINIMUM EMBEDMENT DEPTH, h_{ef} (inches)	SPACING, *s* (inches)	EDGE DISTANCE, *c* (inches)	BASED ON BOND STRENGTH	BASED ON BOND OR CONCRETE STRENGTH f'_c = 2,500 psi (minimum)		
				f'_c = 3,000 psi	A 307	A 193 Gr. B7	SS 304
3/8	1 3/4	5	2 3/4	726	1125	2347	1400
3/8	3 3/8	8	4	726			
1/2	2 1/2	5	2 3/8	677	2000	4170	2500
1/2	4 1/2	9	4 1/2	677			
5/8	5 5/8	11	6	3027	3125	6520	3900

[1]Allowable load must be the lesser of bond or steel strength.

[2]Value are for anchors installed at the specified spacing (s) and edge (c) distances. Apply appropriate factors for reduced spacing.

[3]Bond strength values are based on a safety factor of 4.

Notes:

2.4 Allowable Stress Design Examples (Working Stress Method)

2.4.1 Design Example 1

Determine the tension capacity of four (4) 3/4-inch threaded studs installed near a corner of a concrete slab using the CIA-Gel adhesive anchors. The anchors are embedded 6-3/4 inches (h_{ef} = 6-3/4") and are spaced 10 inches on center (s = 10") with an edge distance of 4inches (see Fig. 6). Concrete: hardrock, f'_c = 2000 psi. Threaded studs: A 193 Grade B7 steel, f_{ut} = 125,000 psi, f_y = 105,000 psi (Ref. 8).

The allowable tension values listed in Table No. 5 for 3/4-inch anchors installed at an embedment of 6-3/4", require an edge distance of 5" and anchor spacing of 10". Table No. 4 allows reductions up to 75% in spacing and 50% in edge distances, provided that the allowable values are reduced by the listed reduction factors.

Bolt no. 1 is not affected by reduced spacing (s_1 = s_1 = 10" $\leq$ 10"). However, it is affected by two reduced edge distances and must be reduced by the combined edge reduction factors as follows:

c_1=c_2=4", c_{min}=2.5", F_t=0.85 (Table No. 4)

Determine reduction factors (interpolate for reduced edge distance):

$$F_{t1} = \left[\frac{(c_1 - c_{min})}{(c - c_{min})}(1.0 - F_t)\right] + F_t$$

$$F_{t1} = \left[\frac{(4 - 2.5)}{(5 - 2.5)}(1.0 - .85)\right] + .85$$

$$F_{t1} = [0.60\ (0.15)] + 0.85 = 0.94$$

Note: since $c_1 = c_2$, $F_{t1} = F_{t2}$

Tension capacity for bolt no. 1:

T_1 = 6685 lbs. (F_{t1} x F_{t2})
= 6685 lbs. (0.94 x 0.94)
= 5907 lbs.

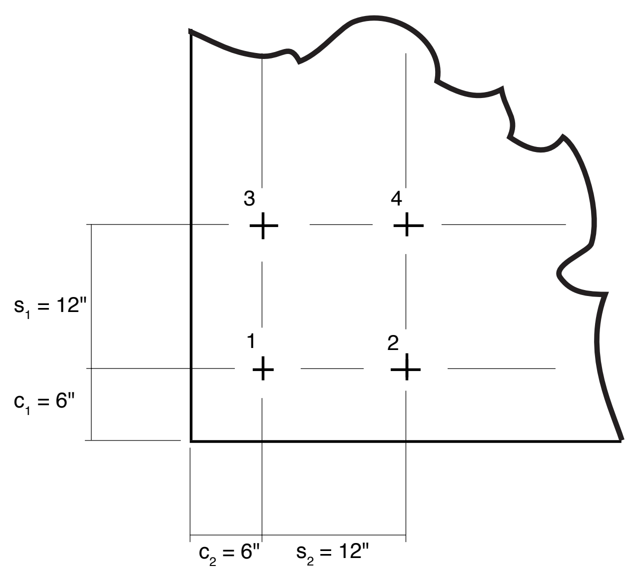


Fig. 6 - 3/4-inch bolt pattern.

Bolt nos. 2 and 3 are affected by one reduced edge distance and must be reduced as follows:

$c_1 = c_2$ = 4"

$F_{t2} = F_{t3}$ = 0.94

$T_2 = T_3$ = 6685 lbs. x 0.94
= 6284 lbs.

Bolt no. 4 is not affected by edge distances, therefore:

T_4 = 6685 lbs.

IMPORTANT: the above example is intended as a guide only. Values presented are for each individual bolt only. When used in combination (such as attachment of a base plate), load capacity of the bolt group should be determined by the designer.

2.4.2 Design Example 2

Determine the tension and shear capacity of anchor no. 1 in Fig. 7 installed using the CIA-Gel adhesive. The anchors are embedded 6-3/4 inches (h_{ef} = 6-3/4") and are spaced 8 inches on center in one direction (s_1 = 8") and 6 inches in the other direction (s_2 = 6"), with an edge distance of 4 inches (c_1=c_2=4"). Concrete: hardrock, f'_c = 3000 psi. Threaded studs: A 193 Grade B7 steel, f_{ut} = 125,000 psi, f_y = 105,000 psi.

The allowable tension values listed in Table No. 5 for 3/4-inch anchors installed at an embedment of 6-3/4", require an edge distance of 5" and anchor spacing of 10". Table No. 4 allows reductions up to 75% in spacing and 50% in edge distances, provided that the allowable values are reduced by the listed reduction factors.

Tension Capacity:

Anchor no. 1 is affected by reduced spacing (S_1 & S_2 $\leq$ 10) and also affected by two reduced edge distances and must be reduced by the combined edge and spacing reduction factors as follows:

Determine reduction factors for reduced edge distance (interpolate for reduced edge distance):

c_1=c_2=4", c_{min}=2.5", F_t=0.85 (Table No. 4)

$$F_{t1} = \left[\frac{(c_1 - c_{min})}{(c - c_{min})}(1.0 - F_t)\right] + F_t$$

$$F_{t1} = [0.60\ (0.15)] + 0.85 = 0.94$$

Note: since $c_1 = c_2$, $F_{t1} = F_{t2}$

Determine reduction factors for reduced spacing (interpolate for direction s_1):

s_1=8", s_2=6", s=10", s_{min}=2.5", F_t=0.65

$$F_{t3} = \left[\frac{(s_1 - s_{min})}{(s - s_{min})}(1.0 - F_t)\right] + F_t$$

$$F_{t3} = [0.73\ (0.35)] + 0.65 = 0.90$$

Interpolate for direction s_2:

$$F_{t4} = \left[\frac{(s_2 - s_{min})}{(s - s_{min})}(1.0 - F_t)\right] + F_t$$

$$F_{t4} = [0.47\ (0.35)] + 0.65 = 0.81$$

Interpolate for 3000 psi concrete:

$$T = \left[\frac{(7840 - 6685)}{(4000 - 2000)}(1000)\right] + 6685$$

$$= 7263 \text{ lb}$$

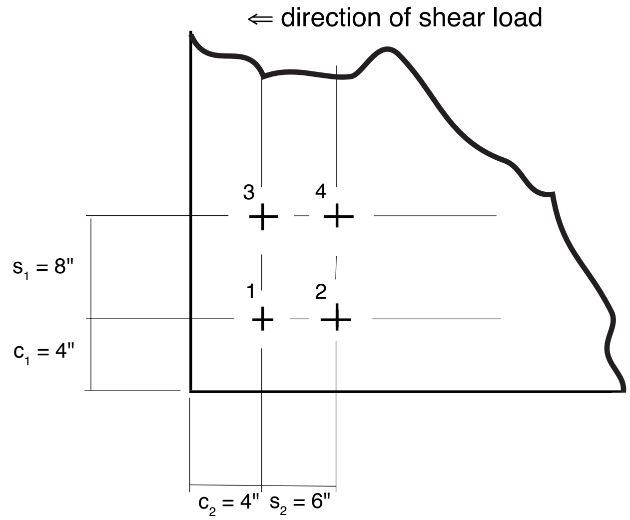


Fig. 7 - 3/4-inch bolt pattern.

Tension capacity for anchor no. 1:

T_1 = 7263 lbs. (F_{t1} x F_{t2} x F_{t3} x F_{t4})
= 7263 lbs. (0.94 x 0.94 x 0.90 x 0.81)
= 4675 lbs.

Tension capacities for the remaining anchors can quickly be determined using the reduction factors determined for the no. 1 anchor. For example, anchor no. 2 is affected by one reduced edge distance (factor F_{t2}) and two reduced spacings (factors F_{t3} and F_{t4}).

∴ T_2 = 7263 lbs. (F_{t2} x F_{t3} x F_{t4})
= 7263 lbs. (0.94 x 0.90 x 0.81)
= 4977 lbs.

Shear Capacity:

Anchor no. 1 is affected by reduced spacing (s_1 & s_2 < 10") and also affected by two reduced edge distances and must be reduced by the combined edge and spacing reduction factors as follows:

Determine reduction factors for reduced edge distance (interpolate for reduced edge distance):

$c_1=c_2=4"$, $c_{min}=2.5"$, $F_v=0.25$ toward edge
$F_v=0.4$ not toward edge

$$F_{s1} = \left[\frac{(c_1 - c_{min})}{(c - c_{min})} (1.0 - F_v)\right] + F_v$$

$$F_{s1} = [0.20\ (0.75)] + 0.25 = 0.40$$

$$F_{s2} = \left[\frac{(c_2 - c_{min})}{(c - c_{min})} (1.0 - F_v)\right] + F_v$$

$$F_{s2} = [0.2\ (0.6)] + 0.4 = 0.52$$

Determine reduction factors for reduced spacing (interpolate for direction s_1):

$s_1=8"$, $s=10"$, $s_m=2.5"$, $F_v=0.6$

$$F_{v3} = \left[\frac{(s_1 - s_{min})}{(s - s_{min})} (1.0 - F_v)\right] + F_v$$

$$F_{v3} = [0.73\ (0.4)] + 0.6 = 0.89$$

Interpolate for direction s_2:

F_{v4} = 1.0 since $F_v = 1.0$ @ $s_{min} = 0.25s$

Shear capacity for bolt no. 1:

V_1 = 6905 lbs. (F_{v1} x F_{v2} x F_{v3} x F_{v4})
= 5,040 lbs. (0.40 x 0.52 x 0.89 x 1.00)
= 1278 lbs.

[1]value for 2000 psi concrete used

Calculate the remaining anchors similar to above.

IMPORTANT: the above example is intended as a guide only. Values presented are for each individual anchor only.

Section 2.5: Introduction

2.5.1 General Information

Chemical anchors transfer load to the concrete by means of a bond between the hardened chemical and the concrete. When a tensile load is applied to a chemical anchor, the resulting stress is transferred along the entire length of the hole with the maximum bond stress occurring near the concrete surface. The bond strength between the chemical and the concrete depends on the compressive strength of the concrete, the surface condition of the hole, and the amount of dust and/or debris left in the hole at the time of installation. Approximate mean bond/cone strength of CIA-Gel epoxy as a function of concrete strength is tabulated below. The values are based on unconfined tension test results of threaded studs installed with CIA-Gel epoxy.

Concrete compressive strength f'_c (psi)	Approximate mean bond/cone strength[1] τ_m (psi)
2000	1350
3000	1400
4000	1450
5000	1500

[1]Values listed are for properly cured CIA-Gel epoxy. Mean bond/cone strength values depend on the condition of the drilled holes; the tabulated values are for holes cleaned thoroughly using a nylon brush and compressed air.

The most common type of failure that occurs during the tension testing of high strength threaded rod installed with CIA-Gel epoxy is a combination bond and concrete cone breakout failure. The de-bonded portion of a failed CIA-Gel epoxy anchor is usually accompanied by a shallow concrete cone which varies from 20% to 50% of the anchor embedment depth. This type of failure is typical for all types chemical anchors which provide high bond strength ($\tau_u \geq$ 1200 psi).

The ultimate tensile capacity of an epoxy anchor based on a bond failure can be estimated from eq. 1.

$$P_b = \tau_u \times \pi d h_{ef} \qquad (1)$$

where τ_u = mean bond strength (psi)
d = rod diameter (in.)
h_{ef} = anchor embedment (in.)

Equation (1) can generally be applied to 3/8" through 1" stud diameters installed in 2000-5000 psi concrete. The nominal drill bit diameter should be 1/8-inch larger than the rod diameter. The drilled hole diameter (d_b) is assumed to be the average actual diameter of a carbide-tipped drill bit which meets ANSI B212.15-1994 specifications (see table below).

Nominal drill bit diameter (in)	Drill bit diameter[2] Max. (in.)	Drill bit diameter[2] Min. (in.)	Hole diameter d_b (in)
1/2	0.530	0.520	0.525
5/8	0.660	0.650	0.655
3/4	0.787	0.775	0.781
7/8	0.917	0.905	0.911
1	1.042	1.030	1.036
1-1/8	1.175	1.160	1.168
1-1/4	1.300	1.285	1.293
1-1/2	1.550	1.535	1.543

[2]Min/Max carbide tip diameter requirements per ANSI B212.15-1994

Tension tests of low grade steel rod such as A 36 or AISI 1018 threaded rod installed with CIA-Gel epoxy at embedments $h_{ef} \geq 9d$, usually result in steel failures. The ultimate tensile capacity of an anchor based on a steel failure can be estimated from eq. 2.

$$P_t = f_{ut} \times A_s \qquad (2)$$

where f_{ut} = ultimate tensile strength (psi)
A_s = tensile stress area (in^2)

Section 2.6: Strength Design Method - Adhesive Anchors

2.6.1. Bond Capacity Method

Tensile capacity of adhesive anchors is governed by a combination bond and concrete failure and varies as a function of anchor embedment to the power of 2 (Ref. 8). The concrete capacity method described in references 8 and 9 for headed anchors should not be used to predict tensile capacity of adhesive anchors. Adhesive anchors should be spaced at $s = 2h_{ef}$ and placed at an edge distance of $1.0h_{ef}$ (Ref. 8) for full tension capacity. Calibration factors (k factors) are provided for epoxy resin and polyester resin anchors (see Table No. VIII). Higher calibration factors, based on empirical evidence provided by the manufacturer, may be used. The basic bond capacity (BC) equation to determine the predicted ultimate tension capacity (P) of a single adhesive anchor installed in uncracked concrete is as follows:

$$P = k \cdot \sqrt{f'_c} \cdot h_{ef}^2 \qquad \text{(B1)}$$

where $4d \leq h_{ef} \leq 15d$

The basic BC equation to determine the predicted ultimate tension capacity (P_{bc}) of a single adhesive anchor close to an edge or corner, or group of anchors installed in uncracked concrete is as follows:

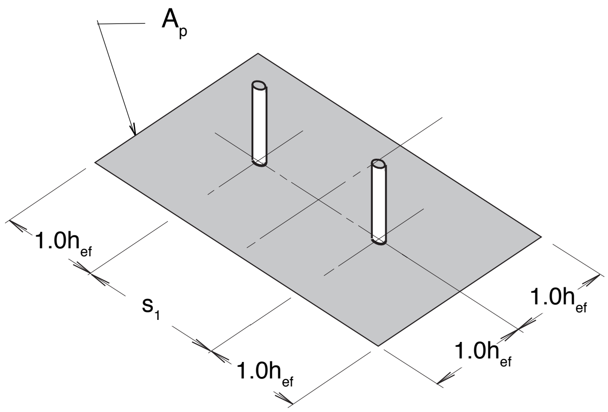
$$P_{bc} = \frac{A_p}{A_{p,o}} \cdot \Psi_{ec} \cdot P_{\text{(Eq. B1)}} \qquad \text{(B2)}$$

Adhesive anchors behave in a similar manner as cast-in-place anchor bolts or mechanical anchors under lateral loads. Therefore, the basic CC equations to determine the predicted ultimate shear capacity for adhesive anchors are the same as for cast-in-place anchors or undercut anchors. The spacing and edge distance requirements for adhesive anchors loaded in shear are also the same as for cast-in-place anchors.

Design examples illustrating the use of the bond capacity method may be found on the following pages.

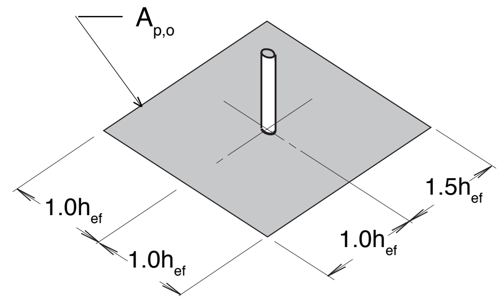
Table No VIII

Type of adhesive Anchor	**Tension Loads**			**Shear Loads**		
	k	**s_{cr}**	**c_{cr}**	**k**	**s_{cr}**	**c_{cr}**
epoxy resin anchors	12	$2.0h_{ef}$	$1.0h_{ef}$	n/a[1]	$3.0h_{ef}$	$1.5h_{ef}$
polyester resin anchors	11	$2.0h_{ef}$	$1.0h_{ef}$	n/a[1]	$3.0h_{ef}$	$1.5h_{ef}$



$A_p = (1.0h_{ef} + s_1 + 1.0h_{ef})\,(1.0h_{ef} + 1.0h_{ef})$

Fig. 8 - projected area for 2 adhesive anchors loaded in tension (A_p)



$A_{p,o} = (2h_{ef})^2$

Fig. 9 - projected area for one adhesive anchor, loaded in tension ($A_{p,o}$)

Notation - Bond Capacity Method

A_p = actual projected area of a single anchor or anchor group loaded in tension, (in^2)
$A_{p,o}$ = maximum projected area of one anchor loaded in tension (in^2)
A_s = stress area, (in^2)
A_v = actual projected area of a single anchor or anchor group loaded in shear, (in^2)
$A_{v,o}$ = maximum projected area of one anchor loaded in shear (in^2)
c = edge distance, in.
c_{cr} = required edge distance or side cover distance (measured from the centerline of the anchor to edge) for full capacity, in.
c_1 = edge distance perpendicular to direction of shear, in.
c_2 = edge distance or side cover distance parallel to direction of shear, in.
d = rod diameter, in.
d_o = outside diameter of anchor, in.
e = eccentricity
f'_c = concrete compressive strength, psi.
h = structural member depth, in.
h_{ef} = effective anchor embedment, in.
k = calibration factor, dimensionless
l = activated load bearing length of anchor, in.
P = predicted ultimate tensile strength of a single anchor (concrete failure), lbs.
P_{cc} = predicted ultimate tensile strength of an anchor or anchor group, (concrete failure), lbs.
P_s = tensile design strength of anchor, (steel failure), lbs.
s = anchor spacing, in.
s_{cr} = required anchor spacing for full capacity, in.
V = predicted ultimate shear strength of a single anchor (concrete failure), lbs.
V_{cc} = predicted ultimate shear strength of an anchor or anchor group (concrete failure), lbs.
V_s = shear strength of anchor (steel failure), lbs.
Ψ_{ec} = factor for eccentricity
Ψ_{sN} = modification factor for close edge conditions
Ψ_{sV} = modification factor for corner conditions

The basic equations to determine the **predicted average ultimate shear capacity** of a single anchor (V_1) or group of anchors (V_{cc}) installed in uncracked concrete (Ref. 9) are as follows:

$$V_1 = 13 \cdot (l/d_0)^{0.2} \cdot \sqrt{d_0} \cdot \sqrt{f'_c} \cdot (c_1)^{1.5} \qquad \text{(B3)}$$

$$V_{cc} = \frac{A_v}{A_{v,o}} \cdot \Psi_{ec} \cdot \Psi_{sV} \cdot V_{(Eq.\ C5)} \qquad \text{(B4)}$$

where:

d_o = outside diameter of anchor (in)

l = activated load bearing length of anchor (in)
= $h_{ef} \leq 8\, d_o$

c_1 = edge distance or side cover distance

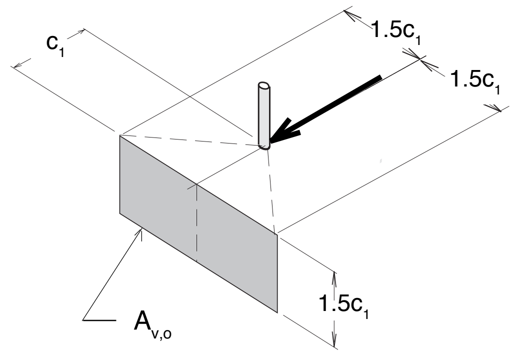


Fig. 10 - maximum projected area for one anchor, loaded in shear ($A_{v,o}$)

The reduction factor for close corner conditions (Ψ_{sV}) is determined in accordance with equation B5.

Modification factor for radial stresses due to anchors located close to a corner (Ψ_{sV}):

$$\Psi_{sV} = 1 \qquad \text{if } c_1/c \geq 1.0$$

$$= 0.7 + 0.3(c_1/c) \qquad \text{if } c_1/c \leq 1.0 \qquad \text{(B5)}$$

where:

c_1 = actual edge distance or side cover distance

c = required edge distance or side cover distance for full capacity

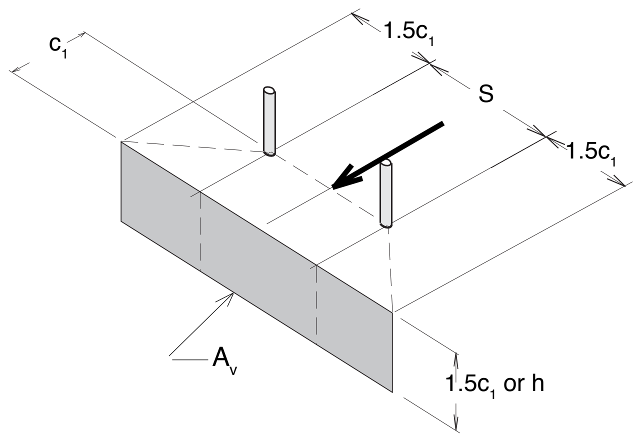


Fig. 11 - projected area for for 2 anchors loaded in shear (A_v)

2.6.2 Design Example (Bond Capacity Method)

One of the biggest advantages of using the CIA-Gel epoxy system is that a single cartridge of epoxy can be used to install various types of threaded rod or reinforcing bar which may range in diameters from 3/8" to 1-1/2", cut at any length. Unfortunately, test data is not always available to the designer for all the variations possible when using CIA-Gel epoxy for anchoring applications. The bond capacity strength design method presented in this section is especially helpful when the designer encounters an application which has not been tested. On the following pages are several examples demonstrating the use of the bond capacity method for adhesive anchors.

Design Example 1

Determine the tension capacity (concentric loading) of the anchor (adhesive - epoxy resin) group in Fig. 12. The anchors are embedded 6-3/4 inches (h_{ef} = 6-3/4") and are spaced 8 inches on center in one direction (s_1 = 8") and 6 inches in the other direction (s_2 = 6"), with an edge distance of 6 inches (c_1=c_2=6"). Concrete: hardrock, f'_c = 3000 psi, minimum base thickness is 12". Threaded studs: A 36 steel, f_{ut} = 60,000 psi, f_y = 36,000 psi.

All four anchors are affected by reduced spacing (s_1 & s_2 < 13-1/2) and also affected by two reduced edge distances ($c_1 = c_2 = 6" \leq$ 6-3/4"). Group capacity is as follows:

$$P_{cc,g} = \frac{A_p}{A_{p,o}} \cdot \Psi_{sN} \cdot k \sqrt{f'_c} \cdot h_{ef}^{2}$$

where A_p = 389 (in^2)
$A_{p,o}$ = 182 (in^2)
k = 12
Ψ_{sN} = 0.7 + 0.3 (6/6.75) = 0.97

$$P_{cc,g} = 2.14 \cdot 0.97 \cdot 12 \cdot 54.8 \cdot 45.6$$

= 62,250 lbs*

Check for ultimate steel tensile strength of the four anchors:

$$P_{ut,g} = n \cdot f_{ut} \cdot A_s$$

where n = number of anchors
f_f = 60,000 psi
A_s = 0.334 (in^2)

$P_{ut,g}$ = 80,160 lbs

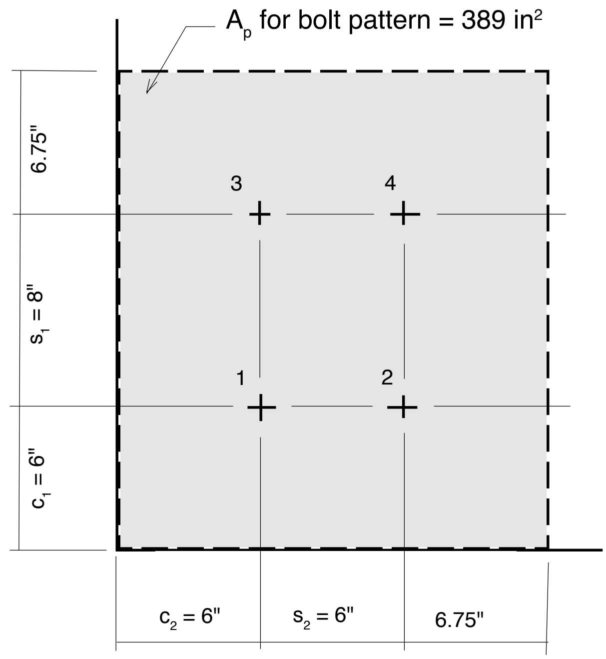


Fig. 12 - Projected area for 3/4-inch bolt pattern.

* $P_{cc,g}$ is the average predicted ultimate capacity of the anchor group. To determine the strength design capacity, the k-factor must reduced for cracked or uncracked concrete (a minimum 40% reduction or k = 7 is suggested) and a proper reduction factor (ϕ) must be applied. It is recommended that the designer follow the requirements of either ACI 349, Appendix B or UBC, Section 1925 and apply ϕ factors where required.

This method can also be used to determine working stress values simply by applying the appropriate safety factor to the load obtained from the formula.

Design Example 2 (Bond Capacity Method)

Estimate the ultimate tension capacity of the holdown anchor in Fig. 13 using the bond capacity method. The anchor is 5/8" in diameter, embedded 9 inches (h_{ef} =9") in a 5" thick concrete foundation at a 1-3/4" edge distance. The anchor is installed using epoxy adhesive. Concrete: hardrock, f'_c = 2000 psi. Threaded studs: A 193 Grade B7 steel, f_{ut} = 125,000 psi, f_y = 105,000 psi. The following assumptions are made: the foundation does not contain reinforcing steel and special inspection is provided during anchor installation.

$$A_p = (1.0h_{ef} + 1.0h_{ef})\ (\text{width of wall})$$

$$= (9 + 9)\ (5)$$

$$= 90$$

$$A_{p,0} = (2.0h_{ef})^2$$

$$= 324$$

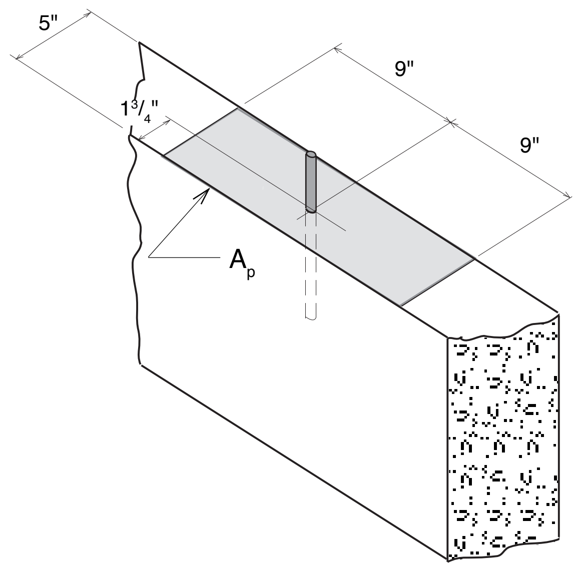


Fig. 13 - A_p for holdown anchor loaded in tension

Predicted ultimate tension capacity of 5/8" holdown anchor:

$$P_{bc} = \frac{A_p}{A_{p,o}} \cdot \Psi_{sN} \cdot 12\sqrt{f'_c} \cdot h_{ef}^{\,2}$$

where $k = 12$

$\Psi_{sN} = 0.7 + 0.3\ (1.75/9) = 0.758$

$$P_{bc} = \frac{90}{324} \cdot 0.758 \cdot 12\sqrt{2000} \cdot (9)^2$$

$$= 9.2^k\ (\text{tension})$$

Note: five anchors installed with CIA-Gel epoxy adhesive in conditions similar to Fig. 13 were tested for ultimate tension capacity. The actual concrete strength at the time of the tests was 2343 psi, which provides a predicted tension capacity of 9.9 kips. The tests resulted in an average tension capacity of 13.8 kips (Ref. 18).

Five tests were also performed on anchors installed in the corner (c_1 = 1-3/4" and c_2 = 5") of the same walls. These tests resulted in an average tension capacity of 11.1 kips (predicted capacity of 7.7 kips) (Ref. 18).

Design Example 3 (Bond Capacity Method)

Determine the ultimate shear capacity of a 1/2" threaded stud (A 193 Gr. B7) embedded 4 inches using CIA-Gel epoxy in 2000 psi concrete installed as follows:

1. With a 6 inch edge distance loaded towards the free edge (see Fig. 14).

2. With a 1-3/4 inch edge distance loaded towards the free edge (see Fig. 15).

3. With a 1-3/4 inch edge distance loaded parallel to the free edge (see Fig. 16).

The predicted average **ultimate** shear capacity of a single 1/2" threaded stud (V_{cc}) installed in 2000 psi concrete (uncracked) at an embedment of 4 inches and an edge distance of 6 inches, is as follows:

$$V_{cc} = 13 \cdot (l/d_0)^{0.2} \cdot \sqrt{d_0} \cdot \sqrt{f'_c} \cdot (c_1)^{1.5}$$

$$= 13 \cdot (4/0.5)^{0.2} \cdot \sqrt{0.5} \cdot \sqrt{2000} \cdot (6)^{1.5}$$

$$= 9160 \text{ lbs}$$

$$V_s = 0.6\, A_s\, f_{ut}$$

$$= 0.6\, (0.142 \text{ in}^2)\, 120{,}000 \text{ psi}$$

$$= 10220 \text{ lbs}$$

The predicted average **ultimate** shear capacity of a single 1/2" threaded stud, loaded towards to the free edge, installed in 2000 psi concrete (uncracked) at an embedment of 4 inches and an edge distance of $1^3/_4$ inches, is as follows:

$$V_{cc} = 13 \cdot (4/0.5)^{0.2} \cdot \sqrt{0.5} \cdot \sqrt{2000} \cdot (1^3/_4)^{1.5}$$

$$= 1443 \text{ lbs}$$

$$V = \frac{A_{v,2}}{A_{v,o}} \cdot V_{cc}$$

since $A_{v,2} = A_{v,o}$

$$V = 1443 \text{ lbs}$$

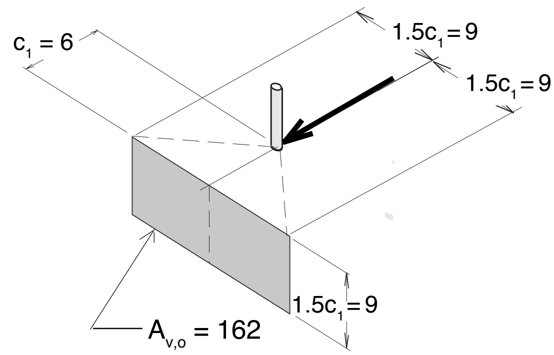


Fig. 14 - maximum projected area for an anchor bolt, loaded in shear towards free edge ($A_{v,o}$)

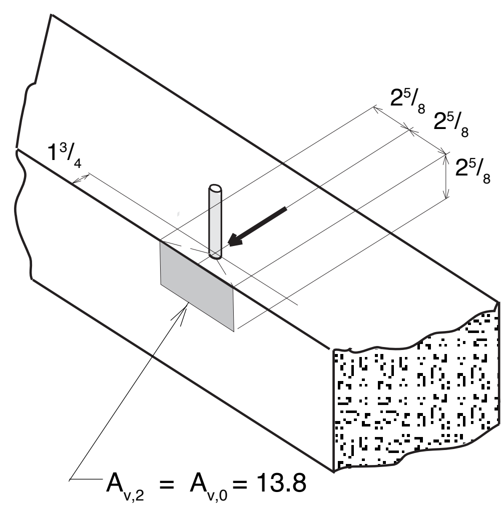


Fig. 15 - projected area for an anchor bolt, loaded in shear towards to free edge ($A_{v,2}$)

The predicted average **ultimate** shear capacity of a single 1/2" threaded stud, loaded parallel to the free edge, installed in 2000 psi concrete (uncracked) at an embedment of 4 inches and an edge distance of 48 inches, is as follows:

$$V_{cc} = 13 \cdot (4/0.5)^{0.2} \cdot \sqrt{0.5} \cdot \sqrt{2000} \cdot (48)^{1.5}$$

$$= 207{,}216 \text{ lbs}$$

$$V = \frac{A_{v,1}}{A_{v,o}} \cdot V_{cc}$$

$$= \frac{885}{10368} \cdot 207{,}216$$

$$= 17{,}688 \text{ lbs}$$

$$V_s = 0.6\, A_s\, f_{ut}$$

$$= 0.6\ (0.142\ \text{in}^2)\ 120{,}000\ \text{psi}$$

$$= 10{,}220 \text{ lbs (steel strength governs)}$$

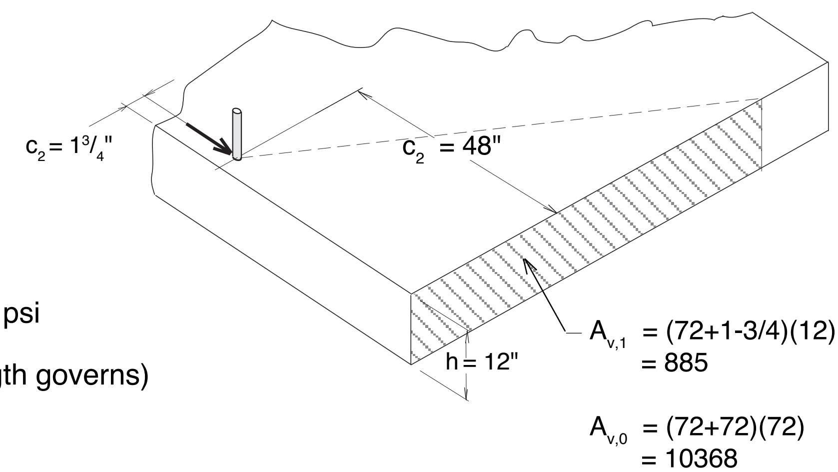


Fig. 16 - projected area for an anchor bolt, loaded in shear parallel to free edge ($A_{v,1}$)

METRIC CONVERSION FACTORS			
Designation	**If you have:**	**Multiply by:**	**To obtain:**
Force & Weight	lbf	4.448	N
	N	0.2248	lbs
Pressure & Stress	psi	0.006895	N/mm^2
	N/mm^2	145.0377	psi
Length	in	25.4	mm
	mm	0.0394	in
	ft	0.3048	m
	m	3.2808	ft
Mass	lb	0.4536	kg
	kg	2.2046	lb

Required embedments to develop tensile yield of ASTM A 615 Grade 60 reinforcing bar installed in concrete using Covert Injection Adhesive. [1, 2]

Rebar Size	Yield Load (lbs)[3]	f_c=2000 psi (inches)	f_c=3000 psi (inches)	f_c=4500 psi (inches)
No. 3	6,600	3.50	3.25	3.00
No. 4	12,000	4.75	4.50	4.00
No. 5	18,600	6.00	5.50	5.00
No. 6	26,400	7.00	6.50	5.75
No. 7	36,000	8.25	7.50	6.75
No. 8	47,400	9.50	8.50	7.75
No. 9	60,000	10.75	9.75	8.75
No.10	76,200	12.00	10.75	9.75
No. 11	93,600	13.25	12.00	11.00
No. 14	135,000	16.00	14.50	13.00

Required embedments to develop ultimate tensile failure of ASTM A 615 Grade 60 reinforcing bar installed in concrete using Covert Injection Adhesive. [1, 2]

Rebar Size	Ultimate Load (lbs)[3]	f_c=2000 psi (inches)	f_c=3000 psi (inches)	f_c=4500 psi (inches)
No. 3	9,900	4.50	4.00	3.50
No. 4	18,000	6.00	5.25	4.75
No. 5	27,900	7.25	6.50	6.00
No. 6	39,600	8.75	7.75	7.00
No. 7	54,000	10.25	9.25	8.25
No. 8	71,100	11.50	10.50	9.50
No. 9	90,000	13.00	11.75	10.75
No.10	114,300	14.75	13.25	12.00
No. 11	140,400	16.25	14.75	13.25
No. 14	202,500	19.50	17.75	16.00

[1] Required embedments calculated using the bond capacity method. ACI 318 and ACI 349 are currently working on drafts of code language which incorporates the basic concepts of the concrete capacity method.
[2] Table applies for anchors spaced at $s=1.5h_{ef}$ and placed at an edge distance of $0.75h_{ef}$ for full tension capacity.
[3] Current Working Stress Design Methods use allowable loads equal to 25% of yield strength. Yield loads are given as an aid for using Strength Design Methods.

Notes: