

Technical Bulletin # 691D

Bulletin Description

Anchor bolt Pull-Out Strength is the force required to pull a single bolt out of its foundation. The separation can occur between the epoxy grout and the concrete foundation or it can occur between the anchor bolt and the epoxy grout itself. This bulletin provides the formulas needed to calculate the force required to pull an anchor bolt out in either manner.

To calculate the Total Pull-Out Strength of the entire machine, multiply the force required to pull one bolt out times the total number of bolts.

When calculating Pull-Out Strength it is assumed that:

1. A clean, threaded rod or bolt with a coarse surface profile is used.
2. A nut and washer are installed at the bottom of the rod to act as a mechanical interference.
3. The anchor bolt hole is clean and dry, with no contaminants.

Bond Strength Epoxy to Concrete

The bond of the epoxy grout to the concrete foundation is stronger than the bond of the concrete to itself. Typically, concrete will separate next to the bond line of the epoxy and concrete. Therefore, the weakest link in the bond of epoxy to concrete is the concrete itself. The force required to pull concrete apart is called its *Shear Strength*. A conservative value for concrete shear strength is 600 psi. To determine the force required to pullout the bolt separating it at the epoxy to concrete bond, use the following calculation:

$$\text{Force} = D \times \pi \times L \times 600 \text{ psi}$$

Where:

F = Bolt Pullout Force in lbs.

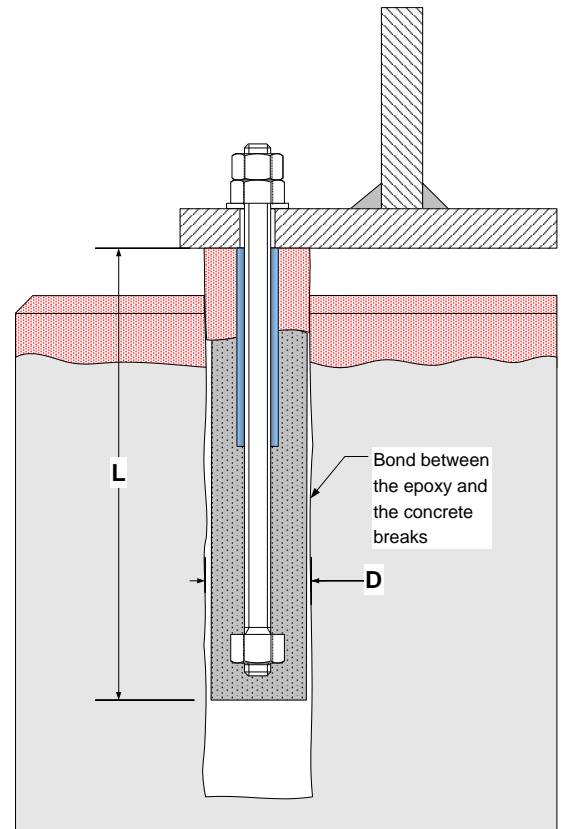
D = Grout Hole Diameter in inches

L = Length in inches of the grout hole

$\pi = 3.1415$

Below are examples of the force required to Pull-Out various size bolts out of various size holes.

PULL-OUT STRENGTH IN POUNDS				
HOLE DIAMETER	BOLT LENGTH			
	3"	4"	5"	10"
5/8"	3,534	4,712	5,890	11,781
3/4"	4,241	5,655	7,068	14,137
1"	5,655	7,540	9,425	18,849
1.5"	8,482	11,309	14,137	28,274
2.0"	11,309	15,079	18,849	37,698



Bond Strength Epoxy to Steel

The bond of grout to the steel anchor bolt can be calculated using 1600 psi as the Bond Strength of epoxy to steel. This too is also a conservative number. To determine the force at the grout-to-bolt interface, use the following calculation:

$$F = BD \times \pi \times L \times 1600 \text{ psi}$$

Where:

F = Bolt Pullout Force in lbs.

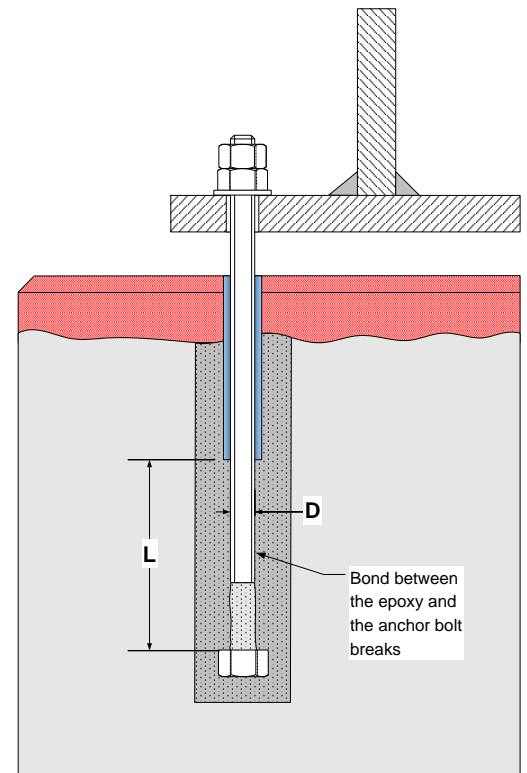
D = Bolt Diameter in inches

L = Length in inches of the bolt embedded in grout
(does not include the portion of the bolt that is wrapped with tape or inside a bolt sleeve).

$$\pi = 3.1415$$

Examples of the force required to separate a bolt from the surrounding epoxy assuming there is no nut.

PULL-OUT STRENGTH IN POUNDS				
BOLT DIAMETER	GROUTED BOLT LENGTH			
	3"	4"	5"	10"
3/8"	5,650	7,530	9,420	18,840
1/2"	7,540	10,040	12,560	25,120
3/4"	11,300	15,070	18,840	37,680
1"	15,070	20,100	25,130	50,260
1.5"	22,610	30,150	37,690	75,380



Pull-Out Strength – Anchor Bolt in Concrete

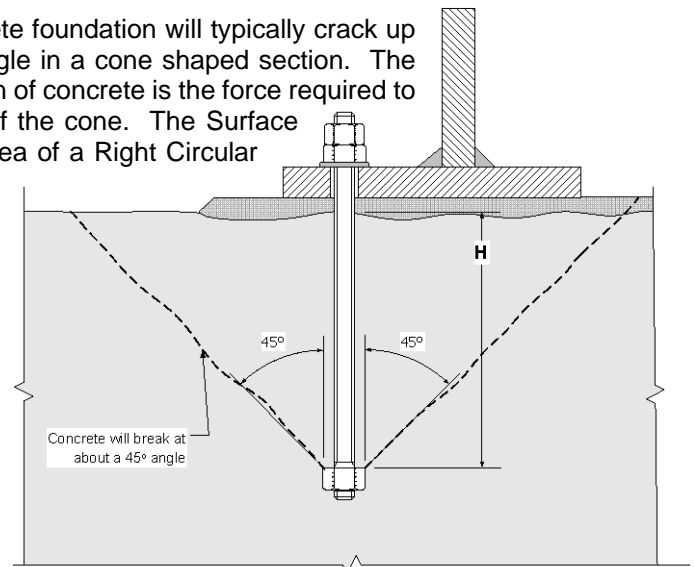
As a comparison, an anchor bolt set in a concrete foundation will typically crack up and out from the bottom of the bolt at a 45° angle in a cone shaped section. The force required to pull up this cone shaped section of concrete is the force required to separate concrete over the total surface area of the cone. The Surface Area of a Cone (SACone) = Lateral Surface Area of a Right Circular Cone with 45° Sides:

$$\text{SACone} = \pi \times 1.4142 \times H^2$$

The force required to pull the concrete apart is the Shear Strength of concrete (800 psi) times the Surface Area of the Cone.

$$\text{Force lbs} = 800 \text{ psi} \times \text{SACone in}^2$$

$$\text{Force lbs} = 800 \times \pi \times 1.4142 \times H^2$$



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