PROPER ANCHOR BOLT TENSIONING AND ITS RELATIONSHIP TO CHOCK LIFE

BY
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The entire concept of tightening an anchor bolt is to provide an additional load to be combined with the equipment deadweight that will hold a piece of equipment in a pre-determined position regardless of the designed operating forces that act upon it. When tightening an anchor bolt, most people attempting this procedure give little or no thought to what results their actions will accomplish.

If a wrench with a "cheater" extension or an improperly calibrated torque wrench is used to tighten an anchor bolt, then the force applied may result in the epoxy chocks being loaded far above or below their design. The condition of the anchor bolt threads and the type of lubricant used can have a dramatic effect on the bolt tightening and resultant chock loads. Some older published bolt torques were based on **DRY** assembly. Variables such as lubrication, plating, thread form, etc., may increase or decrease applied torque values by as much as 20%, and must be considered.

The following table gives the coefficients of friction of various lubricants used as thread lubricants:

lubricant	coeff. of friction	% of effort to friction	% of effort to tension	relative torque in ft. lbs. for a 1-3/8" bolt at 50% minimum yield
moly/oil	0.060	83.1	16.9	642
lead oil	0.094	88.6	11.4	945
copper & graphite with oil	0.100	88.6	10.8	998
* steel on steel	0.400	97.05	2.95	3669
* **DRY** included for reference only				

A bolt elongates as it is tightened. This elongation can be as much as .001" per inch of total bolt length for each 30,000 **P.S.I.** of induced tension.

Most epoxy chocks are designed to carry a minimum load of 500 psi. Improper anchor bolt maintenance can result in a loose chock. When an anchor bolt is initially tightened, it is done when a piece of equipment is shut down and it is cool enough for someone to safely work on it. In the case of an overhaul, then the entire unit is "cold iron". Once the equipment is started up and placed on line the anchor bolt can expand as much as .018" as it goes from its initial temperature, which in some cases could be as low as 30°F, up to operating temperature which normally is around 155°F-165°F. This adds up to a thermal range of around 125°F-135°F. This amount of growth will depend on the coefficient of thermal expansion of bolt material.

It is possible for the anchor bolt to actually come loose simply by thermal growth. Normally when this happens, the chock gets the blame for not being able to hold the engine. Epoxy chocks are designed to be in compression; they are not and never will be designed to act as a super glue to hold down a piece of equipment. Holding the piece of equipment in place is the job of the anchor bolt. Supporting the equipment at a desired elevation is the function of the epoxy chock. Very seldom, if ever, is the equipment shut down and the alignment or anchor bolt tension re-checked.

THE FOLLOWING ARE RULES OF THUMB FOR ANCHOR BOLT TENSIONING:

1. Use the proper type and grade nut for the anchor bolt being used.

2. Thoroughly clean the threads, nut face and flange where the nut face bears. If a rough surface is found dress it out to as smooth a surface as possible.

WARNING: SURFACE FINISH WILL AFFECT THE COEFFICIENT OF FRICTION. FRICTION LOSSES ARE HIGHER WITH VERY SMOOTH FINISHES BECAUSE THEY TRAP VERY LITTLE LUBRICANT AT NORMAL BEARING PRESSURES. HOWEVER, MACHINED FINISHES RANGING FROM 23 TO 250 RMS SHOW NO MEASURABLE EFFECT ON FRICTION LOSSES.

3. Equipment bolt holes and anchor bolts should line up. The distance between the anchor bolt and the vertical face of the bolt hole should be equal on all sides.

4. The nut face and washer should bear evenly for 360°. Misalignment of the anchor bolt by as little as 1° off its vertical axis can result in loss of resistance to fatigue.

5. Flat washers used between the nut face and the equipment will reduce galling if the washer hardness is less than the nut.

6. The lubricant used on the anchor bolt and nut threads must be suitable for the service it will be placed in. The pressure developed between the metal faces of the threads and washer will

range from 25,000 - 50,000 psi. It is important that the lubricant be able to withstand this pressure and not squeeze away or break down. Lubricants containing high percentages of molybdenum disulfide have a bearing pressure limit that allows anchor bolt tightening to a stress equivalent of 100% of yield.

THE FOLLOWING SUGGESTIONS ARE GIVEN AS TO SCHEDULED ANCHOR BOLT TENSIONING.

1. Initial tensioning - the bolt is tensioned and released three times with final tensioning accomplished on the third try. The amount of time between tensioning will be dependent on the anchor bolt material and its elastic property. This could range from a few minutes to many hours for the bolt to relax from the stretch imposed on it.

2. Seven (7) days after the equipment has been placed in service and is at operating temperature the anchor bolt is checked for proper tension. The bolt is NOT loosened for this or other tension checks.

3. Thirty (30) days after the initial tensioning and with the equipment at operating temperature, the anchor bolt is checked for proper tension.

4. Six (6) months after initial tensioning, the anchor bolts are checked for proper tension.

5. The anchor bolts are checked for proper tension every six (6) months thereafter.

Pull down at each anchor bolt should be monitored each time the bolts are checked for proper tension. These readings should be recorded and plotted. If excessive pull-down is recorded then the machine alignment should be rechecked.

The best method of obtaining proper anchor bolt tensioning is to monitor its stretch. There are several ways to monitor the stretch and ultimate load or clamping force exerted by the bolt. One way utilizes an indicator pin mounted in the top of the anchor bolt. Others include mechanical bolt tensioning devices used in lieu of a conventional nut, or load monitoring washers.

MEASURING PULL-DOWN AT ANCHOR BOLTS FOR EQUIPMENT INSTALLED ON EPOXY CHOCKS

When attempting to measure the amount of equipment pull-down, it is a common practice to use a dial indicator to observe the clamping effect on a piece of machinery when the anchor bolts are being tightened. The value and significance of the readings depend on how and where the dial indicators are positioned.

It is apparent why large indicator readings can occur. If the indicator head is positioned to contact the grout at the edge of the chock then only the chock volume change after cure will be measured, typically .0005" to .0015". This volume change after cure is not a problem if all chocks have the same amount of pull-down due to volumetric change during cure, and the amount of pull-down is less than .010" between anchor bolts. In the case of a gas engine compressor the alignment (web deflection) can be affected by a change in elevation at the anchor bolt of .010".

NOTE: FOR EVERY .010" ELEVATION CHANGE AT THE ANCHOR BOLT THE WEB DEFLECTION OF A CRANKSHAFT INCREASES BY APPROXIMATELY .001".

If the chock is poured on a steel soleplate or rail, then the indicator should be set to read off the steel surface. A soleplate or rail is not significantly deflected by the anchor bolt stress, so only the chock compression, if any, will be measured.

AS LONG AS ALL THE ANCHOR BOLTS ARE OF SIMILAR LENGTH AND MATERIAL, AND THEY ARE ALL TENSIONED (OR TIGHTENED) EQUALLY, THEN CRITICALLY ALIGNED EQUIPMENT SUCH AS A GAS ENGINE OR COMPRESSOR WILL NOT HAVE ITS ALIGNMENT ADVERSELY AFFECTED.

WARNING: FAILURE TO MAINTAIN PROPER ANCHOR BOLT TENSION COULD RESULT IN THE FOLLOWING:

Chocks will become loose, and over time oil and dirt (grit) will cause the chock and the equipment base to be abraded (wear) due to movement of the equipment.

The epoxy chock loses its ability to resist lateral forces. The coefficient of friction between the CHOCKFAST epoxy chock and cast iron is 0.7 as compared to 0.15 for steel to cast iron.

The anchor bolt may be placed in a shear condition.

Depending on the length of the equipment and rigidity of the frame, flexing on a horizontal plane could occur.

EQUIPMENT FOUNDATION SYSTEMS

Calculating Anchor Bolt Pullout Strength

Technical Bulletin # 691B

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.

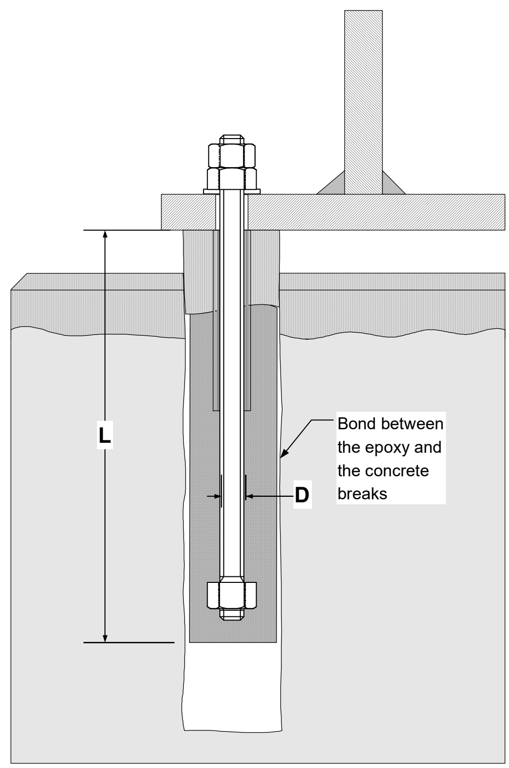
To calculate the Total Pull Out Strength of the entire machine, multiply the force required to pull one bolt out times the total number of bolts.

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 800 psi. To determine the force required to pullout the bolt separating it at the epoxy to concrete bond, use the following calculation:



$$\text{Force} = D \times \pi \times L \times 800 \text{ psi}$$

Where:
F = Bolt Pullout Force in lbs.
D = Grout Hole Diameter in inches
L = Length in inches of the grout hole

π **= 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				
	BOLT LENGTH			
HOLE DIAMETER	3”	4”	5”	10”
5/8"	4,710	6,280	7,850	15,700
3/4"	5,650	7,530	9,420	18,840
1"	7,530	10,050	12,560	25,130
1.5"	11,309	15,070	18,840	37,690
2.0”	15,070	20,100	25,130	50,260

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Bond Strength Epoxy to Steel

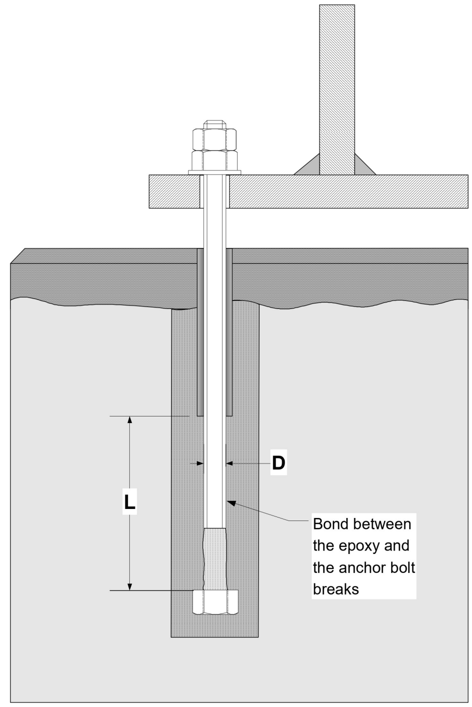
The bond of grout to the steel anchor bolt can be calculated using 1600 psi as the Bond Strength of epoxy to steel. This too is also a conservative number. To determine the force at the grout-to-bolt interface, use the following calculation:

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

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.

π = 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				
	GROUTED BOLT LENGTH			
BOLT DIAMETER	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

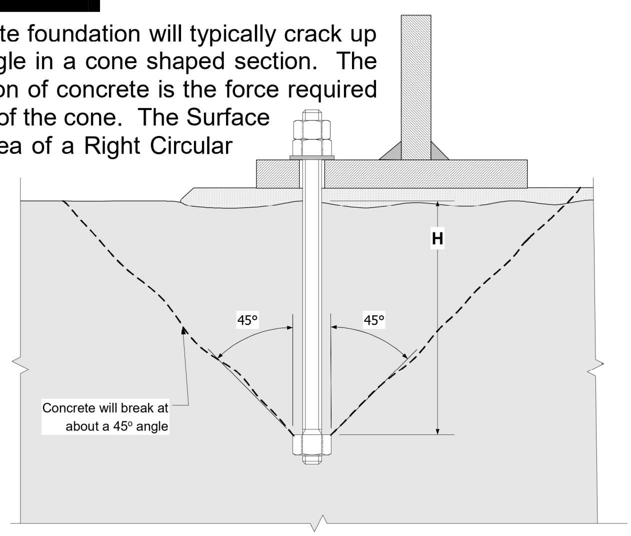
As a comparison, an anchor bolt set in a concrete foundation will typically crack up and out from the bottom of the bolt at a 45° angle in a cone shaped section. The force required to pull up this cone shaped section of concrete is the force required to separate concrete over the total surface area of 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.

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

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



Date

08/2005

Grouting Large Anchor Bolts

Technical Bulletin # 615C

Bulletin Description

This bulletin promotes the use of CHOCKFAST® Red or ESCOWELD 7505E/7530 as a grout for setting large anchor bolts in large, deep anchor bolt pockets. Typical 2-part epoxy chocking compounds (like CHOCKFAST Gray), while good for use in smaller holes, should not be used in such cases because the exothermic heat created by their large mass may crack the epoxy.

Deep anchor bolt pockets - up to 2 meters (6 ft) long and 200mm (8") wide - may be filled conveniently with a single placement of CHOCKFAST® Red or ESCOWELD 7505E/7530.

The gentle exotherm of CHOCKFAST® Red and ESCOWELD 7505E/7530 allows grout placement around large bolts to be executed with a single pour in extremely hot and humid climates with negligible shrinkage.

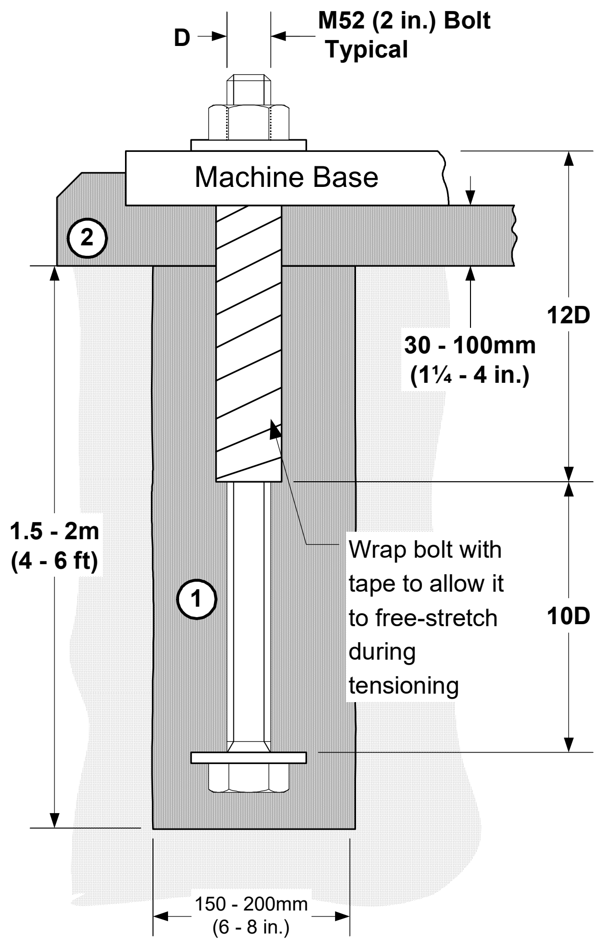
Design Considerations

Most process machinery is critically aligned within hundredths of a millimeter tolerance. Therefore, final horizontal leveling pours in contact with critically aligned baseplates, rails, soleplates or coupled machinery should be limited to a depth of 100mm (4").

Two separate grout pours are required:

1. The first pour in the Anchor Bolt Pocket filled is made using CHOCKFAST® Red or ESCOWELD 7505E/7530

2. The Final Leveling Pour under the critically aligned machinery is then made using CHOCKFAST® RED or ESCOWELD 7505E/7530



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