ANCHORAGE

Anchoring systems are a pretty complicated subject but for the exam you really just need to be worried about two main concepts.

1. How to solve for the Pull out strength of a anchored bolt
2. How to solve for the force applied on an anchored bolt

The underlying premise of anchorage is that rock masses are generally quite strong if progressive failure along planes of low strength can be prevented. Also in order to solve these problems there must be field test performed. Below are some of the tests performed.

Table 3-1
Summary of Purpose and Type of In-Situ Tests for Rock

Purpose of Test	Type of Test
Strength	Field Vane Shear[1] Direct Shear Pressuremeter[2] Uniaxial Compressive[2] Borehole Jacking[2]
Bearing Capacity	Plate Bearing[1] Standard Penetration[1]
Stress Conditions	Hydraulic Fracturing Pressuremeter Overcoring Flat Jack Uniaxial (Tunnel) Jacking[2] Chamber (Gallery) Pressure[2]
Mass Deformability	Geophysical (Refraction)[3] Pressuremeter or Dilatometer Plate Bearing Uniaxial (Tunnel) Jacking[2] Borehole Jacking[2] Chamber (Gallery) Pressure[2]
Anchor Capacity	Anchor/Rockbolt Loading
Rock Mass Permeability	Constant Head Rising or Falling Head Well Slug Pumping Pressure Injection

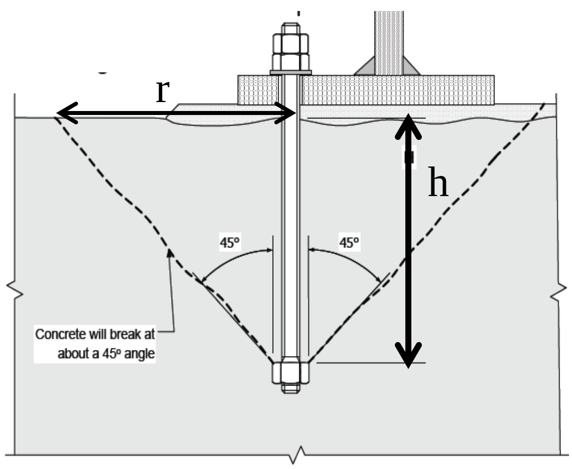
Pull-Out Strength

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. When solving for the pull out strength you need to know.

1. Surface Area of the Failure plane.
2. Depth anchor
3. Tested Shear strength of material

Pull-Out Strength in concrete or rock

An anchor bolt set in a concrete or rock 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 or rock is the force required to separate concrete/rock over the total surface area of the cone.



→ **The Surface Area of a Cone (SACone) =** $\pi \text{ x r} \sqrt{(r^2 + h^2)}$

→ The Volume of the Cone = $\frac{1}{3}\pi \text{ x } r^2 \text{ h}$

→ **If the angle is 45^{O} then the Surface Area of a Cone (SACone) = π x 1.4142 x h^2**

→ The force required to pull the concrete apart is the Shear Strength of concrete (this will be given but is usually 800 psi) times the Surface Area of the Cone.

Force lbs = material cohesion(lbs/in^2) x SACone (in^2)

Example: If an anchor bolt is embedded 12 inches in concrete (800psi shear strength). How many lbs of force will it take for the anchor to fail? Assume a 45^{O} failure surface.

→ SACone = π x 1.4142 x (12in)^2 = 640 in^2

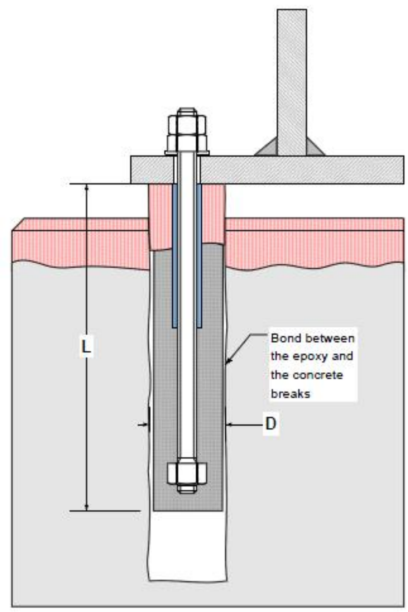
→ **Force = 800 lbs/in^2 x 640in^2 = 512,000 lbs**

Pull-Out Strength epoxy to concrete

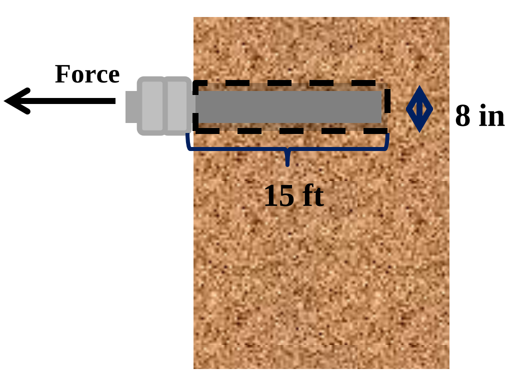
When dealing with pull out strength you also have to consider what if the bond between the epoxy to concrete is the failure plane. Usually the bond of the epoxy grout to the concrete foundation is stronger than the bond of the concrete to itself. Typically, concrete will separate next to the bond line 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:

Force = D x π x L x c

Where:
F = Bolt Pullout Force in lbs.
D = Grout Hole Diameter in inches
L = Length in inches of the grout hole
π = 3.1415
C = cohesion force (lbs/in^2)



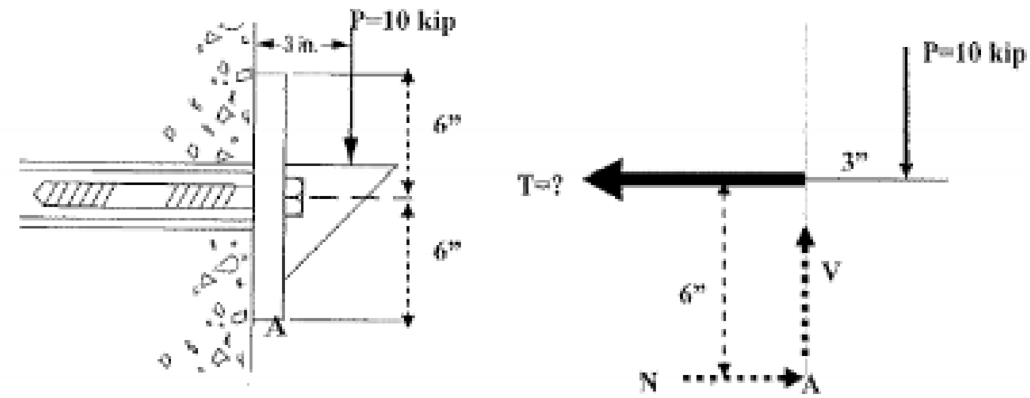
Example: Consider the below anchoring system. The bond between the anchor shaft and stone is 375 psi. The Diameter of the shaft is 8 inches and 15 feet long. What is the force that results in failure.



Force = D x π x L x bond strength
Force = 8 in x π x 15ft(12in/1ft) x 375 lbs/in^2
Force = 1696460 lbs

When solving for forces on a static anchor system you just have to remember the following equation. $\sum M_A = 0$

Example: For the bracket system shown below which includes a bolt and a stiff base plate, what is the force in the bolt?



Solution:

By applying the force P, there will be three reactions on the base plate, a tensile force from the bolt, a compression force N from the wall at point A and a vertical force, V along the wall surface. These forces must be in equilibrium. The best equilibrium equation is the sum of the moments about point A

$$\sum M_A = 0, so\ T(6) - 10(3) = 0 \text{ so therefore T} = 5 \text{ kips}$$