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Design and Installation Considerations for Ensuring Proper Anchoring of Rotating Machinery

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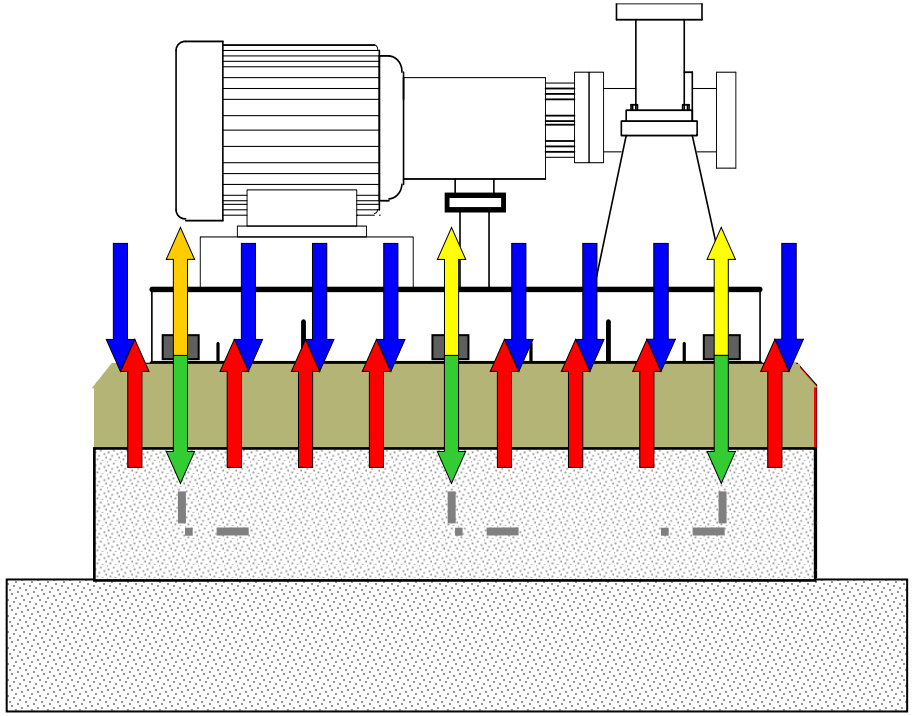
2018 Maintenance, Reliability, Operations Technical Conference

ITW Chockfast

Role of Anchor Bolts in Foundation Design

Role of Anchor Bolts

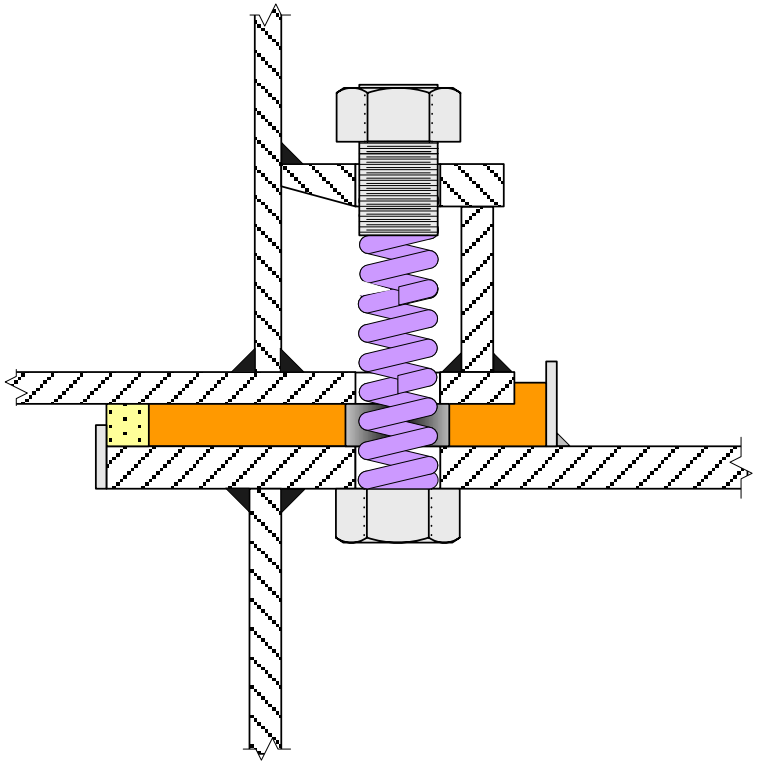
- To impart a downward, anchoring force and prevent upward movement of equipment.
- Work in tandem with properly installed transfer mediums to maintain the aligned position of the equipment.



Role of Anchor Bolts

- Anchor bolts are not intended to act in shear and do not directly transfer shear forces via bolt shank to the concrete.
- Friction provides the primary mechanism for transferring the dominant horizontal forces from the compressor to the foundation. [6]

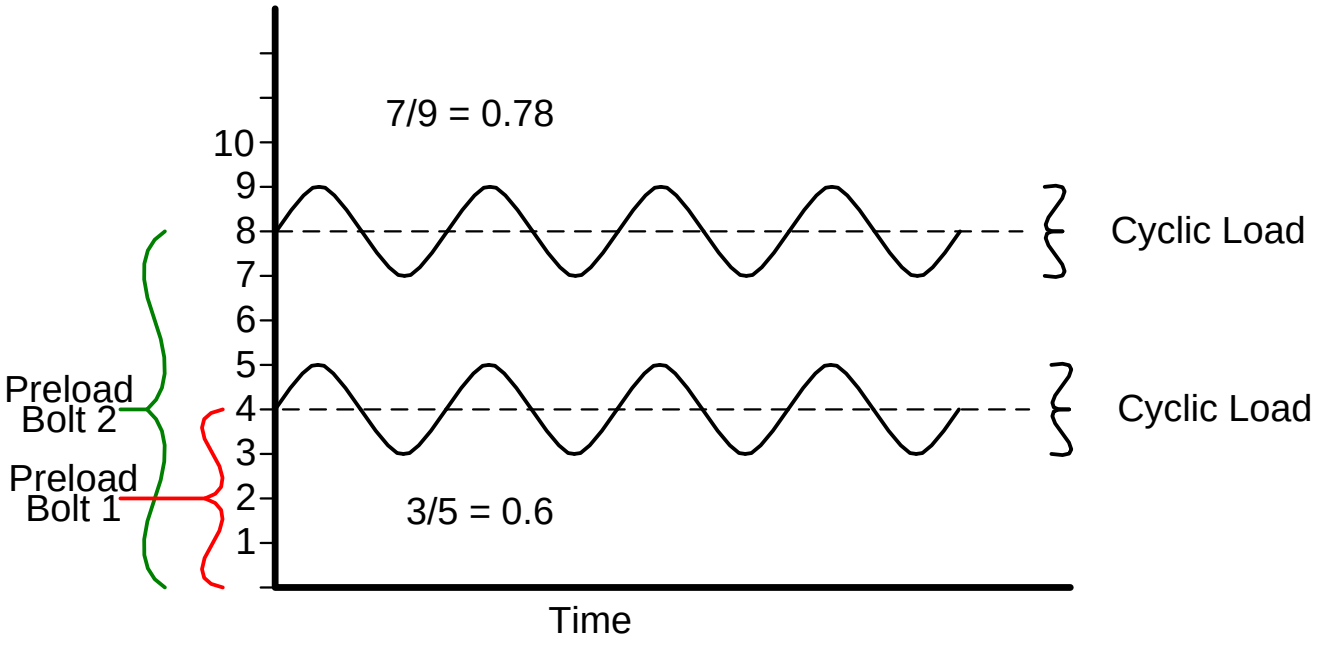
Anchor Bolts are Really Springs



- They store energy in exactly the same way that a stretched spring does.
- Stretching a bolt puts a large amount of energy into a joint and creates the clamping force to keep the joint tight.
- This energy is called Preload

Role of Preload

- Enough preload (clamping force) must be applied to overcome any externally applied cyclic loading. [1]
- Clamping force should be at least 5x the deadweight of the machinery.



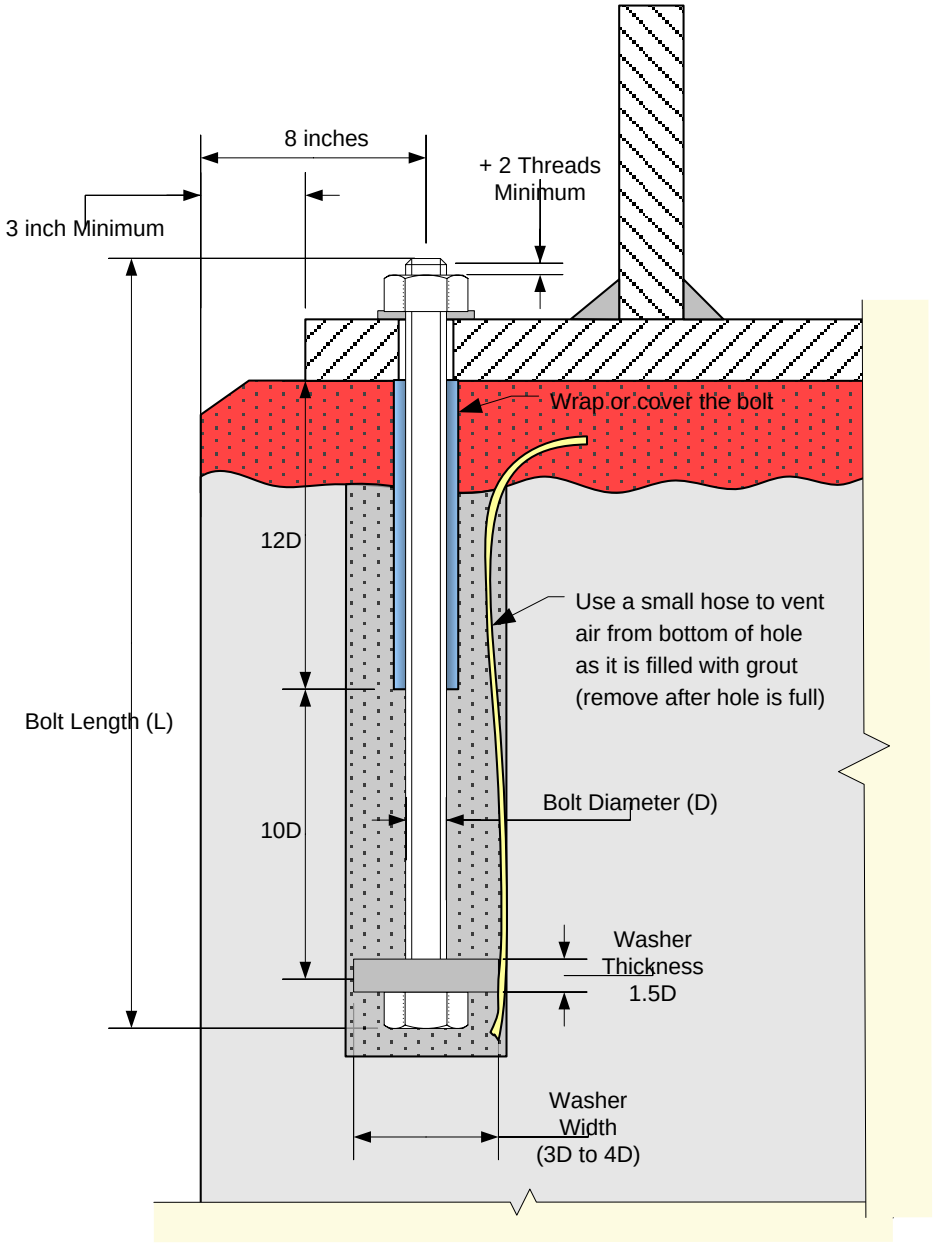
Role of Preload

- The higher the preload force, the better the joint. This is because it will prevent the assembled parts from moving and the joint from loosening.
- A highly preloaded joint is also more resistant to cycling loads since less of the cyclic portion of the load is experienced by the fastener.
- In general, the preload force determines the strength of the joint.
- Joints are stronger and more fatigue resistant with greater preload force.

Design of Anchor Bolts

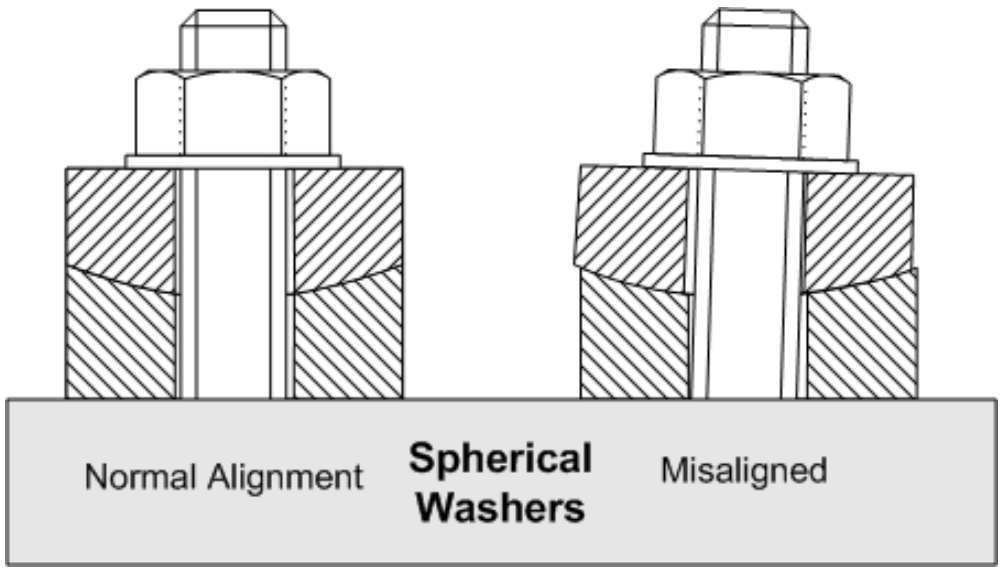
Proper Design of Anchor Bolts

- Grade: 4140 ASTM A193 B7
- Length: 1.2 m (48 inches)
- Terminate anchor bolts in the mat
- Allow 12 times the diameter or 40% to 50% of the length of the bolt to free-stretch
- Allow 10 times the bolt diameter to be embedded



Nuts and Washers

- Nuts
  - Grade: ASTM A194
  - 2H - High Strength
- Washers
  - Spherical Washers

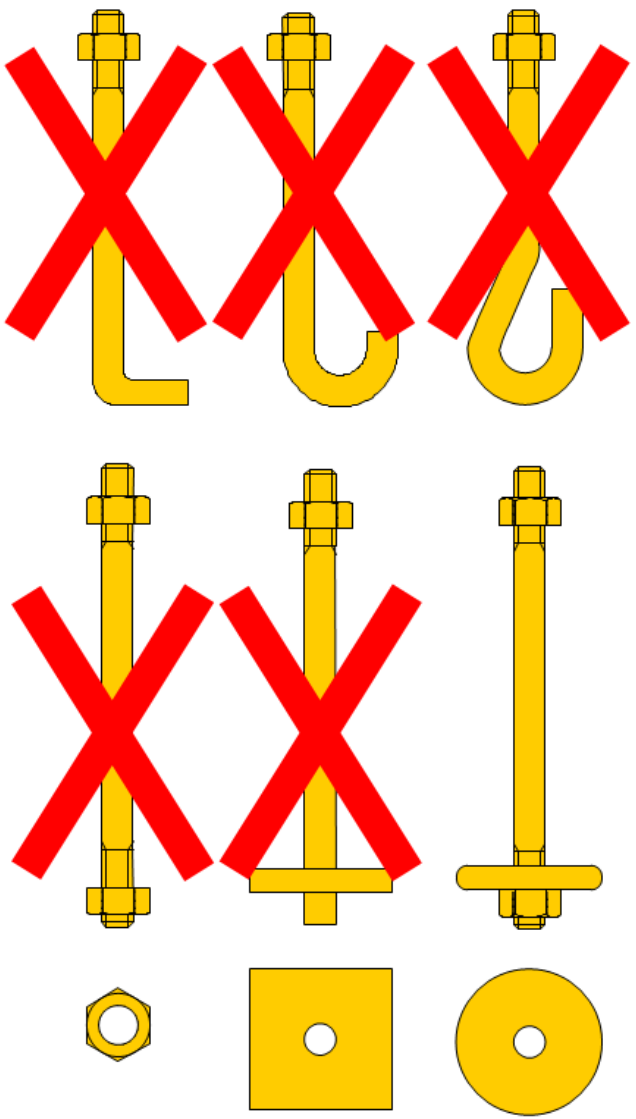


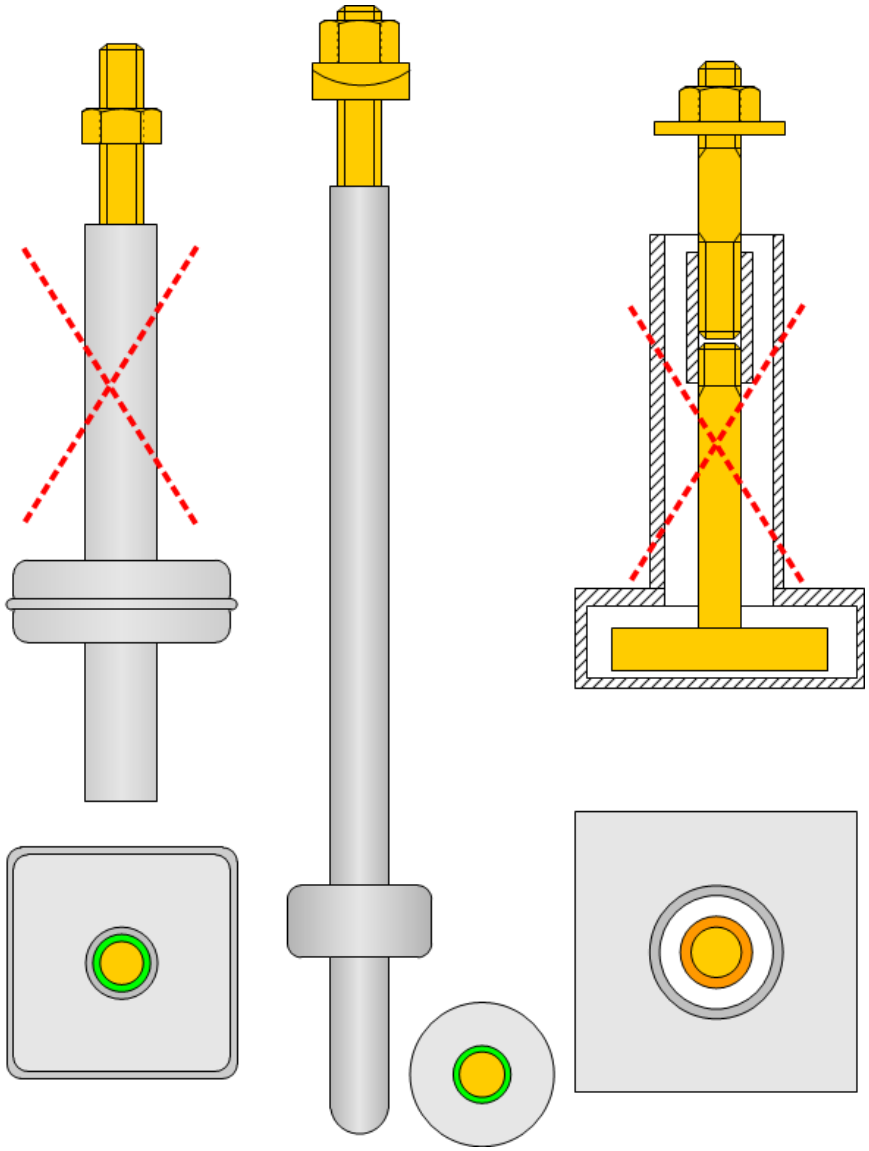
Common Perceptions on Nuts

- Perception – Use of double nuts will “lock-in” tension on anchor bolts and provide security against loosening.
- *Reality – Usage of double nuts does not provide greater security against loosening.*

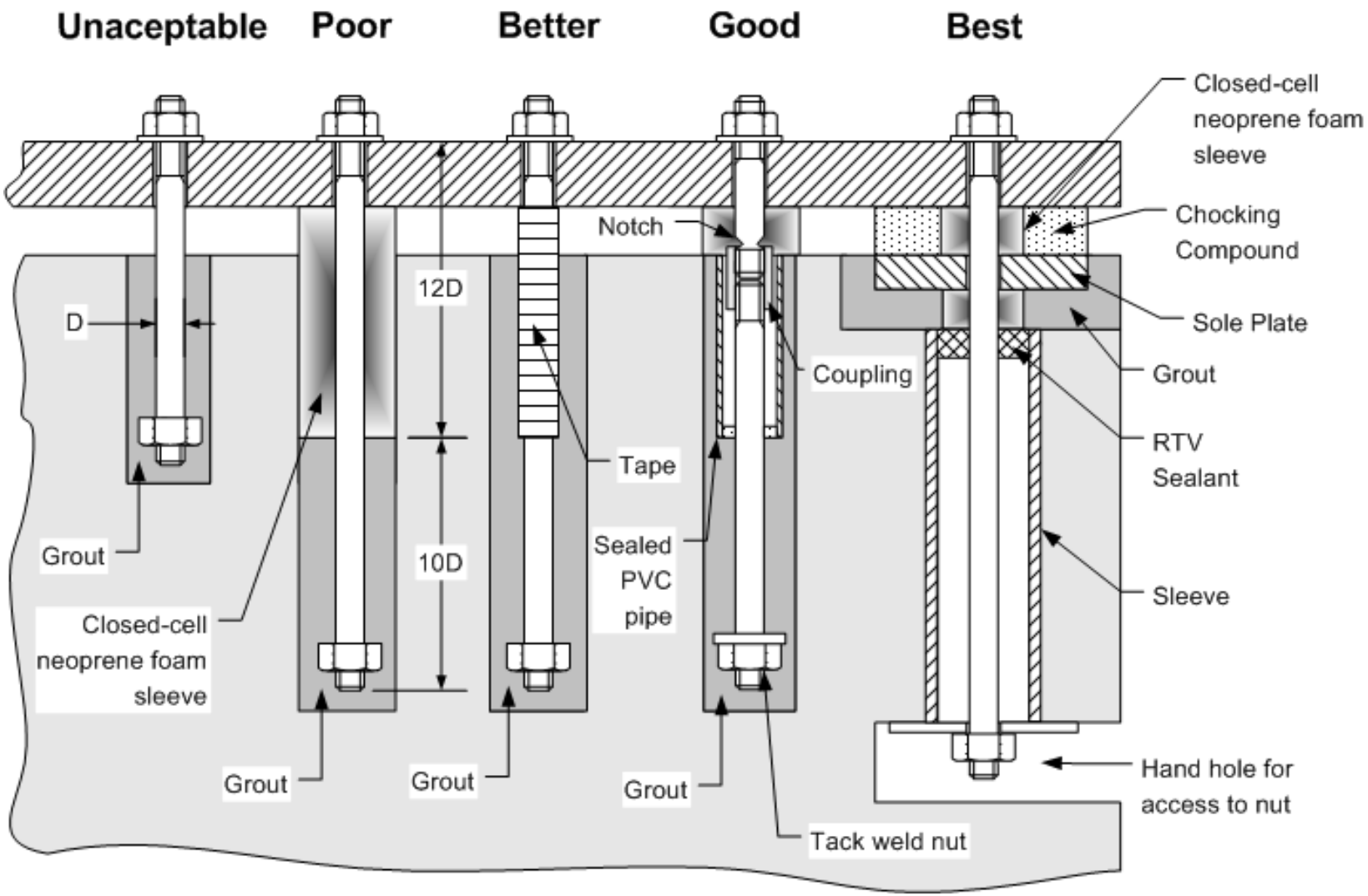
- Perception- Usage of locking or anti-rotation devices will prevent unintended loosening of anchor bolts.
- *Reality- Usage of locking devices has not been shown to reliably prevent lose of anchor bolt tension.* [1]

Types of Anchor Bolts

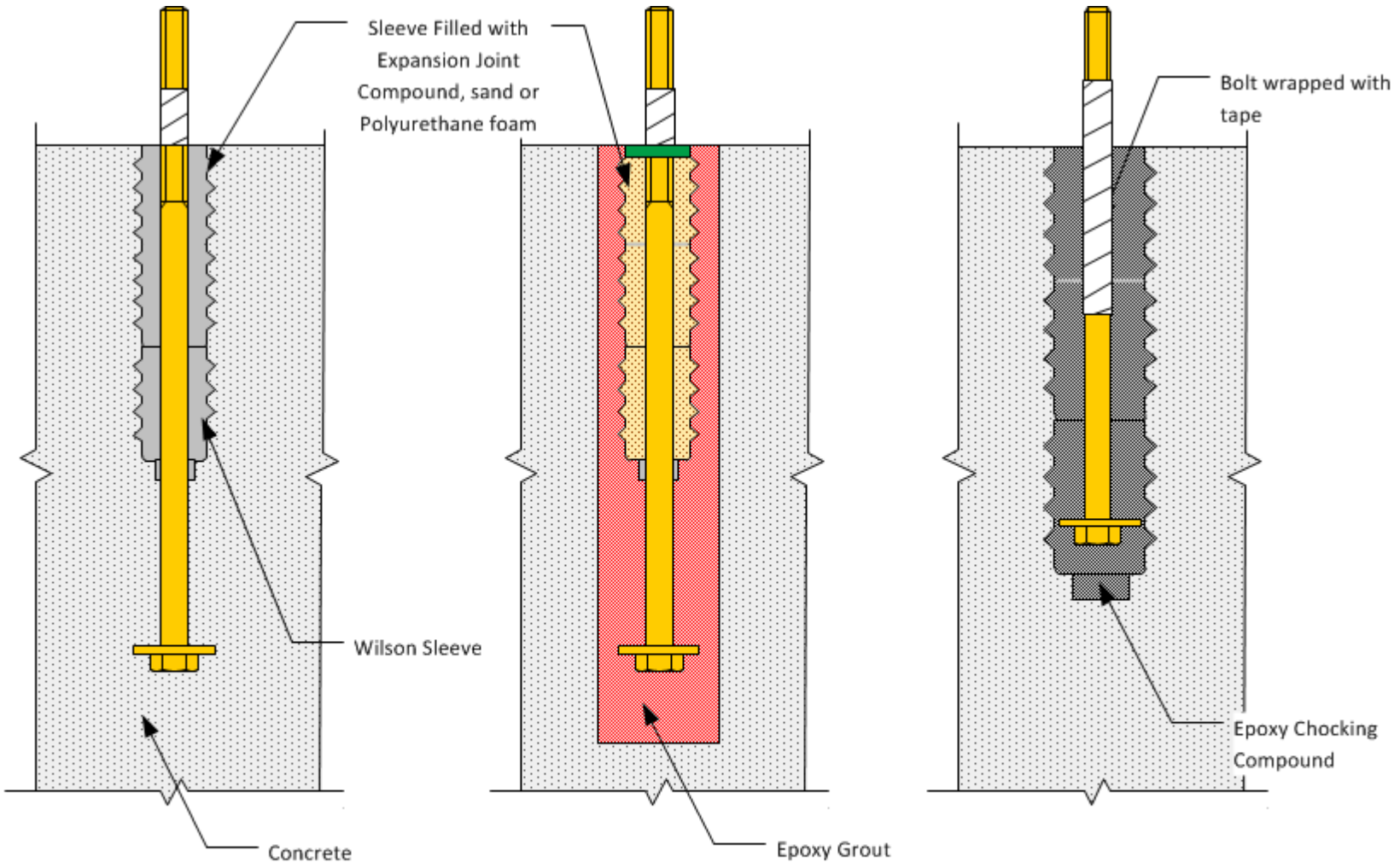




Best Anchor Bolts



Anchor Bolt Configurations

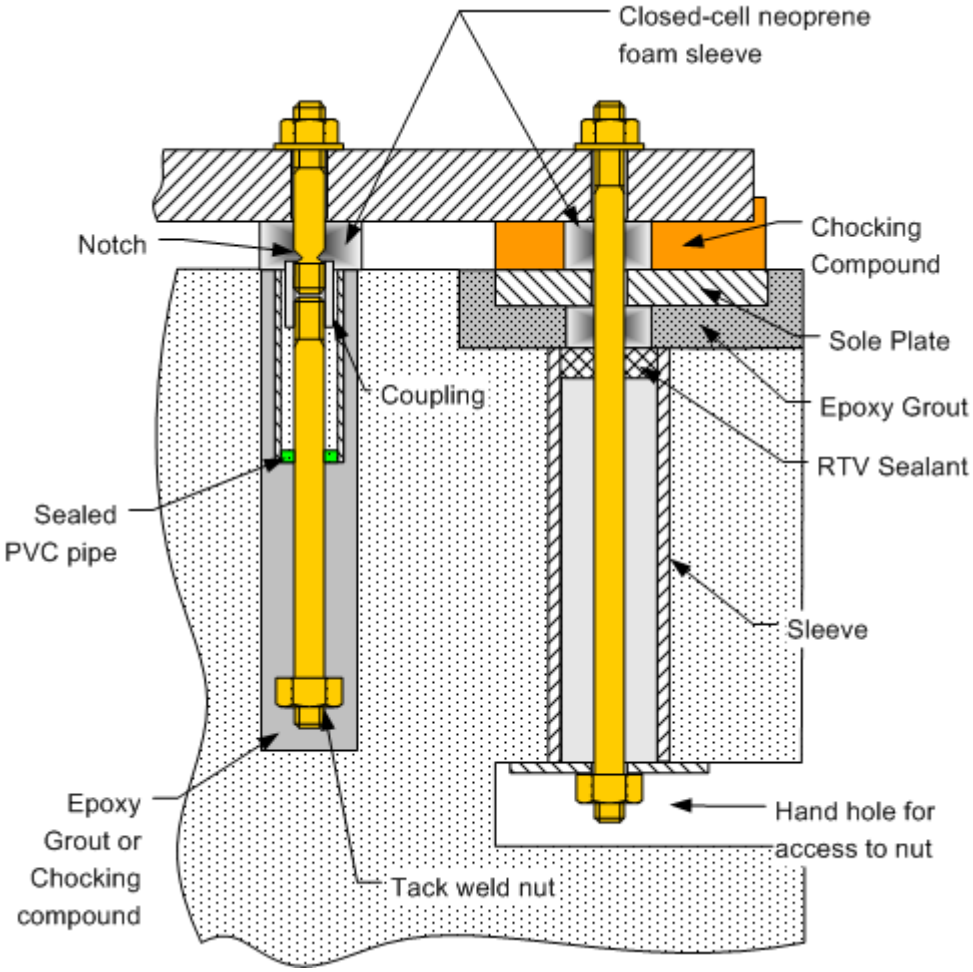


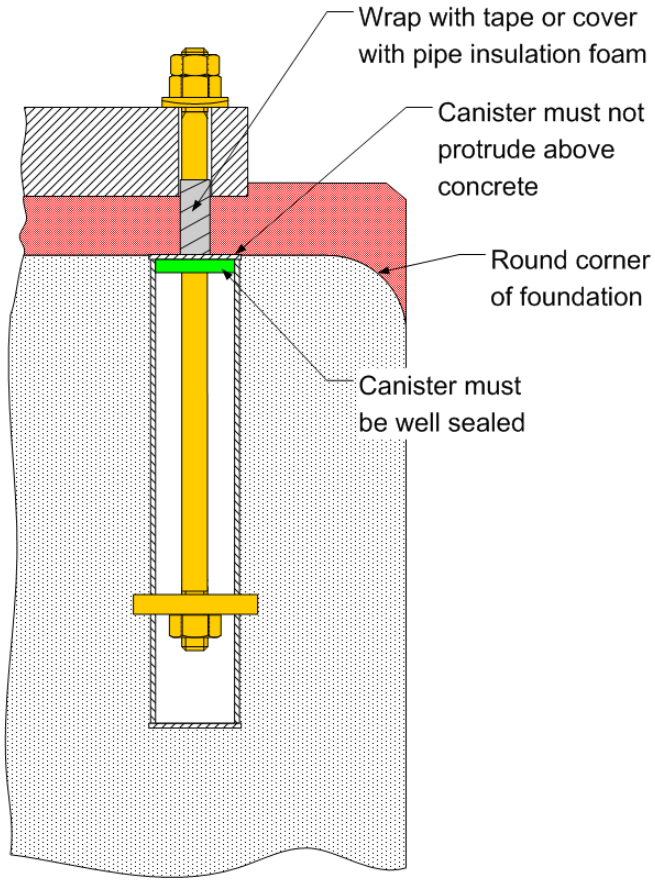
Anchor Bolt Embedded in Concrete

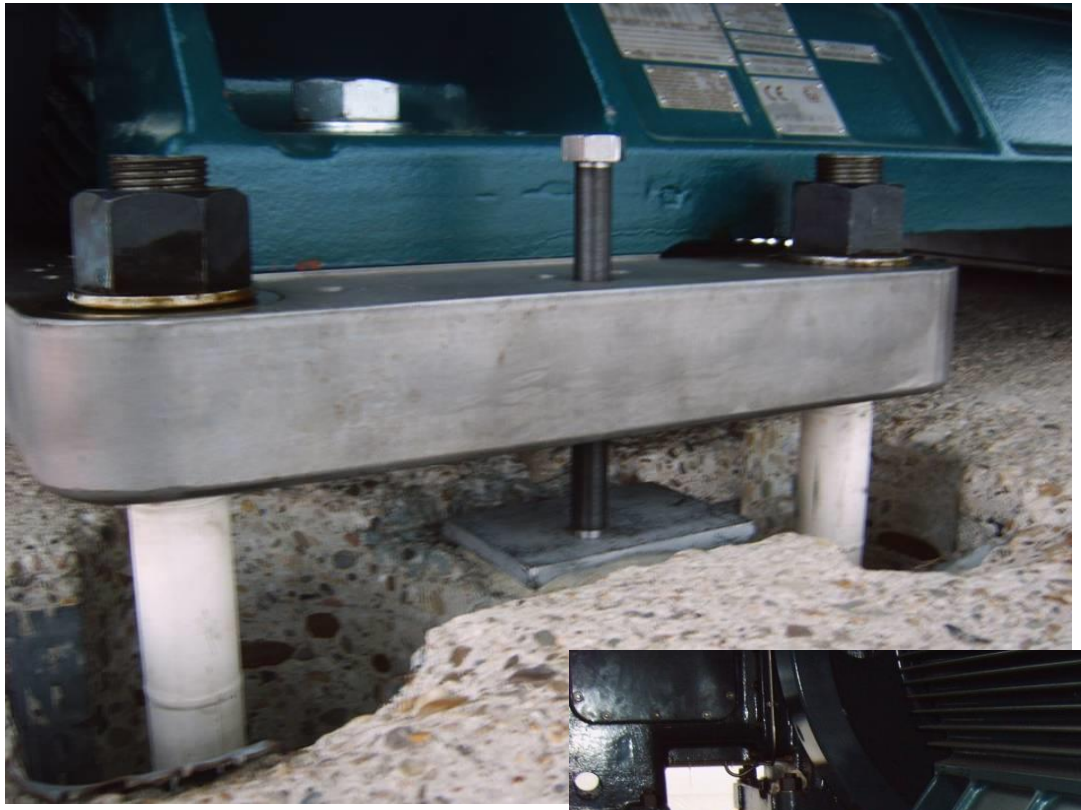
Anchor Bolt Embedded in Epoxy Grout

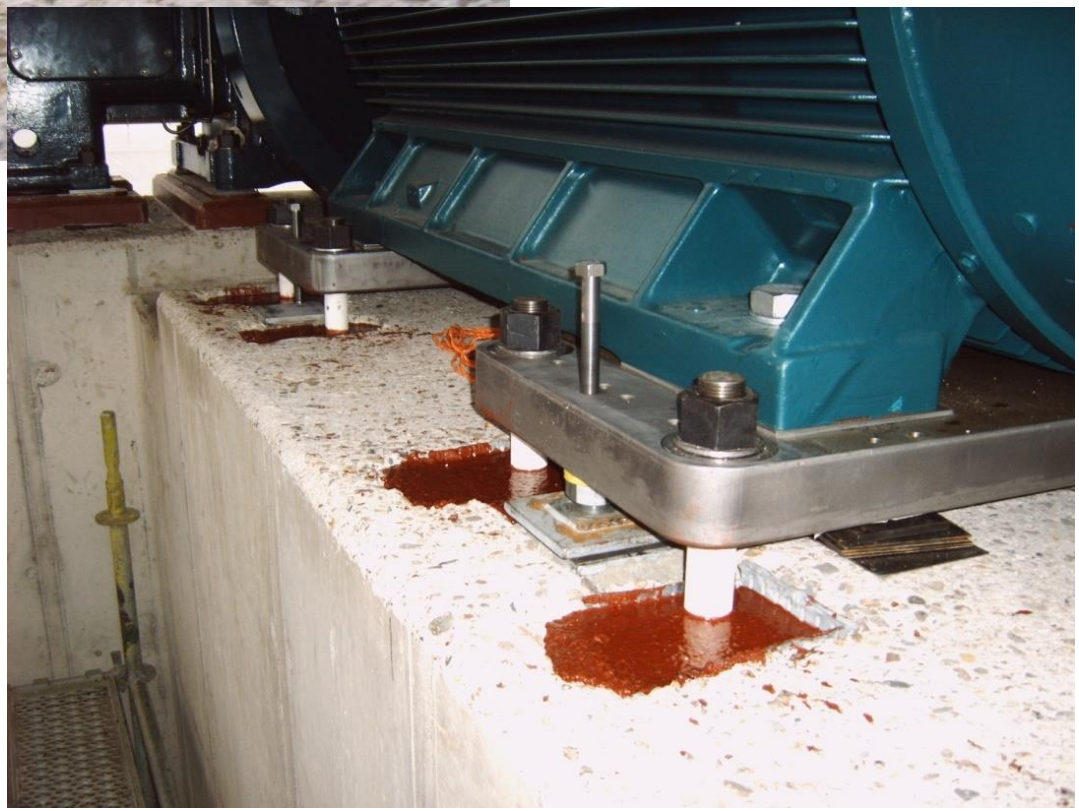
Anchor Bolt Embedded in Sleeve

More Anchor Bolt Configurations







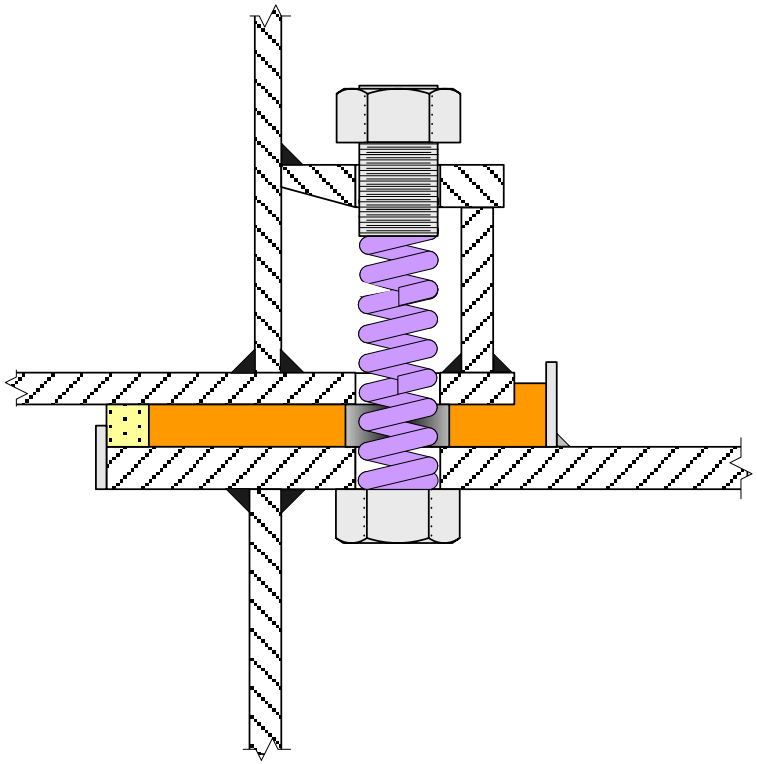


Bolt Tensioning

How a Bolted Connection Works

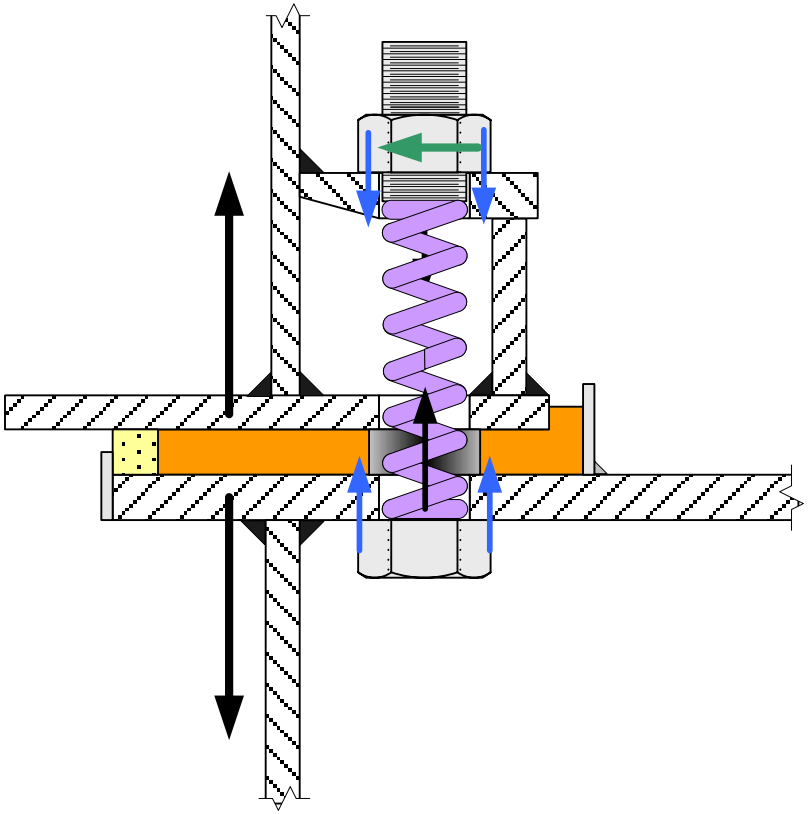
- A bolted connection works (stays together) because it contains energy.
- The greater the energy stored in the connection, the better it works.
- Energy is stored in a connection in one of 3 ways:
  - Elastic energy of the stretched bolt
  - Elastic energy of the compressed transfer medium/epoxy
  - Elastic energy of the compressed metal parts
- Of these, the most important is the energy stored in the bolt.

No Torque – No Tension



Until the nut is torqued there is no tension on the bolt so it does not have the power to hold the equipment to its foundation.

Applying Tension to the Nut…



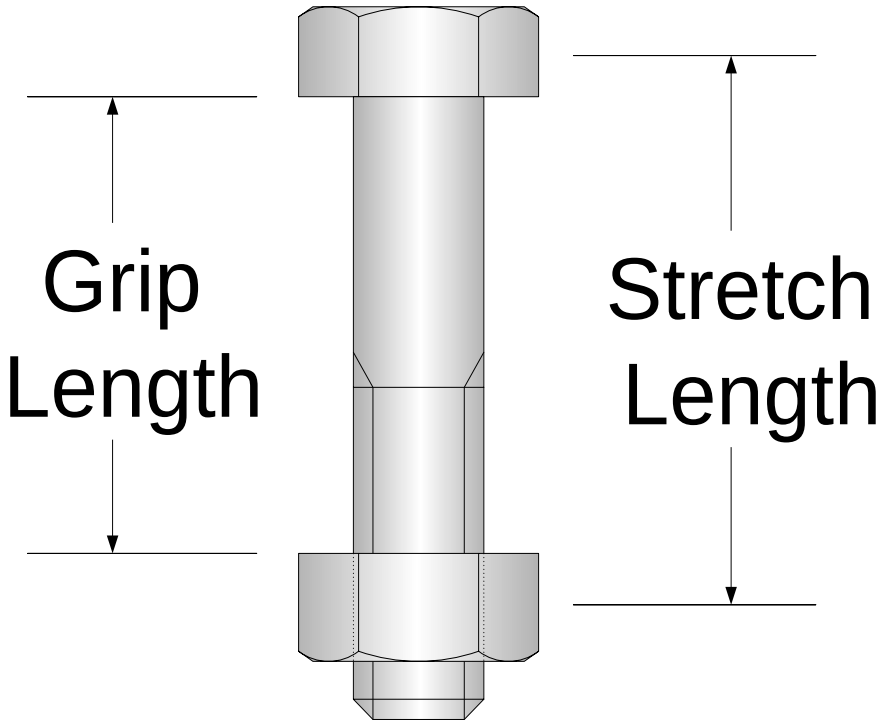
...forces the bolt to stretch like a spring which...

...creates tension inside the bolt causing...

...the nut and bolt head to create a clamping force squeezing the equipment mounting pad and its foundation together with...

...a greater force than the force trying to move them apart

What Part of a Bolt Stretches?



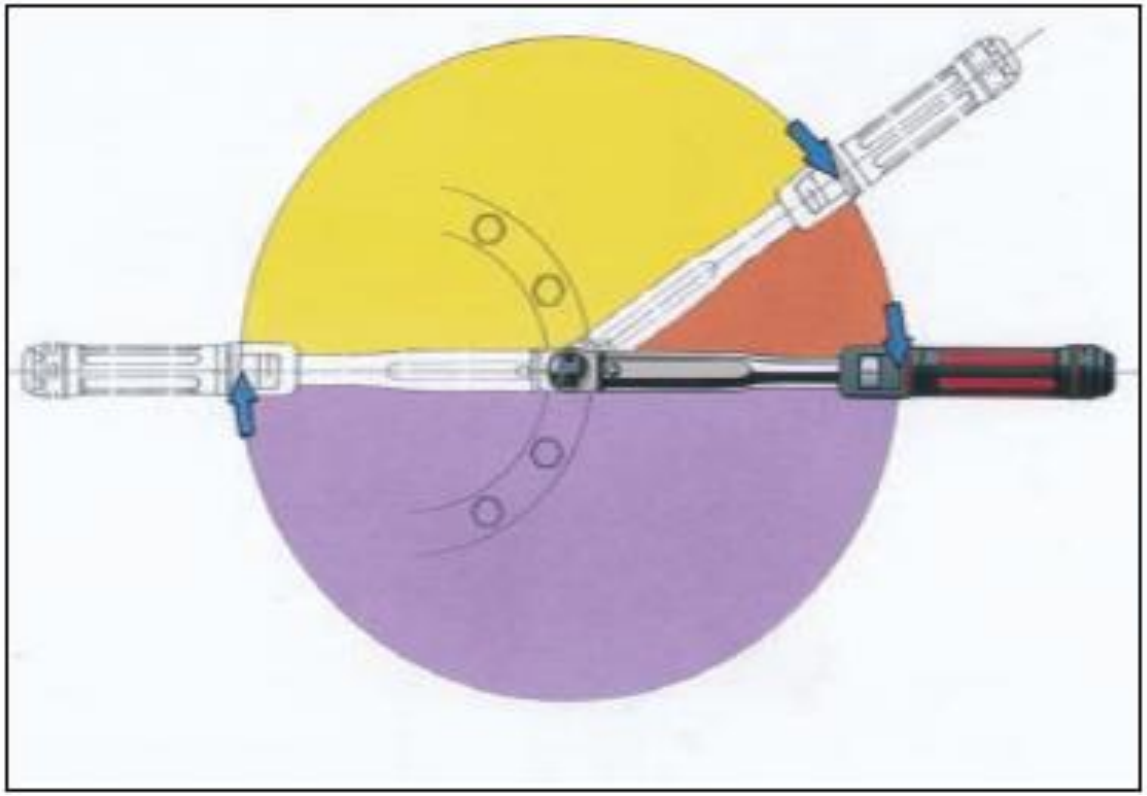
The part of the bolt that stretches is the **Grip Length** plus one half the nut height and one half the head height.

Preload Measuring Method Error

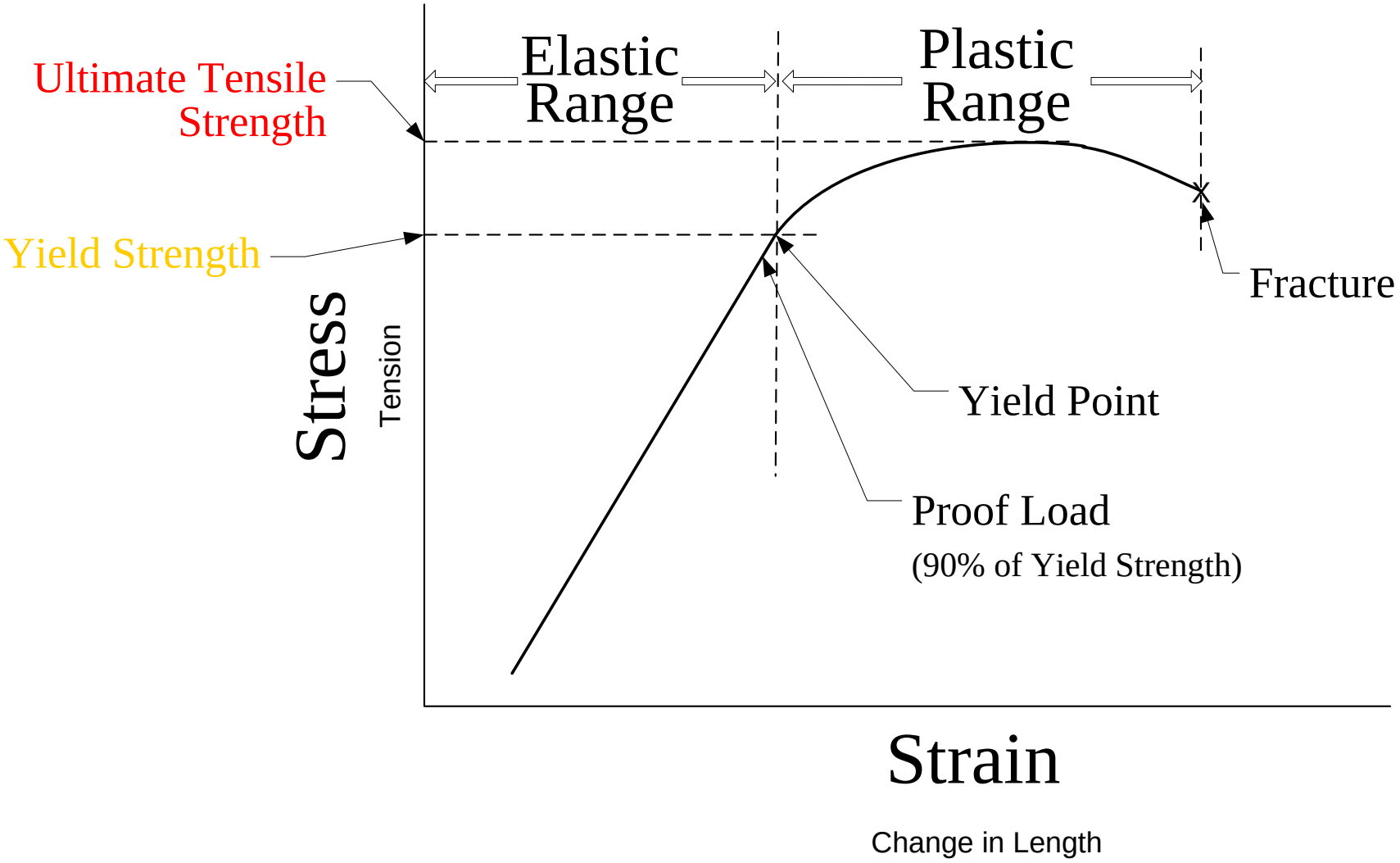
• Operator "Feel"	+/- 35%
• Torque Wrench	+/- 25%
• Angle Torqueing	+/- 15%
• Load Indicating Washer	+/- 10%
• Fastener Elongation	+/- 5%
• Strain Gauges	+/- 1%

*Industrial Fastener Institute's Estimate

Friction Loss in Bolt Torqueing



The Benefits of Bolt Tension



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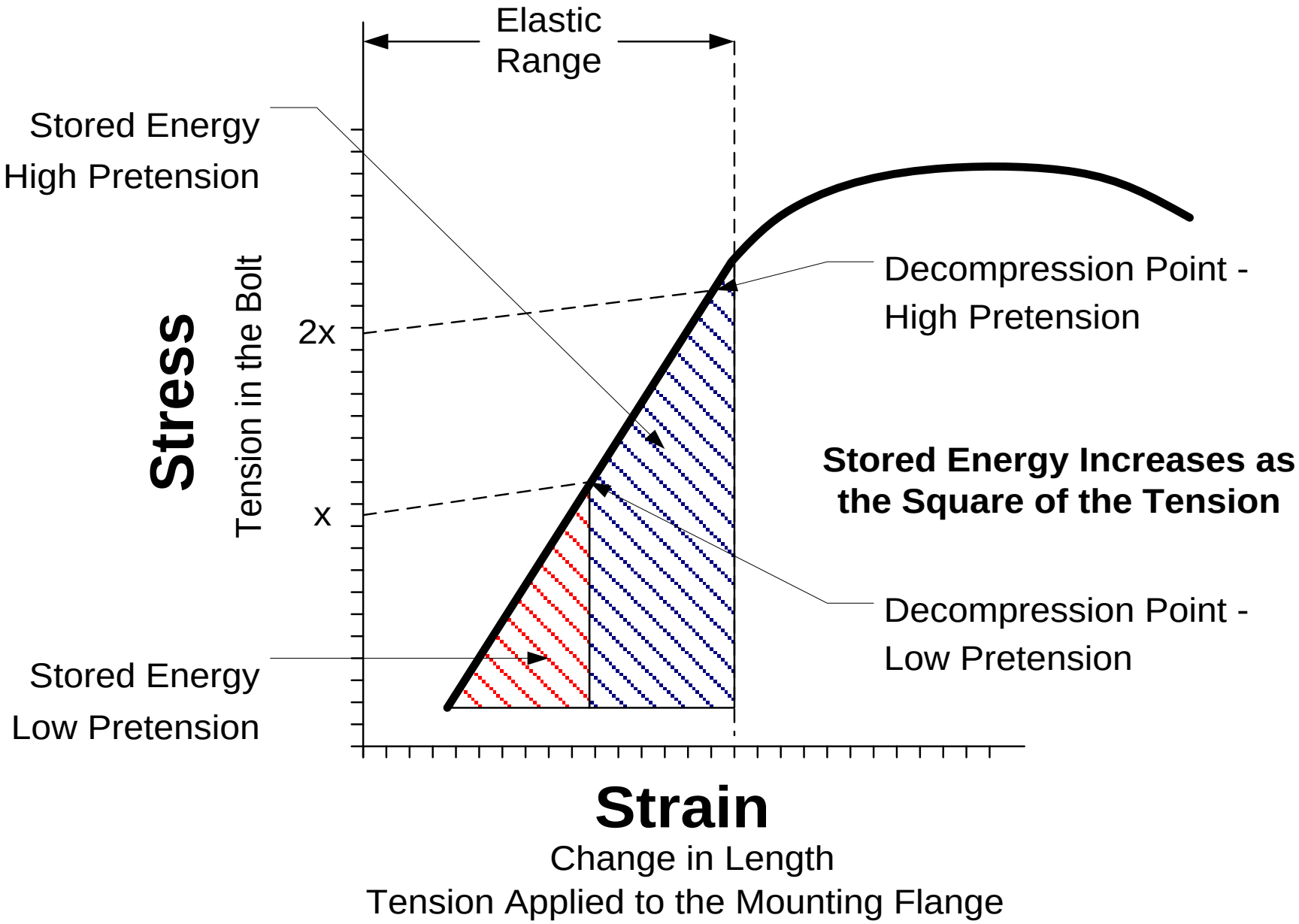


Tensioning Recommendations

- Nuts Hand-Tool tight until grout hardens
- Tension Bolts with Hydraulic Bolt Tension
- Design for a maximum epoxy chock / grout loading is 3,4 MPa (500 psi)
  - Check with epoxy manufacturer for loading recommendations per product and application
- Tension bolts to maximum of 65% to 70% of their yield strength
- Re-tighten after compressor & driver have come up to temperature

Recommended Tensioning Procedure [1]

- Tension and release the bolt two times. Perform final tensioning or preload on the third try.
- Check the anchor bolt for proper tension and make any necessary adjustments seven days after the equipment has been placed in service.
- Thirty days after the initial tensioning, re-check the anchor bolt for proper tension with the equipment at operating temperature.

Recommended Tensioning Procedure[1]

- Six months after initial tensioning, check the anchor bolts for proper tension and make adjustments.
- Check the anchor bolts for proper tension every six months thereafter and make adjustments if necessary.

Why Bolts Fail

Signs of Bolt Failure

- Increased wear rates of bearings and seals associated with rotating equipment elements.
- Damage or catastrophic loss of primary rotating or reciprocating equipment components such as crankshafts, distance pieces, etc.
- Loose anchor bolt washers (spinning during operation).
- “Winking” effect between base plates/sole plates and grout cap on typically oil soaked bases.
- Loss of bolt tension on re-torque regular maintenance inspections.
- Noticeable vibrations present in the equipment where little to no vibrations existed before.

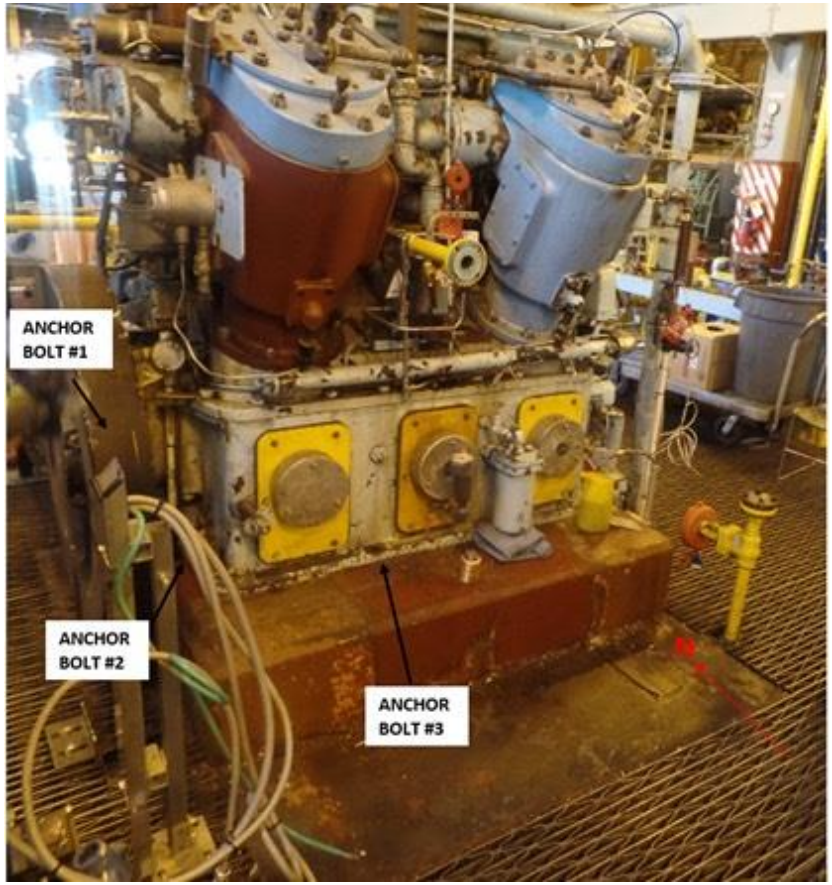
Common Causes of Bolt Failure

- Bolt Loosening
- Bolt Deformation
- Fatigue
- Combined loading in tension and bending
- Corrosion

Case Study

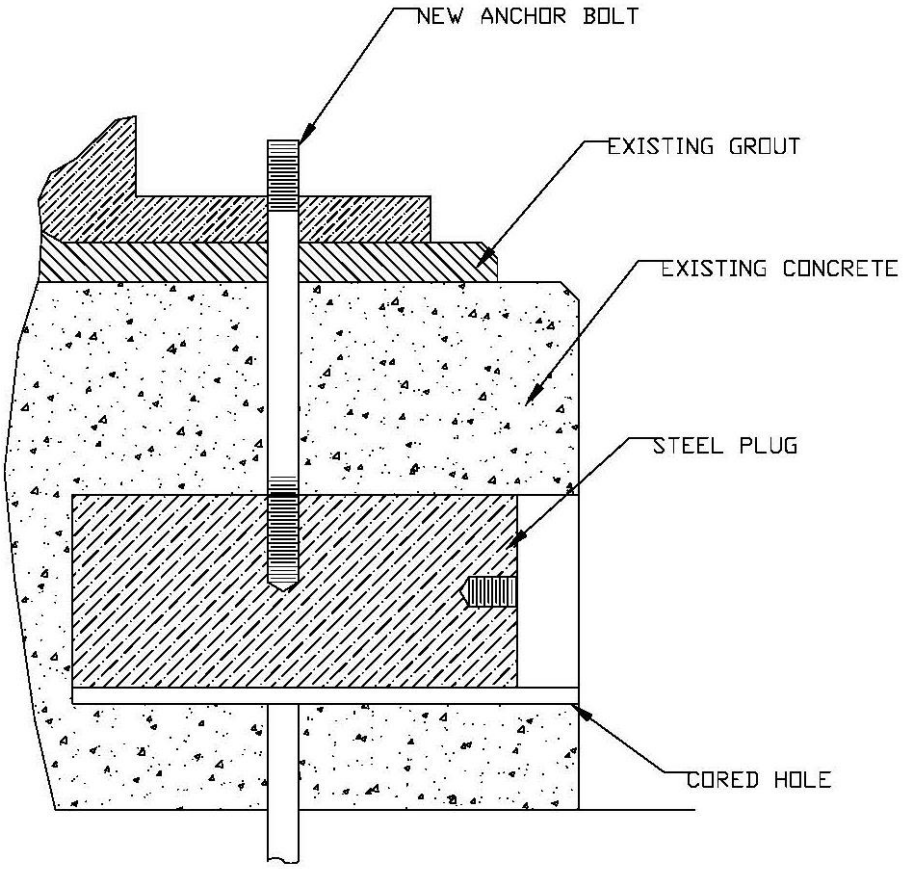
Case Study

- Called to investigate broken anchor bolts.
- When attempting to torque the anchor bolts it was discovered that three anchor bolts had lost tension.
- Out of a total of 8 anchor bolts on this unit…
  - Two of the three anchor bolts were found to be complete sheared off. One was broken approximately 6” down from the flange and the other much closer to the compressor frame (approximately 1” down).
  - The third anchor bolt had yielded but appeared to be intact



Case Study

- Attempted a weld repair to the broken anchor bolt. This weld repair attempt failed at the weld zone within a short time.
- Proposed a solution without removal of the compressor, per the customer request
- Full access to the foundation below the frame was available.



Case Study

- Horizontal coring of the concrete base to intersect the broken anchor bolts.
- Concrete demolition exposed the sleeved end and the embedded end of the anchor bolt.
- The now free upper anchor bolt segment was removed vertically.
- A large steel plug was fabricated and inserted in the excavated cavity.
- New anchor bolt assemblies were threaded into steel repair plugs from above, with wrapping to allow for bolt stretch.

Case Study

- Forms were affixed and sealed overtop of the excavated cavity in the foundation.
- Grout pour piping (large diameter) and vent tubing (small diameter) were installed at the top of forms.
- Chockfast Red epoxy grout was mixed and placed in the cavity until flowing through the vent tubes.
- After sufficient cure time, grout pour pipe, vent tubes and wooden forms removed.
- Final torque applied and was consistent with the load applied to the non-modified anchor bolt positions.

Conclusion

- Proper design, selection, and installation of anchor bolts is key to long-term reliability of machinery foundations.
- Anchor bolts are maintainable item and it is recommended that tension be checked every 6 months to prevent premature failure.

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