



Falsework Shear Values for Bolts/Anchors in Concrete

General Information

It is extremely important to consider the effect on concrete of bolts loaded in shear parallel to the face of the concrete especially within 6 inches of a concrete edge. Examples of these loading conditions are bolts inserted in the edge of decks which may support vertical falsework loads, or for pins which may be placed in decks and loaded horizontally as shear resistance for K-Rail.

Bar reinforcing steel under, and perpendicular to, the axis of a bolt imbedded in an edge of deck provides some resistance to shear failure of the concrete. Bar reinforcing steel under, but parallel to the bolt axis (without perpendicular reinforcing), provides little additional resistance to concrete shear failure. Unreinforced concrete will offer the least resistance to concrete shear failure.

Bolts or anchors inserted into concrete with impact drills or hammers will generally exhibit lower shear resisting capacity because of potential fracturing of the concrete. The lowest shear resisting capacity may well be furnished by wedge fit type anchors in holes made by impact tools since the wedging action can induce additional fracturing of the concrete.

Research

Bolts of 60 ksi tensile strength, approximately 5/8" in diameter and approximately 11-7/8" long, were cast about 7-7/8" deep at various edge distances (d) up to about 6 inches in unreinforced concrete blocks. The bolts were load tested at right angles to the block surfaces after the concrete had gained sufficient strength. Published test results of concrete failure due to the lateral loads on the bolts showed that the modes of failure consisted of concrete failure with and without wedge cones, or with pullout cones, or by shear failure of the bolts.

Test results for concrete shear strengths adjusted to an averaged concrete compressive strength f'_c of approximately 3,000 psi have been plotted in Figure 1. Assuming² that the shear strength of concrete is a function of f'_c a family of curves related to the 3,000 psi curve were generated and included in Figure 1. The curves of Figure 1 represent ultimate values which need to be adjusted with an appropriate safety factor which is determined from Table 1.

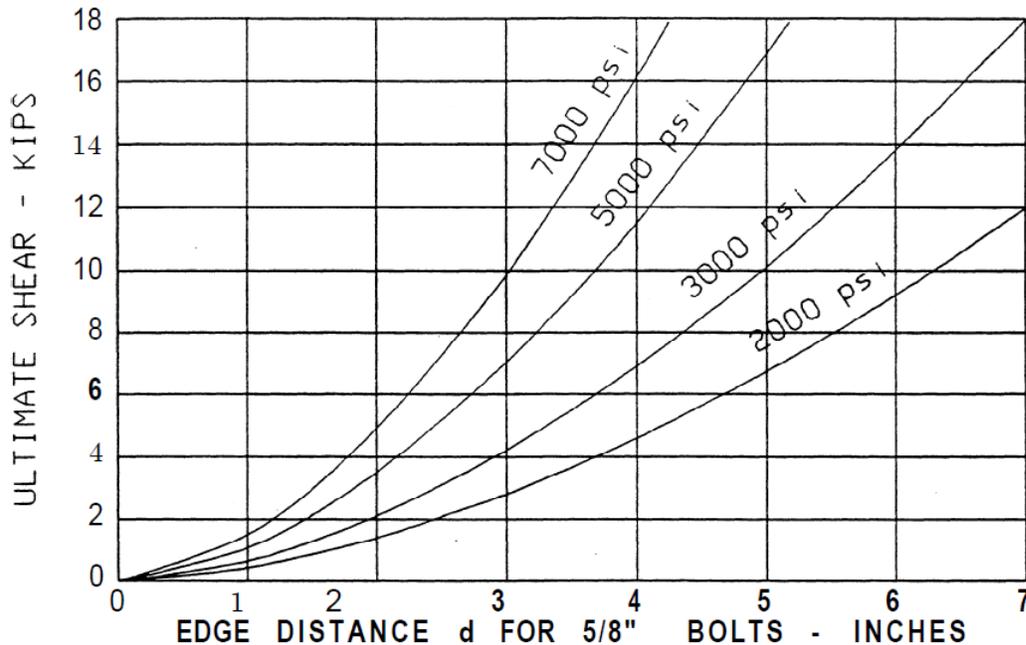


FIGURE 1

One of the most common usages of embedded bolts is depicted in Figure 2. Figure 2 depicts one direction of loading with respect to the concrete surface and shows dimension d which represents the distance from the edge of the concrete to the center line of the bolt.

Permitted Use

Determine the distance the loaded bolt will be from the loaded edge or change in section, of the concrete. The term “bolt” shall be meant to include inserts, rods, or other similar devices. Haunched concrete sections similar to the underside of bridge deck overhang sections, should not be given additional value. Select a concrete shear strength related to an appropriate ultimate concrete strength curve from Figure 1. Divide the selected ultimate concrete shear strength value by an appropriate safety factor as determined from Table 1.

Table 1 lists minimum safety factor values to be used for cast-in-place bolts. A minimum safety factor of 2 may be used where reinforcing is located normal to the axis of the bolt in the concrete shear loaded zone provided the reinforcing is located between the concrete face and the midpoint of the embedded bolt length. This reinforcing must extend through the concrete failure zone (See Figure 2) to sound concrete. Otherwise use a safety factor of 2.25 or higher.

A minimum safety factor of 2.75 may be used when reinforcing steel located parallel to the bolt axis (without reinforcing normal to the bolt axis) will be within the shear loaded zone and will have a length reaching to at least the midpoint of the embedded bolt. If no parallel reinforcing will be within a shear loaded zone use the higher safety factor of 3.0.

Safety Factors:

Reinforcing Type	Cast – In – Place Bolt	Bolt Insert
Bar (s) within 2" of the concrete face located normal to the bolt axis on the loaded side of the bolt.	2.0 – 2.5	2.25 – 2.50
Bars parallel to the bolt axis on the loaded side of the bolt (no normal reinforcing).	2.75 – 3.0	2.75 – 3.0
No reinforcing on the loaded side of the bolt.	3.0	3.0
Torque tightened bolts, regardless of location of reinforcing	3.0	3.0

Table 1

Shear loaded zones are depicted in Figure 2 and are described as follows:

Cone Pullout - A cone with the apex situated behind the embedded end of the bolt with the center line of the cone on the axis of the bolt and with sides sloping a minimum of 45° away from the bolt axis.

Trapezoidal Wedge - A trapezoid volume with the base on the concrete surface a distance d from the bolt center line, having sides sloping inward at 45° angles meeting a plane of length equal to the bolt diameter at the opposite side of the bolt, and with this area having a volumetric length equal to the length of the embedded portion of the bolt.

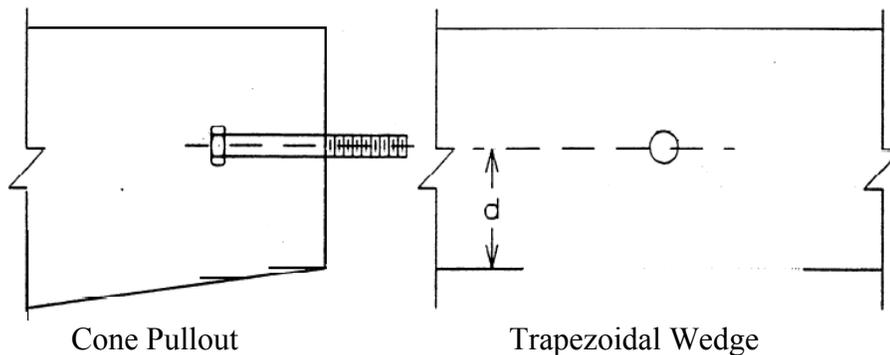


FIGURE 2

When information about reinforcing on the loaded side of a bolt cannot be verified the highest safety factor will be used. No increase or reduction in the safety factor value, will be given to bolts with embedded bolt heads.

Figure 3 illustrates a single bolt placed in a deck overhang. Bolts shall not be spaced closer than 8 times the d dimension or 3.5 times the sum of the embedment lengths of adjacent bolts whichever is larger. The 8 times the d dimension is a recommendation made in the published test results. The 3.5 (two times the tangent of 60°) times the sum of the embedment lengths is based on evidence that the concrete can fracture or fail in shear at an angle of 60° to the axis of the bolt.

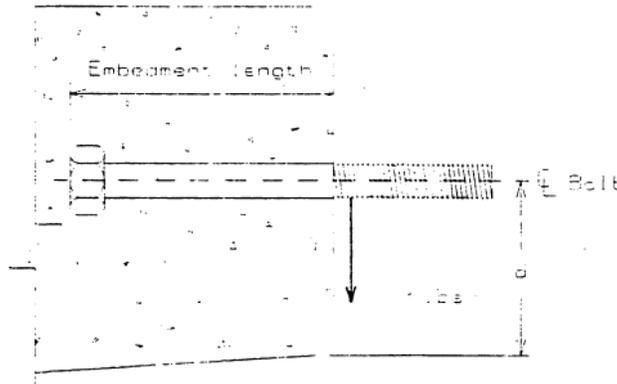


FIGURE 3

Since one of four types of failure modes occurred during testing no adjustments need be made for various bolt sizes up to 5/8" in diameter. For bolts larger than 5/8" diameter use dimension d as being equal to the distance from the edge of the concrete to the nearest portion of the bolt hole (In Figure 3 this dimension would be d minus one-half the bolt diameter).

It is always a good idea to test load a typical section of falsework supported by bolts or inserts to twice the anticipated loading at a safe location.

Example:

Assume 5,000 psi concrete in a deck overhang with no bottom mat reinforcing for which holes for 5/8" bolts are to be drilled 3.75 inches from the soffit with air tools for torque type bolt inserts that are to be used for supporting a falsework system for removal of concrete railing. Determine bolt capacity and minimum bolt spacing for 5 inches of maximum embedment.

From Figure 1 the ultimate value for shear failure may be selected as 10.1 Kips, and from Table 1 the safety factor value should be no less than 3.0.

Assumed safe working load for the bolt = $10.1/3.0 = 3.4$ Kips. Minimum bolt spacing is the larger of $8(d)$ or $3.5(5" + 5")$:

$$\begin{aligned} 8(3.75) &= 30.0 \text{ Inches} \\ 3.5(5" + 5") &= 35.0 \text{ Inches} + \text{ This governs} \end{aligned}$$

References:

1. Ueda,T.; Stitmannathum,B.; and Matupayont,S., "Experimental Investigation on Shear Strength of Bolt Anchorage Group," ACI Structural Journal, V. 88, No. 3, May-June 1991, pp.2920300.
2. ACI Committee 349, "Proposed Addition to: Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-76)"and "Addition to Commentary on Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-76)," ACI Journal, *Proceedings* V. 75, No. 8, Aug. 1978, pp. 329-347,

Additional Information

Consult the *Bridge Construction Records and Procedures Manual* Memo 135-5.0 and Memo 168-2.0 regarding bolts in concrete. Additional information on concrete anchorage devices may be found in Section 75-1.03 of the Standard Specifications. While these references pertain to permanent installations, the guidelines are worthy of note. Installation for temporary work do not require Translab approval. It is important however, that manufacturer's recommendations be followed except where there will be obvious deviations from this memo.