Design Specifications

Design of steel anchor rods embedded in concrete requires the use of the design specifications of two different trade organizations.

♦ The American Institute of Steel Construction (AISC) specification and material standards apply to the design of the steel rod and nut elements.

♦ The American Concrete Institute (ACI) specification and material standards apply to the design of the concrete embedment and associated reinforcing steel.
AISC uses the term “anchor rod” for anchors embedded in concrete. The term “rod” is intended to indicate that they are threaded rods (usually only partially threaded) and not structural bolts.

ACI use the term “anchor bolt” for the same anchors.

For this presentation, the term anchor rods is used to describe the anchors embedded in concrete.
Types Of Anchor Rods

There are two types of anchor rods, **cast-in** or cast-in place (CIP) anchors and **post-installed** anchors (anchors installed in drilled holes after the concrete has hardened).

♦ Anchor rod types are typically specified on the design drawings.

♦ Anchor rod design capacity is determined by calculation based on the AISC and ACI design procedures.

♦ Most larger nonbuilding structures (including equipment) are anchored to concrete by cast-in anchors.

♦ Most smaller nonbuilding structures (including equipment) are anchored to concrete by post-installed anchors.
(A) Cast-in anchors: (a) hex head bolt with washer; (b) L-bolt; (c) J-bolt; and (d) welded headed stud.

(B) Post-installed anchors: (a) adhesive anchor; (b) undercut anchor; (c) torque-controlled expansion anchors ((c1) sleeve-type and (c2) stud-type); and (d) drop-in type displacement-controlled expansion anchor.

Fig. R2.1—Types of anchors. (from ACI 318-14)
Differences Between Buildings And Nonbuilding Structures

**Buildings** are generally regarded as enclosed structures, designed to house and support a commercial or residential occupancy.

♦ Anchor rods are usually not exposed to the outside environment.

♦ For larger buildings, steel columns are often embedded deeply in concrete foundations and anchor rods are not used to resist design forces.

♦ For seismic design, structural steel buildings utilize capacity design concepts which results in very high embedment design forces.
Differences Between Buildings And Nonbuilding Structures

ASCE 7-16 defines **nonbuilding structures** as “… self-supporting structures that carry gravity loads and that may be required to resist the effect of earthquake …”

♦ Generally regarded as either unenclosed or enclosed structures, designed to support an industrial operation.

♦ Anchor rods are often exposed to the outside environment. Corrosion must be considered.

♦ Many nonbuilding structures rely on the ductile behavior of the anchor rods to provide at least some of the system ductility and to justify the seismic response modification factor (R).
Differences Between Buildings And Nonbuilding Structures
Differences Between Buildings And Nonbuilding Structures

The nonbuilding structures design community has developed design criteria to interpret the building code requirements for the unique types of structures found in industrial, chemical, and petrochemical facilities.

♦ Process Industry Practices (PIP), PIP STF05121, Anchor Fabrication and Installation Into Concrete (2017)
♦ American Society Of Civil Engineers (ASCE), Anchorage Design For Petrochemical Facilities, 2013.
In nonbuilding structures, it is common that structural steel columns or equipment are anchored to reinforced concrete pedestals, which are in turn anchored to a supporting foundation.

♦ In these cases, the standard practice is to design the pedestal reinforcing as anchor reinforcement to transfer all of the design loads.

♦ Use of supplementary reinforcing to take a fraction of the design load is not common.
Anchor Rod Design For Nonbuilding Structures
The tension design loads are transferred between the vertical reinforcing steel and the anchors by developing the reinforcing steel on both sides of the 35 degree tension breakout cone originating at the anchor.

- It is unusual to hook the vertical reinforcing steel at the top of the pedestal because of the rebar congestion at that location.
- Anchors are usually long to allow straight bar development of the vertical reinforcing steel.
The shear design loads are transferred between the shear reinforcing steel (ties) and the anchors by developing the reinforcing steel on both sides of the 35 degree shear breakout cone originating at the anchor.

♦ Closed ties are both standard construction practice and necessary to develop the reinforcing steel.

♦ The shear design loads are usually transferred between the pedestal the and foundation by roughening the foundation concrete at the construction joint.
Anchor Rod Stretch Length

The inelastic stretching of anchor rods is important in the seismic design of several nonbuilding structures.

♦ The concept of stretch length was first introduced in ACI 318-11 Appendix D based on observations in the 2010 Chile Earthquake and suggested a minimum stretch length of eight times the bolt diameter.

♦ Engineers often require that anchor rod be wrapped with Teflon tape or be coated with bond breaker to insure that for the embedded portion of an anchor is not bonded to the concrete and that the stretch and freely occur.

Anchor Rod Stretch Length

Fig. R17.2.3.4.3—Illustrations of stretch length. (from ACI 318-14)
Design Of Column Base Plates

We can’t forget the base plates.
♦ A good summary of the design of column base plates and anchor rods can be found in AISC Design Guide 1, 2nd Edition
♦ Design examples include base plates with axial load only, axial load in combination with moments, and shear loads.
♦ The design example includes development of required tension and shear strengths for the anchor rods.
Questions?