Anchor Rod Tightening
for
Highmast Light Towers and Cantilever Sign Structures

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INTRODUCTION
Transportation agencies make extensive use of various configurations of overhead sign structures, signal structures, and luminaries. Many of these structures are supported by a cantilevered pole, or are in themselves cantilevers, i.e. high mast light poles. Proper performance of these structures is not only dependant upon a correct design, but also on proper installation. Design provisions are contained in the AASHTO Standard Specification for the Design of Structural Supports for Overhead Signs, Signals and Luminaries (AASHTO Specification) Guidance on proper installation can be found in various NCHRP Reports, as well as the FHWA “Guidelines for the Installation, Inspection and Maintenance of Structural Supports for Overhead Signs, Signals, and Luminaries.” Many structures were installed, however, before much of this information was available.

Field Inspection
Field inspections of structures located in several states, for both private and governmental agencies, have identified the wide spread presence of loose anchor rod nuts (Figures 1 and 2). This is the result of improper installation procedures and compromises the structural integrity of the pole to foundation connection. It should be noted that the normal method of checking for loose nuts is to strike the nut and washer with a hammer and listen for a sharp ringing sound which is indicative of a tight nut, or look for any movement of the washer or nut or a “dull” tone when struck, indicative of a loose nut. However, this method actually only detects loose nuts and cannot differentiate between a merely tight snug tight and a pretensioned connection. Thus the number of loose nuts reported no doubt underestimates the problem. Increased understanding of the behavior of this connection and the importance of proper anchor rod nut installation can eliminate these loose connections and contribute to increased service life as well as reducing maintenance costs to retighten loose nuts.

FIGURE 1 High mast pole with multiple loose leveling nuts.

FIGURE 2 Missing top nut on cantilever support post.
**Base Connection**

The industry standard anchor rod connection used for traffic sign, signal, and luminary supports is the double nut moment connection as shown in (Figure 3). As can be seen from the Figure, this connection essentially clamps the base plate in position between the lower, or leveling, nut and the top nut. In order to limit secondary bending in the anchor rods and best distribute loads to the anchor rods, hardened washers should be used with both nuts and the exposed length of anchor rod between the top of foundation and bottom of the lower nut should not exceed the diameter of the anchor rod. The double nut moment connection is an attractive method of securing the structure to the foundation partly because it facilitates leveling of the base plate and can accommodate minor variations in base plate thickness or deformations. In the mounting of equipment and industrial structures, it is common to shim under the base plates to achieve level base plate, snug tighten the anchor rods and then place grout under the base plate. Once the grout cures, the shims (ideally) are removed and the anchor rods preloaded by final tightening. This type of mounting is seldom found in highway structures and hence will not be addressed here. However, some older structures may have been installed in this manner.

![FIGURE 3 Double nut moment connection.](image)

For cantilever poles, the governing design condition for anchor rod design is normally the connection fatigue strength. The double nut moment connection is categorized as a Category D detail with a constant amplitude fatigue resistance of 7 ksi by the AASHTO Specification (1). To achieve this fatigue category, the connection must be tightened to provide a preload in the bolt, similar to other structural bolted connections loaded in tension. An anchor rod with a loose nut becomes ineffective, except in the case of extreme overload, and hence the remainder of the anchor rods see increased load. This not only reduces the fatigue life of the anchor rods which remain engaged, but also increases the flexibility of the base plate. This increased base plate flexibility increases the stresses in the pole to base plate weld and contributes to fatigue cracking. Base plates with six or eight anchor rods are now commonly used; four are often found on older structures. Considering that it is not uncommon to find multiple loose nuts (Figure 4) on a single pole, a potential for pole cracking or even collapse is readily apparent.
Tightening Procedures

Tightening of anchor rods for a new installation should follow a standard procedure and assure proper preload of the anchor rod connections. Note that double nut moment connections preload the connection; they do not produce a pretension between the anchor rod and foundation. Prior to tightening, the required connection preload must be determined, based upon the anchor rod material and size.

The anchor rod preload should develop a tension force equal to from 0.5 to 0.6 times the rod material minimum tensile strength, similar to the preload in standard high strength bolts. To determine the preload, the material type and anchor rod size must be known. Currently, anchor rods are supplied in conformance with ASTM F1554 “Standard Specifications for Anchor Bolts, Steel, 35, 55 and 105 ksi Yield Strength”, however anchor rods may vary from these requirements, particularly for structures built prior to the adoption of F1554 in 1994.

The specified minimum yield strength ($F_y$) and specified minimum tensile strength ($F_u$) for common anchor rod materials as given in F1554 (2) are shown in Table 1.

### TABLE 1  Anchor Rod Material Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Anchor Rod Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum yield Strength ($F_y$), ksi</td>
<td>Grade 36</td>
</tr>
<tr>
<td></td>
<td>36</td>
</tr>
<tr>
<td>Minimum tensile Strength ($F_u$), ksi</td>
<td>58</td>
</tr>
</tbody>
</table>
The FHWA Guidelines recommend tightening of anchor rod nuts using the turn-of-nut method, similar to what is used for high strength structural bolts. Table 2 provides the recommended nut rotations from a snug tight condition.

**TABLE 2 Nut Rotation for Turn-of-Nut**

<table>
<thead>
<tr>
<th>Anchor Rod Dia, in</th>
<th>Nut Rotation from Snug and Tight Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F1554 Grade 36</td>
</tr>
<tr>
<td>Less than 1½</td>
<td>1/6 turn</td>
</tr>
<tr>
<td>1½ or larger</td>
<td>1/12 turn</td>
</tr>
</tbody>
</table>

These nut rotations should only be used for double nut moment joints. A tolerance on rotation of 20 degrees beyond the required rotation is recommended. It is important that the nut and washer have a flat bearing surface on the base plate so that secondary bending stresses are not induced in the anchor rod. When the anchor rod is out of vertical alignment by an angle exceeding 1:40, a beveled washer or shims should be used to achieve a flat bearing.

Final tightening using the turn-of-nut method should not take place until the leveling nuts (Figure 5) and top nuts are brought to a “snug tight” condition. “Snug tight” is generally defined as a nut tightened so that all plies in the connection are in firm contact, generally achieved by the maximum effort of a worker using a hand wrench. In structural bolting “snug tight” is often defined as a tightness achieving 10 percent of the minimum preload; this may be difficult to achieve for large anchor rods. However, the snug tight condition requires the full effort (lean into it!) applied at the end of the wrench.

Prior to turn-of-nut tightening, the reference position of the top nut in the snug tight position should be marked on the nut and base plate. The nuts are then rotated as required by Table 2. Nuts should be tightened in a “star” pattern, tightening nuts opposite one another until all nuts are tightened. This brings the connection up to final tightness more uniformly than if the

![FIGURE 5 Tightening leveling nuts with wrench.](image)
nights were tightened in a simple circular sequence, and applies to both the snug tight condition and final tightening.

Anchor rod threads and nuts are lubricated prior to shipping to the field. The lubricants facilitate tightening and must be present when tightening is undertaken. If the lubrication is not present, as may happen due to weathering effects, a commercial bolt lubricant or beeswax should be applied. Lock washers should not be used with anchor rod nuts. Considerable force is required to achieve the required nut rotation, particularly for the larger anchor rods. For smaller nuts, it may be possible to achieve the required rotation using a standard wrench with an extension, such as a piece of pipe, attached to the handle. This extension, or “cheater bar”, may be several feet long and must be carefully used to avoid possible injury. Final tightening may utilize striking “slugger or knocker” wrenches, or hydraulic wrenches. Figure 6 shows a striking wrench on an anchor rod nut. The heavy end of the wrench is struck repeatedly with a sledge hammer, generally in the 16 to 20 pound range, till the required rotation is reached. A hydraulically powered wrench is shown in Figure 7. Hydraulic powered wrenches are very efficient and can also provide tightening to a specified torque if so desired.

Retightening Existing Bases

Retightening or replacement of missing or damaged anchor rod nuts follows a similar procedure to initial installations. While in-place nuts may be retightened, providing new nuts offers the advantage of a nut that is free of any corrosion or damage, and with the old nut removed, cleaning and lubrication of the existing anchor rod threads is facilitated and broken or missing washers can also be replaced. Prior to nut removal, the thread pitch and rod diameter must be measured to assure proper nuts are available before removal begins. New nuts must match the existing in size and should be heavy hex nuts. Washers should also be structural washers conforming to ASTM F436.

For existing installations, the anchor rod material type may not be known. While it is most likely that the rod material is at least Grade 55, it may be prudent to use the turn-of nut rotations recommended for Grade 36 material rather than risk damage to the existing anchor rods. Field hardness testing of the rod end might be utilized to investigate the rod material type.

Before removing any nuts, tighten all leveling and top nuts to a snug tight condition. Remove the first nut and clean the threads using a wire brush. If threads are severely corroded or
possibly damaged, the threads can be reconditioned by “chasing” them with an appropriate sized
die. The threads should then be lubricated and the new nut installed to a snug tight condition.
The opposite nut is then similarly retightened, and the process continued till all nuts are snug
tight. Any gaps between the nuts and base plate should be shimmed with tapered washers.
The nuts are then tightened to the required nut rotation in two passes, each pass achieving
one half of the final rotation. Again, tightening should proceed in a crosswise or star pattern.
Replacement nuts and washers should be heavy hex nuts conforming to ASTM. No rotation of
the leveling nut should occur during top nut tightening.
While the turn-of-nut method is recommended for anchor rod tightening, the Guidelines
(3), provide the following equation for determining the torque required to achieve a desired rod
pretension.
\[
T = 0.12d_b P
\]
Where
\[
T = \text{Installation torque (inch-kips)}
\]
\[
d_b = \text{nominal body diameter of the anchor rod (inches)}
\]
\[
P = \text{installation pretension (kips) equal to 50 percent of the specified minimum tensile }
\text{strength of F1554 Grade 36 rods, and 60 percent for Grade 55 and higher strength rods}
\]
This equation was taken from NCHRP 469 (4). The 0.12 factor was developed from
research on large diameter anchor rods by Till and Lefke (5).
This torque requirement is based on new and well lubricated anchor rod threads and nuts.
The NCHRP 469 report recommends that new installations have rod tightness rechecked after
two days using a verification torque of 110 percent of that calculated from the above equation.
Apparently, the reason for this check is possible connection loosening due to deformation or
creep of the galvanizing within the threads.
These torque valves are not recommended for use in retightening due to the likely
increase in friction resulting from weathering. They can however be monitored as a precaution
against retightening a bolt to the point of damage.
In addition to use of hydraulic torque wrenches, hand operated torque wrenches with
extension handles and torque multipliers can be used for torque controlled installation.

Installation Inspection
Field inspection during anchor rod nut installation is strongly recommended in order to assure
proper connection tightness. Direct Tension Indicator washers as are used for high strength bolts
are now available in sizes to accommodate anchor rods. These offer an attractive option to
verify proper connection tightness, but their use needs to consider the possible oversize holes
generally present in base plates. Plate washers may be required.

CONCLUSIONS
Loose anchor rod nuts in the base plate connection for cantilever sign, signal, and luminaries can
significantly shorten the life of the structure. Proper installation can, preclude these problems
and is not difficult. Existing structures may have their base connections retightened using a
similar procedure, preferably starting by sequential nut removal.
REFERENCES


