Project Summary

Texas Department of Transportation

9-1526: Investigation of the Fatigue Life of Steel Base Plate to Pole Connections for Traffic Structures

Background

Fatigue tests and analytical studies undertaken in this research program have revealed that the rather simple looking connection of a tubular member to the end or base plate is not easy to quantify in terms of fatigue. The simple fatigue category approach used in the American Association of State Highway and Transportation Officials (AASHTO) and other structural design specifications cannot account for the influence of the connection geometry upon fatigue performance.

Research Performed by:

Center for Transportation Research (CTR), The University of Texas at Austin

Research Supervisor:
Karl Frank, CTR

Project Completed: 8-31-09

What They Found

The fatigue strength of the connection is dependent upon the variables listed below:

End/Base Plate Stiffness - End plate thickness, diameter of internal hole, and number of anchor bolts in ring type end plates used in high mast light towers.

Weld Profile - Unequal leg weld profile greatly enhances fatigue strength.

Relative Stiffness of Mast or Pole to the Stiffness of Base Plate - Larger diameter or thicker poles need thicker base plates to maintain fatigue performance. An external collar increases the pole stiffness at the connection improving fatigue performance reducing the effect of base plate stiffness and number of anchor bolts.

Galvanizing - Appears to reduce the fatigue strength in some connections. Toe cracks formed during galvanizing reduced fatigue on large high mast specimens. These cracks appear to be a function of relative temperature of shaft and base plate during immersion in the zinc bath.

What This Means

Fabrication and Erection Recommendations

Backing Bar Recommendations:

1. Due to the limited welder access, welding of the end of backing bars should not be allowed on signal mast arm structures. The backing bar should be caulked after galvanizing.
2. Backing bars used on high mast structures should be fillet welded to seal the joint before galvanizing. The weld should be detailed as a fillet weld, not as seal weld, to insure adequacy of the workmanship.

Base Plate Center Hole on High Mast Lighting Poles - The base plate of the round structures forms an annulus with an outer diameter, as required for the anchor bolts connecting the base plate to the foundation. The center hole should have an inside diameter of 12 in. or ½ the nominal diameter of the pole, whichever is larger.

Profile of Base Plate Weld and External Collar Weld - A weld with unequal legs should be used to reduce the stress at the weld toe. The AASHTO requirement of a 30 degree angle is adequate and should be applied to the fillet and the reinforcement of full penetration welds connection to the shaft and/or collar to the base plate. In addition, the same unequal leg weld geometry should be used to attach the end of an external collar to the shaft.

Ultrasonic Inspection of Welds after Galvanizing - Ultrasonic inspection after galvanizing of the base plate to shaft weld should be specified to prevent structures with pre-existing cracks from entering service. This appears to be a problem with high mast light structures. These shallow cracks can be repaired without jeopardizing the performance of the structure. Specialized procedures using small transducers must be employed.

Mast Arm to Pole End Plate Connection - Welding of the mast arm to the end plate may cause the end plate to warp. The mating plate on the pole may also be warped. It is impossible to flatten these plates using the connection bolts which results in a gap at the joint and limited contact between the plates. The uneven seating of the two plates can cause an unequal distribution of forces among the bolts and in the weld connecting the end plate to the mast arm. Galvanized washers on the bolts should be used between the two plates. The washer insures contact under the bolt head which will produce a symmetric distribution of the forces. All of the mast arm test specimens used a washer on the bolt between the end plate and connecting box structure.

Anchor Bolts on High Mast Towers - Increasing the number of anchor bolts on simple connections such as the socket and full penetration welds increases the fatigue performance of the connection. The anchor bolts must be installed correctly to insure that they participate in transmitting the forces from the base plate to the foundation. A loose anchor bolt increases the stress at the weld toe, reducing fatigue performance and producing the performance of connection with fewer bolts. The leveling nuts must be uniformly snugged against the bottom of the plate before final tightening of the bolts. The bolts should be tightened in a cross pattern to insure uniform tightening. A large wrench is required to properly tighten the large diameter galvanized anchor bolts. Normally hydraulic or other powered wrenches are required.

Base Connection Design Recommendations

Mast Arms - The preferred mast arm connection is a full penetration weld using the Wyoming detail and a 2-inch end plate. The fatigue life of the full penetration weld was comparable to a category C detail. Based on the finite element analysis performed in this project, thinner 1 ½-inch end plates can be used with arms less than 8 inches and arms larger than 12 inches should use 3-inch end plates to produce comparable performance. The top of the backing ring should be sealed with silicone caulk after galvanizing.

High Mast Light Towers - These recommendations apply to poles of approximately 24 to 48 inches in diameter. The use of a full penetration external collar or ground sleeve is recommended. This detail provided the best fatigue performance and is less sensitive to the number of anchor bolts. It is recommended that 12 anchor bolts be used with this detail along with a 3-inch base plate. The inside hole diameter of the base plate should be 12 inches or ½ the nominal diameter of the pole, whichever is larger. An internal backing ring with a fillet weld at the top to seal the ring should be used. The ground sleeve may need to be vented during the galvanizing to prevent the bowing of the wall due to the expansion of the gas trapped between the sleeve and the poll.

For More Information:
Research Engineer - Wade Odell, TxDOT, 512-416-4730
Project Director - Tim Bradberry, TxDOT, 512-471-2179
Research Supervisor - Karl Frank, CTR, 512-471-4590

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Texas Department of Transportation
Research and Technology Implementation Office
P.O. Box 5080
Austin, Texas 78763-5080
512-416-4730