Abstract

For many years, steel poles have been reliable sports lighting support structures. Tubular steel poles have performed admirably at some of America’s most popular sporting venues.

However, in recent years, there have been numerous failures of sports lighting structures across the country. Planned maintenance and inspection of steel poles including careful attention to the base welded connection will ensure the safety of the structure, prolong their lifespan, and protect the public.

A pole base plate connects the structure via the anchor bolts to the foundation. As the only connection and one that is non-redundant, the structural adequacy and integrity of this connection is crucial to the performance of the pole structure. A failure, if one was to occur at this joint, will in almost all cases be catastrophic resulting in the collapse of the pole.

A crack in a pole base plate weld connection can occur during fabrication, galvanizing, or after loading of the structure. It is imperative that inspections of this connection are carried out by qualified personnel with CWI and non-destructive ASNT credentials.

This article will present current methods used to inspect sports lighting structures from a non-destructive examination standpoint. Specific techniques for nondestructively examining the base weld connection including visual testing, magnetic particle testing, and ultrasonic testing will be discussed.

Introduction

Tubular steel poles are a popular support structure in many industries. Steel poles have been utilized as support structures in the sports lighting, utility, transportation, and communications industries for many decades. Combining a long history of reliable performance, competitive pricing, and ease of use installation, steel poles are the sports lighting industry’s preferred support structure and have performed admirably at some of America’s most popular sporting venues. A typical application and sports lighting pole can be seen in Figures 1 & 2 on the next page. However, in recent years, there have been multiple failures of sports lighting pole structures across the country. The property damage in some cases has been significant. As with America’s other aging infrastructure, the cost of ignoring this issue can be significant to public safety and welfare.
Steel Poles

Steel poles in the sports lighting industry can be anchor based, direct burial, or stub based. Anchor based poles are supported with anchor bolts embedded into a concrete foundation. Direct burial structures are directly embedded into the soil. Stub based poles are flanged to a pipe section that is also directly embedded into the soil. Typically galvanized and in some cases weathering steel, steel poles are pressed in polygonal shapes such as 12-sided, 16-sided, or 18-sided cross sections. Poles may also be provided in round cross sections. Polygonal pole shells are long seamed (vertical weld along pole axis joining pole half-shells) via submerged arc welding (SAW) techniques and round tapered poles are long seamed via SAW or electric resistance welding (ERC) methods. In most cases, the structures taper over their reinforced steel frames. Steel poles are typically fabricated with high strength steel plate and range in height from 55 ft to 150 ft. The structures can be designed to support as little as four lighting fixtures or as many as 100 fixtures. A large percentage of structures are of the steel anchor based variety.

An anchor based pole base plate connects the structure via the anchor bolts to the foundation. More specifically, the base plat attaches the pole shaft structure to the anchors. The connection is facilitated by welding of the members during fabrication at the original manufacturer’s facility. As the only connection and one that is non-redundant, the structural adequacy and integrity of this connection is crucial to the performance of the structure. A failure, if one was to occur at this joint, will in almost all cases be catastrophic resulting in the collapse of the pole structure. The connection detail of the pole shaft structure to the base plate can vary depending on the type of pole or the original manufacturer.

Typical pole base details include complete joint penetration groove weld (CJP) and socket style connection as shown in Figures 3 and 4. The CJP connection base plate is butted against the pole shaft and consists of a groove weld with 100% complete weld penetration and reinforcing fillet weld. In other words, the connection zone is all weld material. The connection style is very popular in a cost economical method of fabrication for a pole manufacturer. The socket connection base plate sleeves over the pole shaft and is welded with double fillet welds. The connection is also popular because a non-destructive examination (NDE) ultrasonic test is not performed on this joint post-fabrication which reduces quality assurance costs. While other joints may be possible, including stiffeners, the majority of anchor based poles manufactured fall into one of these two base joint categories.
Pole collapses in the sports lighting industry, while traditionally an infrequent occurrence, have made news in recent years due to a rash of failures. With their proximity to areas where the public gathers for sporting events, there is a significant potential for loss of life and injury. A typical full height collapse of a sports lighting pole is shown in Figure 5.

The recent pole failures have possessed similar characteristics:

1. Toe cracks in the pole structure shaft wall above the base plate weld that propagate along the weld over time causing the pole to collapse full height
2. Thin base plates allowing for excessive movement resulting in fatigue at the base plate/pole wall welding connection
3. Anchor bolt failure

Understanding defects and cracks in steel pole structures is critical to establishing a maintenance and NDE program for sports lighting poles. According to the American Welding Society (AWS), a defect is a discontinuity which exceeds the permissible limit of a code (AWS A3.0, 2010). A crack is a fracture type discontinuity characterized by a sharp tip and high ratio of length and width to opening displacement (AWS A3.0, 2010). Cracking occurs in a weld and base metal when the localized stress at the connection exceed the ultimate strength of the steel material. Left in place without repair, cracks may propagate over time and loading and can be very detrimental to structural adequacy. In addition, cracks greatly reduce the fatigue strength of a member. AWS Structural Welding Code D1.1 does not allow a crack to be left in the weldment after inspection per Table 6.1, Part 1, regardless of size or location (AWS D1.1, 2008).

While all the contributing issues and their interactions are not yet fully understood, cracks at pole bases can occur due to problems in the following areas:

1. Design — incorrect base plate design resulting in an under-sized base plate and too much joint flexibility.
2. Materials — includes quality of material being joined, yield strength, and brittleness.
3. Production — poor welding quality, lack of pre-heat during welding fabrication, incorrect welding settings in the factory.
4. Quality — poor manufacturing quality control; quality checks at the original manufacturer after fabrication and galvanizing overlooked or incorrectly performed.
5. Galvanizing — cracks due to thermal expansion during the galvanizing process—referred to as “toe cracks” occurring immediately after galvanizing or delayed.
6. Installation — loose leveling nuts or improper grouting of the base plate which may cause unanticipated stress increase in the weld joint.

7. Fatigue — long term loading effects in combination with any of the above.

In instances where preventative field repairs have been performed on the base plate weld connection, cracks have been found in the pole shaft wall in the toe above the base plate weld at the bend points. The has occurred on multi-sided poles in both CJP groove weld and socket base plate connections. In addition to the base weld, cracks can occur and have been found in the pole long seams, around handhole penetrations (high stress areas), and in the anchor bolts. Field repairs conducted to date show the importance of monitoring and repairing this important connection on an on-going basis.

**Maintenance**

In many cases, in the sports lighting industry, there is little to no maintenance of steel pole structures. The structures are typically installed and forgotten. Unfortunately, this issue combined with economic challenges, budget constraints, and manpower has resulted in many structures going virtually unmaintained since installation. Planned maintenance and inspection of steel poles including careful attention to the base welded connection will ensure the safety of the structure, prolong the structure lifespan, and protect the public. Properly maintained, tubular steel poles can safely remain in service well over a half century.

Routine structural maintenance includes the NDE of the base welds and anchors, visually inspecting the pole and its connections, checking the tightness of the anchor hardware, and inspecting the foundation. To ensure the long term performance of a sports lighting pole structure, the maintenance of a pole should be accomplished as follows:

1. Visual inspection (VT)
2. Coating thickness test
3. Magnetic particle test (MT)
4. Ultrasonic test (UT)
5. Structure connections inspection
Visual Inspection

The first step of a sports lighting steel pole visual inspection (VT) should be identifying the type of pole base weld connection (CJP vs. socket). In addition, the locations of other base welds to be inspected should be located and identified. These welds will include longseam welds if present and reinforcing handhole welds. VT consists of a visual inspection of all welds in the base area of the structure. The goal is to identify any abnormalities in the weld joints to AWS D1.1 Table 6.1 criteria (2008).

Per AWS, the inspector will specifically look for the following (AWS D1.1, 2008) and (AWS B1.10, 2009):

1. Crack – a fracture type discontinuity characterized by a sharp tip and high ratio of length and width to opening displacement. Any crack shall be unacceptable, regardless of size or location.
2. Weld/base-metal fusion – thorough fusion shall exist between adjacent layers of weld metal and between weld metal and base metal.
3. Crater cross section – all crates shall be filled to provide the specified weld size.
4. Weld profile – slightly convex, flat, or slightly convex fillet weld profiles. Groove welds should have minimum face reinforcement; weld finish.
5. Undersized weld – the size of a fillet weld versus drawing requirements.
6. Undercut – a groove melted into the base metal adjacent to the weld toe or weld root and left unfilled by weld metal.
7. Porosity – cavity-type discontinuities formed by gas entrapment during solidification.

VT should be conducted by a Certified Welding Inspector (CWI) or inspector meeting the qualifications as stated in the AWS Structural Welding Code (2008).

While crucial to the overall inspection system, note that VT will only detect surface defects. In almost all cases, this is not sufficient for a thorough inspection and conclusive results of the integrity of the base weld connection.

As can be seen in Figure 6, visual inspection tools required include the following:

1. Fillet weld gauges
2. V-WA gauge
3. Butt-weld reinforcement gauge
4. Tape measure
5. Ruler
6. Caliper
7. Micrometer
8. Magnifying glass
9. Flashlight
10. Soapstone and marker

Figure 6
Visual Inspection Tools
Coating Thickness Test

The majority of sports lighting pole structures are hot-dip galvanized per ASTM's Standard A123 Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products (2009). As part of the sports lighting pole maintenance program and structure examination, the thickness of the galvanizing coating should be measured and recorded. This will alert the weld inspector to the thickness of coating he will be inspecting while conducting his non-destructive weld examinations (NDE) and will also serve to alert the owner on the condition and expected lifespan of the coating. Per ASTM A123, the coating thickness for hot-dip galvanized steel plate for common steel pole shaft thicknesses should be around 3.0 to 3.9 mils (ASTM A123, 2009). It is not uncommon to measure a thicker galvanizing coating. Coating thickness can be measured with a paint and coating thickness gauge for steel materials as shown in Figure 7.

Magnetic Particle Testing

Magnetic particle testing (MT) is conducted by creating a magnetic field in a part and applying iron particles onto the surface of the part. This non-destructive examination is utilized to assess surface and near-surface cracks in welded joints. Typically red iron particles are applied to the joint with a blower while the area is magnetized with a yoke as can be seen in Figure 8. Any defects present in the material hold the magnetic iron particles applied during the test and identify the presence of a crack as shown in Figures 9 and 10. The base weld...
**Magnetic Particle Testing (Cont.)**

connection, longseam(s) if present, and reinforcing hand-hole welds should all be tested with MT. Note that the galvanizing coating and/or paint coating is typically not removed for this process. Experienced MT inspectors will utilize a pie gauge or Castrol strips and MT over the existing coating to verify that the MT exam will be effective over the coating.

MT is a relatively easy and fast inspection method in the field. The test is very effective at locating surface defects. A drawback of this particular NDE exam in the field is wind which has a tendency to blow the iron particle away from the surface being examined. MT should be conducted by an inspector with American Society for Non-Destructive Testing (ASNT) II Certification (SNT-TC-1A, 2006).

As shown in **Figure II**, equipment required for MT includes the following:

1. **Yoke**
2. **Power source**
3. **Iron particles**
4. **Particle blower**
5. **Pie gauge or Castrol strips**

---

**Ultrasonic Testing**

Ultrasonic testing uses high frequency sound waves, well above the range of human hearing, to measure geometric and physical properties in materials. The test utilizes ultrasonic waves that are interrupted by any material inconsistency (crack) in the joint and can ‘see’ through the material (AWS WIT, 2008). UT is not limited to seeing surface defects only. This test is specifically utilized for testing of pole base weld joints that are 100% complete penetration joints (CJP) and for longseam welds. UT of a socket joint will readily show that this joint is not 100% weld material. UT will determine the presence of any defect in a CJP connection or the presence of a defect or lack of penetration in a longseam weld. UT is performed with a transducer and an electric base unit.

Shear waves, or angle beam transducers, are used for weld evaluation because they transmit sound at an angle avoiding the removal of the weld reinforcement. A 70 degree transducer is commonly used. Longitudinal waves or straight beam transducers are used to determine material thickness or the depth of a discontinuity below the material surface. Shear wave and straight beam can be seen in **Figures 12 and 13**, respectively.

UT is a volumetric test capable of helping the inspector locate the length, lateral location, and depth of the defect (AWS WIT, 2008). However, UT requires more...
inspector skill and experience for interpreting the results of the examination. It also can be implemented from one side only, not requiring access to the back side of the weldment. UT should also be conducted by an inspector with ASNT Level II Certification (ASNT SNT-TC-1A, 2006).

As shown in Figure 14, equipment required for UT includes the following:

1. Electronic instrument
2. Straight beam transducer
3. Angle beam transducer
4. Transducer couplant
5. Calibration standards
6. Ultrasonic thickness gauge

---

**Figure 12**
UT Shear Wave

**Figure 13**
UT straight beam of anchor bolt

**Figure 14**
Ultrasonic test tools
Other Structure Connections and Components

The inspector should inspect the pole structure connections. The structure connections include the telescoping slip joints and/or flanged connections. Excessive gaps or movement in the slip joints and loose or missing hardware in flanged connections or light supports should be identified. Any safety climb equipment installed should be visually inspected, also.

The anchor bolt connection hardware should be inspected and checked for tightness. Typically, the full effort of a man on a 4 ft wrench will be sufficient. With structures that have not been maintained, it is common to find loose anchor bolt nuts. In addition, loose anchor nuts are often removed by vandals. Improperly tightened anchor nuts or missing anchor nuts increase the possibility of fatigue related defects. The foundation tip, if visible, should be inspected for cracks, spalls, or any other structural issues.

Conclusion

It is imperative that sports lighting pole inspections are carried out by qualified personnel with pole engineering experience, CWI credentials, and non-destructive ASNT credentials. It is strongly recommended sports lighting structures are inspected at a two (2) to five (5) year intervals depending upon age, type of structure, condition of the structure, and initial inspection results.

There is certainly much to be learned on this subject by the industry. While there appears to be many contributing factors and variables, careful attention to the following is recommended to prolong the lifespan of sports lighting poles:

1. A maintenance program should be established for sports lighting structures
2. An inspection of sports lighting poles must include NDE of all base welds and anchors
3. Do not relocate or change loading on a sports lighting structure without a complete inspection including NDE
4. Following any significant wind event a comprehensive inspection including NDE should be completed

With increased attention to sport lighting pole maintenance including base weld connection NDE, the owner will prolong the structure lifespan and ensure public safety.


