should determine, based on the soil characteristics encountered, the pullout resistance that can be used with screw anchors, or calculate the volume of concrete and soil required for uplift with dead-man anchors. Additional information about the selection, installation, and testing of guy anchors can be obtained from the manufacturers and by referring to ASCE (1997).

In addition, guy wires can be terminated into precast stub anchors, which are actually smaller poles or piles that are embedded (using one of the methods already described). These stub anchors are designed to take concentrated loads (shear, axial, and moment) at the tip end, which extends only a few feet out of the ground.

REFERENCES

ASCE. (1997). "Design of guyed electrical transmission structures." *ASCE Manual of Practice No. 91*, Reston, VA.

ASCE. (2010). "Guidelines for electrical transmission line structural loading." *ASCE Manual of Practice No. 74*, Reston, VA.

7

MANUFACTURING AND QUALITY ASSURANCE

Prior to approving bids from concrete pole Manufacturers, the Purchaser should be satisfied that each bidder has procedures in place to ensure that every pole supplied will be in compliance with the specifications. The Manufacturer should provide either a full copy or a summary of the quality assurance program if requested. The Purchaser may inspect the Manufacturer's equipment and process facility to ensure that the procedures are in accordance with the quality assurance program.

The exact contents and procedures in the quality assurance program will vary depending on the production process (e.g., spun cast or statically cast), the types of poles being manufactured (e.g., mass-produced street lighting poles or custom manufactured transmission line poles), and the general quality control philosophy of the Manufacturer. There are, however, several considerations that should be covered by all quality assurance programs.

The following guidelines may serve in preparing specifications that include a quality assurance program.

DESIGN AND DRAWINGS

The quality assurance specification should indicate the degree of involvement by the Purchaser and the procedure for review of the design concept, detailed calculations, stress analysis, and the Manufacturer's drawings. Stress analysis of the main structure and its component parts, including all attachments and connections, should be considered. The hole sizes and locations need to be clearly defined on the concrete pole drawings to meet the Purchaser's requirements. In addition, holes specifically for pole pickup points need to be identified on the drawings as well as horizontal support points. The Manufacturer's drawings should be checked to ensure that they contain proper and sufficient information for manufacturing and erection in accordance with the requirements of the Purchaser.

MANUFACTURING PROCESS

Prestressed concrete poles can be spun cast or statically cast.

Spun-Cast Poles

To manufacture spun-cast concrete poles, concrete is pumped or placed into a steel form consisting of two separable halves equipped with rolling rings. These rings rest on the wheels of a spinning machine that rotates the form at high speeds (see Fig. 7-1). The spinning provides centrifugal compaction to the concrete mixture and creates an inner core void.

The high consolidation forces and low water-cement ratios produce exceptionally dense concrete with a high compressive strength (dry unit weight of approximately 155 to 165 pcf for spun-cast poles). The spinning process also results in improved bond between steel and concrete, greater shrinkage reduction, and a smoother, denser surface finish. Concrete cover requirements over reinforcement steel can be reduced to 3/4 in. as a result of the density and compaction of the concrete.

Statically Cast Poles

Statically cast poles are typically made in tapered configurations that are square, polygon (multisided), or H-shaped in cross section. The square

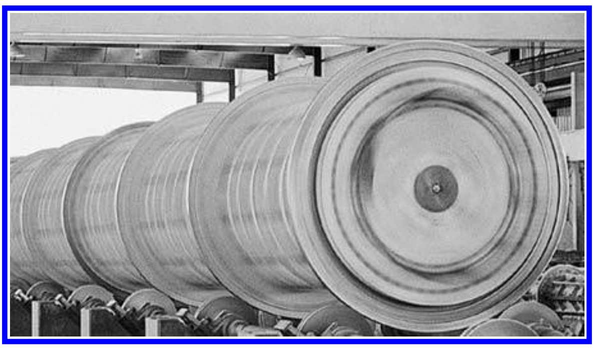

Fig. 7-1. Mold spinning a prestressed concrete pole
Source: Photograph courtesy of Valmont Newmark. Reproduced with permission.

or polygon shaped sections can be either solid or made hollow by the use of retractable mandrels or fiber tube voids. Solid poles can have a wire raceway provided by a plastic tube extending through the center. Although not as dense as spun concrete (dry unit weight of approximately 145 to 150 pcf), statically cast poles also can achieve high compressive cylinder strengths. Considering the more porous quality of the concrete, the concrete cover requirements of static-cast poles should be greater than for spun-cast concrete poles. The requirements of PCI (1999) should apply.

Materials

The specification should include the requirement for review and agreement on the Manufacturer's materials specifications, sources of supply, material identification, storage, traceability procedures, and acceptance of certified material test reports.

The Manufacturer should maintain records of mill certifications and test reports from material suppliers to show that all materials used conform to applicable ASTM specifications. Tests on the concrete mix should be maintained, whether these tests are performed by independent laboratories or by the Manufacturer. In either case, these tests should be conducted in accordance with ASTM procedures.

Manufacturing Tolerances

Spun-Cast Pole Tolerances: Product tolerances (see Fig. 7-2) are to be limited to the following:

Fig. 7-2. Pole fabrication inspection
Source: Photograph courtesy of Valmont Newmark. Reproduced with permission.

Overall length: +3 in. / –2 in.
Pole diameter: ±1/4 in.
Wall thickness: Allowable variation along the pole is to be not greater than +20%, with a maximum reduction of 1/4 in. provided that coverage over steel is maintained. Each pole is to be inspected for uniformity of inside appearance and wall thickness variation. If irregularities are encountered, then actual thickness measurements are to be taken by drilling pilot holes through the wall at 10 ft intervals on the longitudinal axis of the pole. These holes are to be alternated 90° at each interval.
End squareness: ±1/2 in. per ft of pole diameter.
Pole sweep: Sweep is the deviation of a pole from straightness. Sweep will be allowed in one plane and one direction only. A straight line joining the edges of the structure at both the top and the butt shall not be distant from the pole surface at any point more than 3/8 in. for each 10 ft of length between these two points.
Weight: ±10% of computed value.
Location of longitudinal reinforcement at stressing header: ±1/4 in. for individual strands, ±1/8 in. for the centroid of a group of strands.
Spiral reinforcement: ±25% spacing variance, with total quantity per ft maintained.
Location of a group of bolt holes from pole tip: ±2 in.
Location of centerline between groups of bolt holes: ±1 in.
Location of bolt holes within a group of bolts: ±1/8 in.
Bolt hole diameter: +1/8 in. of specified hole diameter or +1/4 in. greater than actual bolt diameter.
Bolt hole alignment within a group of bolts: within 1/2 of the hole diameter from the bolt plane that is longitudinal to the pole's cross-sectional centerline in a group.

Statically Cast Pole Tolerances: Product tolerances are to be limited to the following:

Overall length: +3 in. / –2 in.
Pole diameter: ±1/4 in.
Wall thickness: Allowable variation along the pole is to be not greater than +20%, with a maximum reduction of 1/4 in. provided that coverage over steel is maintained. Each pole is to be inspected for uniformity of inside appearance and wall thickness variation. If irregularities are encountered, then actual thickness measurements are to be taken by drilling pilot holes through the wall at 10 ft intervals on the longitudinal axis of the pole. These holes are to be alternated 90° at each interval.
End squareness: ±1/2 in. per ft of pole diameter.

Pole sweep: Sweep is the deviation of a pole from straightness. Sweep will be allowed in one plane and one direction only. A straight line joining the edges of the structure at both the top and the butt should not be distant from the pole surface at any point more than 3/8 in. for each 10 ft of length between these two points.

Weight: ±10% of computed value.

Location of longitudinal reinforcement at stressing header: ±1/4 in. for individual strands, ±1/8 in. for the centroid of a group of strands.

Spiral reinforcement: ±25% spacing variance, with total quantity per ft maintained.

Location of a group of bolt holes from pole tip: ±2 in.

Location of centerline between groups of bolt holes: ±1 in.

Location of bolt holes within a group of bolts: ±1/8 in.

Bolt hole diameter: +1/8 in. of specified hole diameter or +1/4 in. greater than actual bolt diameter.

Bolt hole alignment within a group of bolts: within 1/2 of the hole diameter from the bolt plane that is longitudinal to the pole's cross-sectional centerline in a group.

Sealing Strand Ends

The ends of strands must be properly sealed against water intrusion. It has been demonstrated that the helical prestressed strand reinforcement can act as capillary tubes and draw water up into the member. Hence, it is extremely advantageous to burn back the strand into the member approximately 1 in. and then seal the area with an epoxy grout or similar impervious material. This is especially desirable when pole installations are in areas with high water tables or for those placed directly in sea water. Wherever strands are terminated in a pole, care should be taken to ensure that the strands are protected against weathering and corrosion. Strands that are attached to bolted flange ends should be similarly sealed.

Concrete Mix

Concrete mixes for prestressed concrete should be established by methods in accordance with ACI 318 (ACI 2008), Chapter 4. Mixes may be designed either by a commercial laboratory or by qualified plant personnel. All mix designs should be developed using the specified proportions and type of water, cement, aggregates, and admixtures proposed for use in plant mixes. Each mix design needs to be validated by adequate test data. If any of the variables are changed, the mix should be reevaluated. Unless specified, the producer shall have the choice of the type of cement to use for achieving the specified physical properties. Acceptance tests for concrete mixes shall include compressive strength (ASTM 2007, 2010c), slump (ASTM 2010e), unit weight (ASTM 2005, 2010d), and air content (ASTM 2010a,b).

Curing and Finishing

Once the concrete has been placed in the form (see Fig. 7-3), the concrete is compressed either by spinning (spun cast) or vibrating (statically cast). The form filled with freshly placed concrete is then put in a curing cell that elevates the ambient temperature to accelerate the curing process. After the required curing time has passed, the pole is removed from the form, inspected, and placed in the final production stage for completion for its intended end use. At this point, the pole is inspected and compared with the design requirements to ensure the product is complete.

QUALITY ASSURANCE

To ensure that proper methods for all phases of production are being followed and the finished product complies with the specified requirements, a regular inspection program that inspects all aspects of production are to be provided. Each pole is to be uniquely marked and inspected per the procedure and a detailed written inspection report on record.

Fig. 7-3. Placing concrete
Source: Photograph courtesy of Valmont Newmark. Reproduced with permission.

To establish evidence of proper manufacture and quality of precast concrete products, a system of records is to be used in each plant. The system shall provide full information regarding the testing of materials, tensioning, concrete proportioning, placement, curing, sweep, member dimensions, concrete strength, and the finished product. Generally, pole manufacturing inspections occur before, during, and after concrete placement into the form, after form release, as a completed product, and prior to shipment.

Concrete Cylinder Tests

Testing is to be an integral part of the total quality control (QC) program. Testing for quality control of the precast unit is to follow the Manufacturer's standards, unless otherwise specified.

If the plant has contracted for quality control to be performed by an outside independent laboratory, the lab is to be accredited by the Cement and Concrete Reference Laboratory of the National Institute of Standards and Technology. The lab is to conform to the requirements of ASTM E329 (ASTM 2011a), and the plant or independent lab is to meet the concrete inspection testing section requirements of ASTM C1077 (ASTM 2011b).

For the control of concrete, testing, and mixes, each plant is to be adequately equipped with the certified testing equipment and staffed with personnel trained in its proper use. A system of records is to be maintained to provide full information on material tests, mix designs, concrete tests, and any other necessary information (see Fig. 7-4).

Inspection of Poles During the Manufacturing Process

Certain QC inspections and records of inspections are important to the process review and manufacturing traceability for all poles produced. A review should be made and agreement reached on all quality control procedures. Rejection criteria should be established and agreed upon prior to the start of any fabrication. All structures ready for shipment should have complete and proper identification to avoid confusion at the delivery point. The markings should coincide with the type, length, strength, weight, and identification number required by the customer and approved on the shop drawings. The following inspections and records are required as a minimum:

QC Library, Files, and Equipment

- manual of standard QC practices;
- QC records; and
- equipment calibrations.

Fig. 7-4. QC cylinder break
Source: Photograph courtesy of Valmont Newmark. Reproduced with permission.

QC Inspections and Records
- pre-pour inspections;
- post pour inspections; and
- final inspection.

Materials-Aggregates
- cement;
- sand;
- stone;
- mixing water;
- admixtures;
- visual inspections;
- moisture content; and
- gradations.

Materials-Steel
- steel reinforcement;
- prestressing strand;
- spiral wire;
- steel reinforcing bars; and
- miscellaneous steel.

Concrete Mix
- mix design;
- water-cement ratio;
- mixing procedures;
- moisture compensation;
- temperature; and
- hot and cold weather adjustments.

Equipment Calibrations
- strand stressing jacks;
- batch plant weight and flow rate measuring devices;
- comprehensive strength cylinder testing machine; and
- product weigh scales.

Pole Curing Concrete
- duration and moisture control.

Cylinder Tests
- concrete production sampling size;
- concrete cylinder compression test results;
- strength comparison to standard deviations; and
- strength comparison to correlation factor (spun concrete).

REFERENCES

American Concrete Institute (ACI). (2008). "Building code requirements for structural concrete." *ACI 318*, Farmington Hills, MI.

ASTM. (2005). "Standard test method for determining density of structural lightweight concrete." *C567*, West Conshohocken, PA.

ASTM. (2007). "Standard practice for making and curing concrete test specimens in the laboratory." *C192/C192M*, West Conshohocken, PA.

ASTM. (2010a). "Standard test method for air content of freshly mixed concrete by the pressure method." *C231/C231M*, West Conshohocken, PA.

ASTM. (2010b). "Standard test method for air content of freshly mixed concrete by the volumetric method." *C173*, West Conshohocken, PA.

ASTM. (2010c). "Standard test method for compressive strength of cylindrical concrete specimens." *C39*, West Conshohocken, PA.

ASTM. (2010d). "Standard test method for density (unit weight), yield, and air content (gravimetric) of concrete," *C138/C138M*, West Conshohocken, PA.

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