IEEE Guide to the Assembly and Erection of Concrete Pole Structures

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Abstract: Good practice that will improve the ability to assemble and erect self-supporting and guyed concrete pole structures for overhead transmission lines is presented. Construction aspects after foundation installation and up to the conductor stringing operation are covered. Some aspects of construction related to other materials use in concrete pole structures are covered, but the treatment is not complete. The guide is intended to be used as a reference source for parties involved in the ownership, design, and construction of transmission structures.
Keywords: assembly and erection, concrete pole structures, transmission structures

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Introduction

(This introduction is not a part of IEEE Std 1025-1993, IEEE Guide to the Assembly and Erection of Concrete Pole Structures.)

This guide, covering all aspects of overhead transmission line construction, is one of several that are being prepared by the Working Group on Construction of Overhead Lines. This particular guide presents construction considerations for material delivery, assembly and erection of concrete pole structures, and installation of insulators and hardware. This guide is intended to be used as a reference source for parties involved in the ownership, design, and construction of transmission structures.

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IEEE Guide to the Assembly and Erection of Concrete Pole Structures

1. Overview

1.1 Scope

This guide presents various approaches of good practice that will improve the ability to assemble and erect self-supporting and guyed concrete pole structures. This guide covers construction aspects after foundation installation and up to the conductor stringing operation.

Concrete pole structures may have components made of other materials (i.e., steel, wood, aluminum). Though some aspects of construction related to these materials are covered in this document, it should not be considered complete. Other documents cover these materials in more detail (see IEEE Std 951-1988[1]).

1.2 Purpose

The purpose of this guide is to present the construction considerations for material delivery, assembly and erection of structures, and installation of insulators and hardware.

1.3 Application

This guide is intended to be used as a reference source for parties involved in the ownership, design, and construction of transmission structures. Since methods will be strongly influenced by the nature of each project, various methods that have been successfully employed are presented.

If any recommendations contained within this guide are to be adopted, they should be specifically stated in the owner's design and construction specifications. Any legal requirements of national, state, provincial, or local regulations must, of course, be observed.

1.4 Safety

Handling, assembly, and erection of concrete pole structures requires conducting a safety and health program which takes all reasonable precautions to protect the safety and health of workers and members of the public and to prevent damage to public and private property. Workers must not be allowed to work in sur-

[1]Information on references can be found in clause 2.

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roundings or under working conditions which are unsanitary, hazardous, or dangerous to their health or safety. In the United States, compliance is required with the latest effective standards promulgated by the Secretary of Labor for the Department of Labor, Occupational Safety and Health Administration, Safety and Health Standards (29 CFR 1910), and the Construction Safety and Health Regulations promulgated under Section 107 of the Contract Work Hours and Safety Standards Act (29 CFR 1926) [B10].[2]

1.5 Legal disclaimer

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2. References

This guide shall be used in conjunction with the following standards. When the following standards are superseded by an approved revision, the revision shall apply.

ASTM A780-90, Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.[3]

IEC 826-1991, Loading and Strength of Overhead Transmission Lines.[4]

IEEE Std 524-1991, IEEE Guide to the Installation of Overhead Transmission Line Conductors (ANSI).[5]

IEEE Std 951-1988, IEEE Guide to the Assembly and Erection of Metal Transmission Structures (ANSI).

3. Definitions

3.1 concrete pole structures: Structures consisting of one or more concrete poles. Other members of the structure may be reinforced concrete or other materials (i.e., wood, steel, aluminum). These structures are prefabricated, as opposed to being cast-in-place. Concrete pole structures may be manufactured in a variety of ways. A few examples are listed below:

a) Hollow or solid members
b) Different cross-sectional shape (i.e., round or square)
c) Spun or statically cast (see figure 1)
d) Pretensioned, posttensioned, or nontensioned reinforcing steel
e) Single-piece or multipiece poles

[2]The numbers in brackets correspond to those in the bibliography in clause 9.

[3]ASTM publications are available from the Customer Service Department, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, USA.

[4]IEC publications are available from IEC Sales Department, Case Postale 131, 3 rue de Varembé, CH-1211, Genève 20, Switzerland/ Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

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Combinations of the above may be used to achieve the desired results (see figure 1).

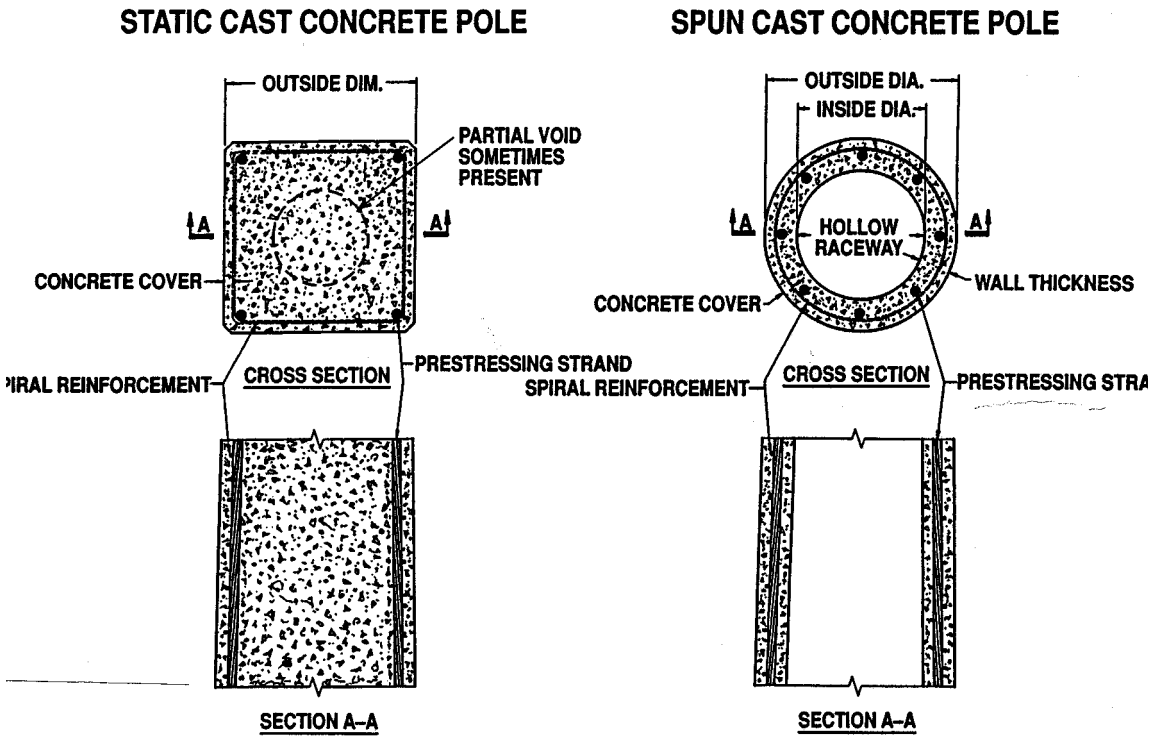


Figure 1—Various concrete pole sections

3.2 constructor: A party who undertakes the assembly and erection of a transmission structure for an owner, or an owner who undertakes all or part of a project alone. Synonymous with contractor, installer, construction agency, or construction department.

3.3 line designer: A party who develops structure-loading criteria, structure types, and structure locations based on line routing, maintenance, and construction requirements. The line designer should establish design criteria for construction and maintenance that will affect the structure designer and constructor. The line designer could be an owner or an agent acting for the owner.

3.4 owner: A party who owns the transmission line during the construction phase of the line and may include a person who acts for, or on behalf of, an owner as the owner's agent or delegate.

3.5 structure designer: A party who designs the structure based on criteria given by a line designer. The structure designer could be an owner, an agent acting for the owner, or a manufacturer.

4. Structural design considerations

4.1 Construction and maintenance loads

The line designer should review and define acceptable methods of construction and maintenance. Consideration should be given to the structure types, site conditions, applicable equipment, and worker skills. Structural or other details that relate to the safety of construction and maintenance work should be considered in the design of the structure. At the time of line design, the constructor may not have been selected. However,

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the line designer should consult with knowledgeable constructors and maintenance personnel and utilize their experience to develop a reasonable balance between construction flexibility and efficiency vs. cost.

The line designer should specify the maximum anticipated loads that may be applied during construction and maintenance of the line, as well as the location of these loads (see IEEE Std 524-1991). Some of these loading considerations are as follows:

a) Fully or partially assembled structures should be subjected to dead-weight loads, temporary guying loads for stability, worker loads, wind loads, and rigging loads during assembly and erection. Reasonable combinations of these loads should be anticipated by the designer and discussed with potential constructors to ensure safety and efficiency and prevent structural damage.

b) Members on which a worker is expected to climb or stand should be designed to carry a load at midspan. This load should include the weight of the worker, the equipment, a safety factor, and possible dynamic loads (see IEEE Std 524-1991). Some construction or maintenance methods may require more than one worker to stand on a particular member.

c) Portions of a structure may be subjected to additional loads due to one or more workers during construction and maintenance (e.g., the end of a cross arm). These loads, in addition to the normal wire loads anticipated during construction and maintenance, should be considered.

d) If fall-prevention systems are required by the owner, additional facilities should be provided for safety equipment.

e) Rigging attachment points should be provided for lifting the structure, hoisting insulators and travelers, stringing, clipping in, dead ending, and maintenance. All of these points should be explicitly identified. A diagram giving the allowable construction loads on the erected structure should be prepared and provided to the constructor.

   Particular attention should be given to the following loading conditions:

   1) Rigging methods used in hoisting may multiply the load at the attachment point [B11].

   2) At the beginning and end of each conductor stringing operation, the conductors may be brought down to stringing equipment, anchors, or both. The vertical and horizontal components of tension imposed on the structure may become significant at these locations, and failures have occurred on both suspension and dead-end structures. The positioning of the stringing equipment or anchors is critical, especially in mountainous terrain (see IEEE Std 524-1991 and figure 2).

   3) Various dead-ending techniques will apply different loads. For example, aerial dead-ending techniques may impose lower vertical loads than dead ending on the ground. Temporary back guying may be required depending on the longitudinal strength and flexibility of the dead-end structure and dead-ending technique used.

   In addition, short spans between dead ends with high conductor tensions may result in loads in excess of maximum design tensions when the conductor is overpulled during the dead-ending operation.

4.2 Material delivery

The design of the structures should consider limits to the length, size, and weight of individual members due to shipping, handling, erection, terrain, and equipment restrictions (see 5.3).

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Figure 2—Conductor stringing

4.3 Constructability of concrete pole structures

Construction can be enhanced by a number of considerations, both in the design of the structure and in the detailing of the connections. Some special considerations arise due to the large size and weight of the components being assembled.

It should be noted that these considerations could increase material costs, although these costs may be offset by reduced field costs and improved safety.

a) Clearly and permanently mark (i.e., stamp) each member. This mark should be legible after any coatings are applied to facilitate identification and possible field replacement. These permanent markings should be visible after the structure is erected. Additional stencilling with waterproof paint will further facilitate field identification; however, care should be taken to avoid adverse visual impact (i.e., any additional stencil should be on the embedded portion of the pole).

   Identification marks may include the following information:

   1) Structure type
   2) Structure height
   3) Structure weight
   4) Structure manufacturer
   5) Date of manufacture
   6) Groundline moment capacity

b) Design the structure with a minimal assortment of bolt diameters, types, and lengths.

c) Provide adequate clearance around nuts and bolt heads for wrenches or sockets.

d) For safety and ease of erection, provide a place for a worker to stand below a pole splice. As an example, two step bolt holes could be provided 1.37 m (4 ft 6 in) below each splice for optional step bolts.

e) Ensure that the Bill of Materials provides the product finish (i.e., galvanized or painted for metal members and treated for wood). The Bill of Materials should also provide the approximate weight of each item (i.e., members, plates, fills, bolts, and nuts) in order to determine the loads to be lifted.

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f) Provide legible erection drawings. The drawings should show the member mark identification, bolt size and length, bolt pattern, orientation of members, and whether a member is inside or outside its connecting member (i.e., use hidden lines and detailed or enlarged views). In addition, these erection drawings should show the rigging attachment points identified in 4.1, item e).

g) Fabrication tolerances that are either too restrictive or too liberal can result in increased field costs (see IEEE Std 524-1991).

h) Consideration should be given to the method of locking fasteners. The method selected will influence construction efficiency. Typical methods and devices are lock nuts, lock washers, punched threads, etc.

i) Avoid connections where workers have to insert their hands between large members during assembly. For example, avoid joint designs that require insertion of tools or hands into the joint area during assembly.

j) The pole supplier should include provisions for pick points and cant holes to minimize damage to the finish of the pole during the handling and erection process. Position of the lifting eyes or pick points should take into account construction methods, equipment, and site restrictions (see figure 3).

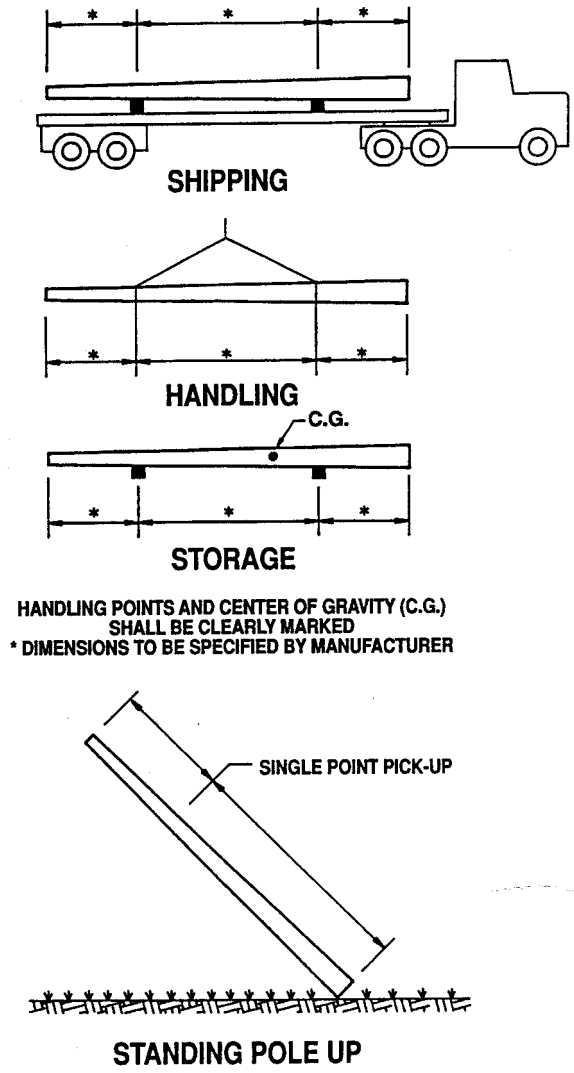


Figure 3—Concrete pole support points

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k) Make provisions for the constructor to verify orientation as shown on the erection drawings.

l) Provisions for climbing devices and specific work locations may be desirable for construction and maintenance on the structures.

m) Ensure that bolts to be threaded into precast inserts do not cause possible punch-through problems. Bolts with thread lengths greater than the threaded depth of the insert could be overtightened and break the bottom of the insert. Further overtightening may produce sufficient force to damage or spall the interior concrete wall (see figure 4).

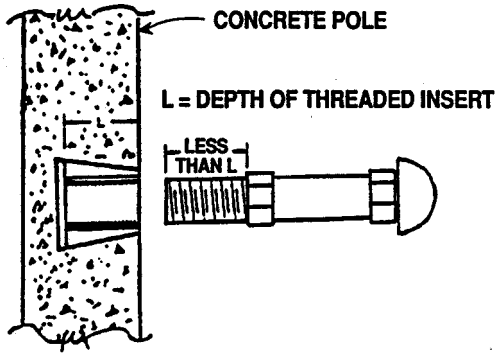


Figure 4—Bolt insert

4.4 Helicopter construction

Special consideration should be given to structures designed for helicopter erection. Items to consider include the following:

a) Provision for attachment of guide members to the structure
b) Lifting capacity of aircraft available at the site altitude and ambient temperature
c) Weights, centroids, and lifting points of each subassembly
d) Minimizing the number of mating points to be connected simultaneously
e) Whether or not workers will be allowed on or near a structure during setting by helicopter

5. Material delivery

This clause covers recommended procedures for the receipt and inspection of material; disposition of overages and surplus material; and storage, handling, transportation, shortages, corrections, and replacement of material. The constructor should be very familiar with all special design, transportation, handling, lifting, blocking, stacking, storing, loading, and off-loading requirements of all materials. Careful attention given to these details, along with adequate planning of equipment, materials, and space, will help ensure proper care of materials. Metal components, as well as other material, are commonly used on concrete pole structures. The following subclauses include information related to the handling, loading, storage, and repair of these type pieces.

5.1 Material yard

Detailed planning for the development and preparation of the material yard results in efficient loading and unloading operations as well as accurate identification and inventory of material in the yard. In choosing the

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location of the material yard, due consideration must be given to the proximity of the yard to the project, accessibility to the storage site from all-weather roads for material to be transported by truck, and the location and condition of rail sidings for the receipt of material to be delivered in this manner. A suitable receiving yard should be selected and prepared for the anticipated climatic conditions which may be encountered during the project. Consideration should be given to the type, size, and quantity of equipment to be utilized within the yard in determining the layout, width, turning radii, and surface of the roadways. With the increasing problem of vandalism and material pilferage from the yard, considerations regarding the use of security personnel and perimeter fencing and lighting should be incorporated in the planning stage.

Length of the line, structure type and quantity, terrain, construction sequence, and the construction methods to be utilized are generally the factors which determine if more than one material yard will be established for the project. Use of multiple yards requires additional coordination considerations to ensure that the correct type and quantities of material are delivered to and disbursed from each yard.

Material should be arranged by type, taking into consideration the order in which the items will be received and used. Proper arrangement will facilitate hauling the material to the structure site or other staging areas.

5.2 Receipt and inspection of material

The constructor should maintain a current inventory, by location, of all material for the project. It is recommended that the construction specifications for the project contain a statement requiring the constructor to have a material coordinator assigned to receive, store, and disburse all material. This coordinator should remain assigned, in this capacity, for the duration of the project. This procedure is in the best interest of both the constructor and the owner to maintain continuity for receipt and disbursement of material.

Prior to the delivery of material, an itemized tabulation showing the quantity and description of the items to be received should be furnished to the constructor by the owner.

All material delivered to the project should be promptly unloaded to avoid or minimize demurrage charges. However, unloading procedures should not decrease safety to personnel or increase potential damage to the materials. It is recommended that the constructor’s material coordinator and owner’s representative inspect and inventory all material received against the manifest or bill of lading and the itemized tabulation referred to above, indicating all missing, extra, or damaged items. If possible, discrepancies should be indicated on the appropriate document before signing the delivery ticket. Problems encountered during the delivery should be communicated to the manufacturer/vendor as quickly as possible to minimize possible delay to the constructor.

Inventory methods will be dependent upon how the material is shipped. In the case of structural members, it is recommended that bundles be opened and inventoried at the material yard if the delivery is by “like pieces.” If the structure is delivered by “structure components,” inventory of members should not be done until the bundles are taken to the structure site. In the latter case, only the number of bundles can be verified at the time of delivery. If inventory is taken at the structure site, time should be allowed for fabricating replacements. If damages are noticed at the material yard, immediate steps should be taken for replacement even if bundles must be opened. Opening of barrels, kegs, crates, etc., should be done at the structure site to minimize potential losses.

Upon receipt of insulators and hardware assemblies, the constructor and owner should make a check for compliance with the specifications, quantity, fit, and condition of all components (see 7.1).

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5.3 Handling and storage of material

In the unloading, handling, and storage of structures, care should be exercised so as not to damage the surface or surface coating, or deform the members. Bare wire rope or steel chains should not be used for handling without adequate protection of the surface. Structural members should not be dumped, dragged, rolled, dropped, nor used as loading or unloading skids or blocking. Heavy members should not be stacked on top of lighter members. The maximum weight of material bundles should not exceed a specified weight, typically 1600–1800 kg (3500–4000 lb), to facilitate handling and unloading. Components with dissimilar finishes should not be stored over one another to minimize discoloration of the lower members.

Care should be taken to ensure proper blocking, stacking, and handling of concrete members. Refer to the structure drawings and instructions to verify correct lifting methods, replacement of support blocking, and stacking limitations. It is very common for concrete poles to require a two-point pickup due to the weight and possible long lengths (see figures 3 and 5). Identifying the correct blocking locations is important to eliminate the potential of overstressing the member. The constructor should verify correct blocking and number of possible layers for stacking to avoid damage to concrete members lower in the stack.

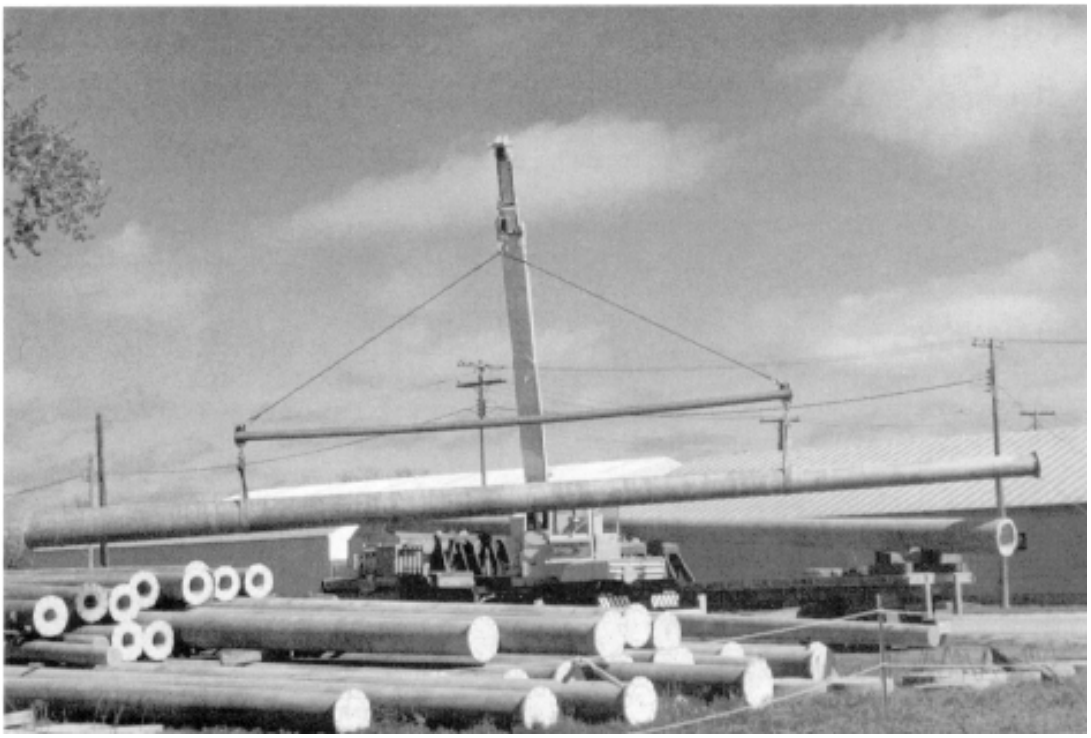


Figure 5—Two-point pickup

All members should be placed on wood blocking or other suitable material to ensure that the material to be stored is not in contact with the ground. Blocking should also be used to separate layers of stacked material. It should be noted that oak wood blocking or oil-treated timbers can bleed and stain a structure finish. Members should be supported in such a manner as to prevent bending and distortion as well as to allow water to drain from the material.

Failure to provide for proper drainage of stacked, galvanized steel components could result in the formation of “white rust.” White rust (zinc oxide) forms when two galvanized surfaces are closely nested for an extended time without adequate ventilation. Ingress of water between the surfaces forms an electrolytic cell which may, in time, erode some of the zinc layer. The white rusting action will stop after exposure to air.

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When extended transport or storage is anticipated, either of the following two methods can be used to prevent oxide formation:

a) Spacers may be placed between the nested pieces to ensure adequate ventilation.
b) Galvanized members may be treated with a solution which will inhibit oxide formation for six months to one year.

Weathering steel fasteners, though rarely used on concrete poles, and other materials subject to deterioration should be protected from the elements during storage.

During the course of the project, the material yard should be kept relatively neat and clean and the growth of vegetation kept to a minimum. Good housekeeping minimizes damage and loss of material in the yard, facilitates material handling and periodic physical inventories, and complies with environmental considerations.

If delivery of material is made initially to the structure site for storage, care should be taken to avoid interference with foundation construction, access roads, or drainage. Truck delivery of complete structures from the manufacturer directly to the structure site can be advantageous since it eliminates at least one unloading and loading cycle (see 4.2). However, security of material stored at a structure site is minimal and the subsequent loss of time due to missing items can result in significant construction cost increases.

5.4 Overages, shortages, and replacement material

Shortages of materials may result from damage during delivery and installation, misfabrication, and losses. It is the responsibility of the owner to ensure that the required quantities and types of materials are furnished to the constructor. Information regarding shortages or damaged material must be promptly communicated to the owner, in writing, to allow sufficient time for replacement material to be ordered, fabricated, and delivered, or for damaged material to be repaired.

Depending on a number of factors (project location, size, and ease of obtaining replacement quantities), it is common practice for the owner to order overages of small hardware such as fasteners, conductor hardware, insulators, etc. For structures, it is common that an overage of nuts, bolts, washers, and fills in the range of 3–5% be ordered. Overages of insulators are dependent upon the type and quantity of insulators required for the line. For small to medium size projects, an insulator overage of 3% is practical, while on larger projects an overage of 1–2% is generally adequate.

If mismanufactured or damaged components are discovered during the assembly of the structures, the constructor should immediately notify the owner who will decide if the errors or damage should be corrected by the constructor, by the manufacturer, or by local shops.

5.5 Surplus material

After completion of construction, all surplus material furnished by the owner should be inventoried and returned to the location stated in the construction specification. The material should be sorted, counted, and tabulated by quantity and description. Material items which are not complete (missing nuts, cotter keys, etc.) should be identified and stored separately from complete items. Material returned in this manner will enable the owner to inspect the condition of the surplus material and determine the disposition of the items.

6. Assembly and erection of concrete pole structures

This clause covers the recommended assembly and erection procedures for concrete pole structures. The process will be divided into the following two main categories:

a) Single-pole structures
b) Framed structures—two or more poles joined by rigid members

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The field assembly and erection methods chosen will be influenced by such variables as line and structure design, line route, terrain, climatic or seasonal weather conditions, the impact of any environmental restrictions, line route access, schedule requirements, and the availability of critical resources in both man-power and equipment.

Poles that consist of one or more sections are generally assembled either at the structure site or in a marshalling yard and then transported to the structure site.

Erection techniques vary greatly depending on the specific job variables. An erection crane with a telescoping boom is an efficient method for structure erection. If extensive preassembly is used, the time spent in final erection is greatly reduced.

Preplanning of desired crane locations at the structure site allows for any necessary grading work (building of ramps, soil stabilization, etc.) to be accomplished during the foundation construction operations when suitable equipment is available at the site. Caution should be used when cutting into hillsides as this may precipitate slope failures. Depending on soil conditions, additional bearing support may be required under outriggers, tracks, and tires. All soil should be returned to a condition acceptable to the owner after erection.

Aerial lifts can be effective in providing a safe-work position for workers handling large connection bolts to make aerial connections. The aerial lift can eliminate the need to install a variety of either temporary or permanent rigging and climbing devices on each structure. Whenever possible, efficient field procedures will include attaching all insulator assemblies on the structure during erection. Stringing travelers and finger lines installed during erection can greatly expedite the wire stringing operation (see figure 6).



Figure 6—Installation of conductor arm using an aerial lift

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6.1 Handling and transportation of poles, arms, and component parts

When delivering poles from the storage area to the erection sites, special care should be taken during the loading, hauling, and unloading to prevent any damage to the surface of the poles and arms. Slings for handling the poles and arms should be made of, or covered with, nylon or some other nonmetallic material to protect the finish. Poles should be handled in such a manner that no portion of the pole is dragged along the ground or against the pole trailer or other objects that could damage the surface of the pole.

A check of each component's identification marking and the required quantities during this phase of work can minimize potential lost time during assembly of the structure.

Proper initial placement of pole sections at the job site can increase the efficiency of the assembly operation.

Poles and arms should be placed on suitable cribbing to prevent damage and provide a level plane that will prevent overstressing of the structure components (see 5.3).

6.2 Single pole structures

6.2.1 Assembly

All assembly should be as shown on the drawings using methods and equipment which will not cause damage or distortion of any part of the structure. Methods of assembly and erection may be subject to review by the owner.

Whether the structure is assembled on the ground or in the air depends on right-of-way considerations and the constructor. Most constructors assemble the structure on the ground.

Various types of wrenches can be used to tighten nuts [e.g., spud, adjustable, ratchet, torque, box end, and impact (electric, pneumatic, or hydraulic)]. Impact wrenches must have adjustable torque limiters to prevent inadvertent overtightening of nuts. The use of any wrench that may deform nuts or cut or flake the coating on the nut should not be permitted. There are several acceptable methods of specifying bolt and nut tightness, depending upon application. Three commonly used methods are: the snug tight method, the turn-of-the-nut method (see IEC 826-1991), and quoting a specific torque value.

During assembly and erection, members should not be bent or overstressed to force them into place.

6.2.2 Assembly on the ground

Structures assembled on the ground should be placed on suitable blocking so as to be kept free of dirt, mud, or other foreign material that might adhere to the structure or damage the coating. Blocking should be placed so as to provide a flat surface to prevent overstressing or distortion of members and to maintain the true geometric shape of the assembled members. Mud, dirt, and other foreign material should be removed from the contact surfaces of joints prior to assembly.

The structures should be assembled in accordance with the manufacturer's erection and detail drawings. The diameter, type, and length of bolts as shown on the drawings should be used for each connection. Orientation of bolts can facilitate access, final tightening, installation of locking devices, and subsequent checking of the erected structure. Care should be taken when tightening bolts into threaded inserts which are precast in the concrete pole (see figure 7). When the bolt's thread length is greater than the depth of the insert, overtightening may break the bottom of the insert. Further overtightening may cause some local spalling of the interior concrete wall [see 4.3, item m)].

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Figure 7—Field assembly of climbing devices

When pole sections, arms, and other miscellaneous hardware are assembled prior to erection, assembly shall be on level blocking placed outside the attachment point areas to maintain the true alignment of the assembled structure. The pieces should be oriented so that all attachment points are accessible and all attachments can be added with minimal or no need to rotate the structure.

All finish touch-up should be performed prior to erection. Insulators, hardware, travelers, and climbing devices (if specified by the owner) may also be attached while the structure is on the ground. See clause 7 for precautions against damage during erection. Once the structure is totally assembled, it should be thoroughly inspected. Climbing devices, where they may interfere with the erection process, should be temporarily removed from the structure.

6.2.2.1 Flange-plated pole sections

Contact surfaces of joints should be clean and free of foreign matter before assembly.

Flange-plated pole sections should be aligned to the orientation marks and the bolts should be tightened as specified. The bolt tightening sequence should ensure that proper alignment between the two pole sections is maintained throughout the tightening sequence. Gaps between flanges at bolt locations may be filled by use of shims if allowed by the owner and structure designer. Alignment of the pole should be checked after all flanged joint bolts are installed and tightened as specified (see figure 8).

6.2.2.2 Splice-jointed concrete poles

Splice-jointed concrete poles are most commonly assembled in the air rather than on the ground. Normally, the lower pole section is set into the foundation hole and backfilled. The upper section is then lifted into position over the lower section and checked for proper alignment. The lower end of the upper section is normally a tapered steel tube designed to slip over the top end of the lower section. The two joining regions of these pole sections usually have a guide device to ensure proper orientation. The upper section is lowered

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onto the lower section. Tag lines attached to the upper section help maintain proper alignment. The weight of the upper section is usually sufficient to completely engage the joint.

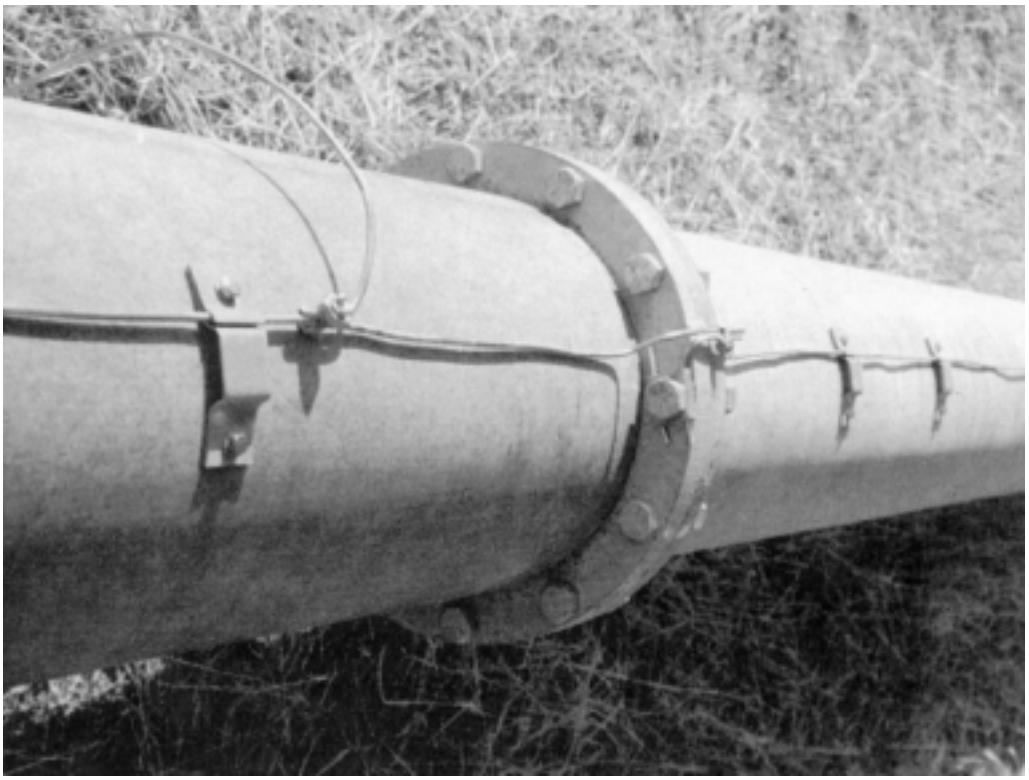


Figure 8—Flanged joint on a multipiece pole

If the splice joint is to be assembled on the ground, lay the lower pole section level and blocked off the ground. Make sure no blocking material is located in the splice zone. Apply a water-soluble nonstaining lubricant to the surfaces to be engaged: the exterior upper end of the lower section and the interior of the lower end of the upper section. Lifting the upper section horizontally, slip it as far as possible over the lower section while checking for proper alignment. Attach the jacking device, specified by the supplier, and increase the jacking force to the maximum allowed. Slight upward and downward movement of the upper section by the crane may facilitate the assembly. Once the joint is fully engaged, the upper section can be blocked level and the crane can be released. Secure the upper section to the lower section if the pole is to be lifted at a point on the upper section. It is not recommended that the joint's friction fit be relied upon to safely lift the pole into a vertical position.

6.2.2.3 Attachments to pole

Arms or other attachments should be blocked and leveled to the proper position. Attachment bolts and nuts should be tightened as specified.

If conductor and static arms are assembled to the structure and the wire is not installed in a reasonable period of time, there may exist a potential of fatigue failure due to wind-induced vibration. These arms can have their natural frequency or damping characteristics modified sufficiently to eliminate this type of damage. Two acceptable methods are suspending weights or insulators from the ends of the arms or tying the arm tips together and to the structure.

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6.2.2.4 Damaged and misfabricated members

Damaged or misfabricated members that prevent proper assembly and fit should be immediately reported to the owner for corrective action. The damaged or misfabricated members should not be repaired by the constructor without written approval from the owner. Members may be damaged to such a degree that replacement rather than repair is necessary.

Structural metal components are commonly used with concrete poles. The edges of clipped angles, new or reamed holes, or any member which has its coating scratched or damaged should be repaired with a coating approved by the owner. If field fabrication of a member is permitted, the bolt spacing and edge distances should be in accordance with the fabrication detail drawings. Field welding and flame cutting should be approved by the owner.

Holes should not be reamed for alignment unless approved by the owner. Bolts should not be driven in any manner that will distort them or damage the threads. Prior to assembly, all joint surfaces, including those adjacent to the bolt heads and nuts, should be free of any material that would prevent solid seating of the parts.

6.2.2.5 Field drilling holes in concrete

Field drilling of holes by the constructor is generally accepted provided it has been approved by the owner. The constructor should follow the recommended procedures furnished by the manufacturer.

Generally a rotor-hammer drill or core saw is used (see figure 9). For hollow spun holes, drilling from the outside to the center of the pole and rotating 180 degrees, staying at the same elevation, and again drilling from the outside to the center is recommended to complete a hole through the pole. This method tends to reduce or eliminate possible local spalling of concrete. Small diameter reinforcing steel, if encountered, can normally be drilled through with little effort. If high-strength steel stressing strand or large diameter rebar is encountered, it may be possible to move the hole location to avoid interference. This steel may be cut, if approved by the owner, after the design is reviewed. Flame cutting is one method to remove the steel that is in the path of the hole. All exposed metal reinforcing should be properly coated to provide adequate protection from corrosion (see 6.6.2 and 6.6.3).

For solid static-cast poles, drill the hole all the way through the pole from one side. If the drilled hole passes through a void in the center of the pole created by a sono-tube, then it may be necessary to install a PVC pipe liner to prevent possible corrosion of the through bolt due to chemicals in the material.

6.2.3 Erection of assembled structures

Structures may be erected by any suitable method that will not overstress structure members, in the sequence best adapted to the equipment, worker experience, and site conditions.

The assembly and erection methods proposed by the constructor should be submitted to the owner for review prior to commencing assembly. These methods should be reviewed to ensure that members are not overstressed.

The structure should be laid out in accordance with a predetermined plan to minimize effort and maximize safety during the erection of the structure.

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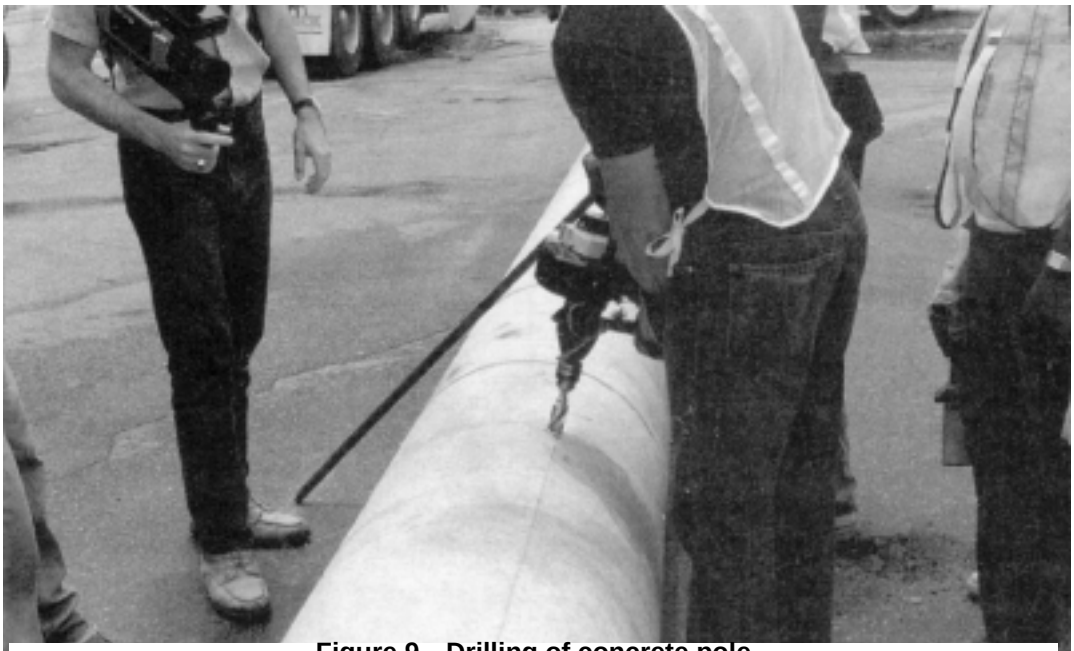


Figure 9—Drilling of concrete pole

Concrete poles may be erected by using the lifting holes (if provided) or by rigging the pole with a padded cable choker or sling choker. Provisions should be made to ensure that the choker cannot slide up the pole as the structure is being erected. One method is to attach the choker just beneath an arm assembly. This may be acceptable, provided that the arm connection design was reviewed and approved by the owner to ensure that the connection is capable of sustaining the lifting load without damage. The lift point may be supplied by the manufacturer. The lift point may need to be field determined as it varies with the number of arms and accessories on the pole; if so, the constructor should obtain the owner's approval and assurance that the lifting device can handle the additional weight. Tall, slender structures, such as guyed structures, may require a two-point lift to prevent overstressing during erection. Proper care should be taken to ensure that there is no damage to the choker during the erection process.

As the structure is being lifted, tag lines or other means of control can be used to safely handle and guide the structure into its foundation (see figure 10). Once the structure is in place, its plumb should be checked, preferably with a transit. At times, deflection limitations are imposed on some angle structures. This requirement can be met by field raking the structure during erection.

Structures should be completely erected and correctly oriented, with all members in place and all bolts installed and properly tightened, and the entire structure should be checked in accordance with the specifications prior to the installation of conductor and shield wires.

Guyed structures should be erected with the guys pretensioned as specified by the owner. After stringing, the guy tensions may require adjustment to final values.

CAUTION

When erecting structure members or sections in the vicinity of energized lines, care should be taken to ground these members or sections before any workers come in contact with them.

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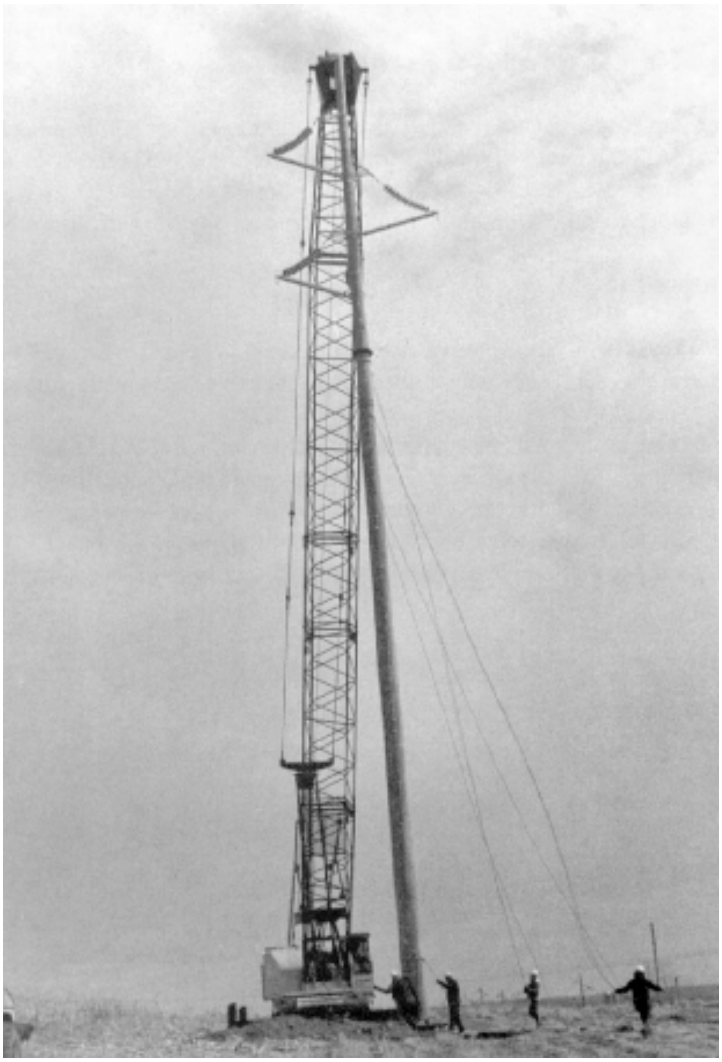


Figure 10—Pole erection

6.2.4 Assembly in the air

At times, the terrain and environment dictate the need for aerial assembly. Close inspection of all parts to ensure proper fit is highly recommended prior to the lift operation.

If a single pole structure is made up of two or more pieces, the bottom pole section is set first, inspected for plumb and alignment, and secured to the foundation. As each subsequent pole section is stacked, the joint is secured. Because of possible impact loads, insulators may not be installed until all of the pole sections are completely assembled.

For pole joints, the structure designer's recommendations should be followed. Upper and lower pole sections in the area of the joint should be marked for proper orientation and, if required, as a guide for minimum/maximum engagement tolerances. Proper orientation and tolerance for each joint should be shown on manufacturer's drawings. Care should be taken to properly match orientation marks while verifying proper alignment of arm connections, hardware, and climbing devices (see 6.2.2.1 and 6.2.2.2 for further information).

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6.3 Framed structures

Much of the information in 6.2 also applies to the assembly and erection of framed structures.

The most common example of a framed structure is the H-frame. The assembly process is very similar to that of a single-pole structure. Permanent locking devices may be required at joints in order to prevent joint movement after the structure is erected and loaded. Maximum adjustability in a framed structure is maintained by leaving all connections loosely bolted until the structure is totally assembled.

6.3.1 Assembly on ground

Assemble poles as described in 6.2.1. Minor variations in assembled pole lengths can be accommodated by adjusting the depth of the excavation of direct-embedded structures prior to setting the structure.

After the poles have been assembled, place the poles in proper relation to each other and level (see figure 11). Install the arms and then the x-braces (if required), leaving all connections loosely bolted. Special care must be taken to maintain the structure geometry when installing x-braces with adjustable bands. The correct distance between pole shafts must be verified before tightening the bands. The framed structure should be checked to ensure that it is square. All bolts and nuts should be tightened as specified.

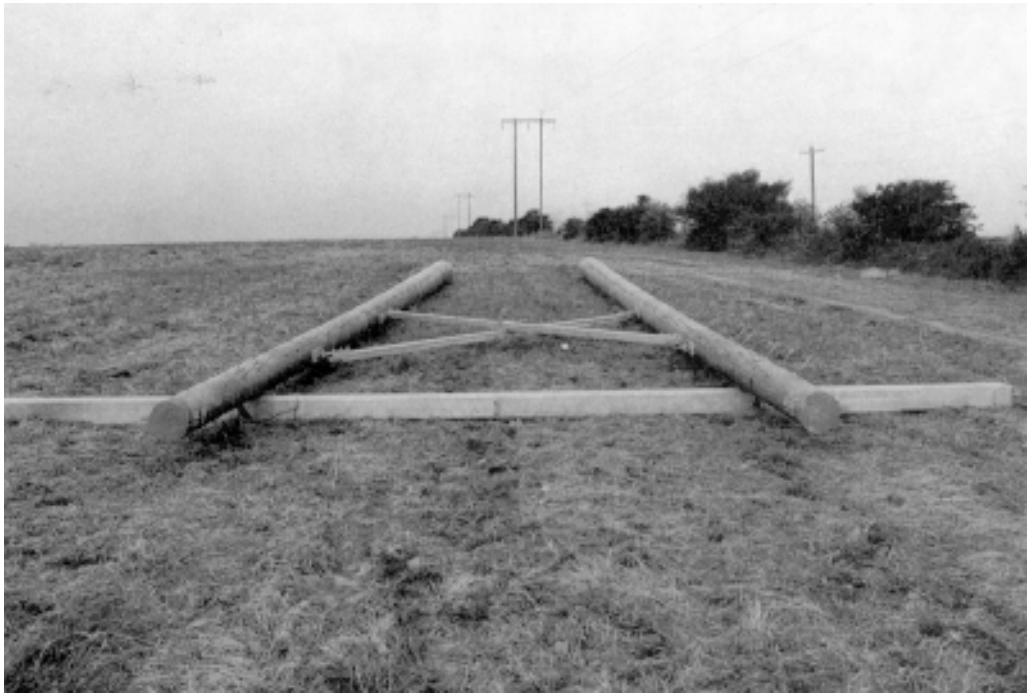


Figure 11—Framed two-pole structure

All finish touch-up should be performed prior to erection. Insulators, hardware, travelers, and climbing devices (if specified by the owner) may also be added while the structure is on the ground. See clause 7 for precautions against damage during erection. Once the structure is totally assembled, it should be thoroughly inspected. Climbing devices, where they may interfere with the erection process, should be temporarily removed from the structure.

6.3.2 Erection

When handling a framed structure, a spreader bar or other device with proper points of attachment should be used to avoid distorting or overstressing members and to maintain the true geometric shape of the structure.

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A spreader bar or yoke should be used between the two legs of an H-frame type structure while it is being lifted (see figure 12). On some structures, it may be necessary for an additional crane to lift the base of the structure due to site conditions or weight of the structure.



Figure 12—Erection of two-pole structure

Tag lines can be used to guide the structure to its foundation. Equipment, such as a bulldozer, tractor, or truck, may be required to guide the structure.

6.3.3 Assembly in the air

Single-piece poles or flanged joints are recommended for structures requiring assembly in the air (see figure 13).

On smaller framed structures, each lower pole section can be set and then the entire upper frame can be pre-assembled on the ground and erected as one unit. On larger framed structures, each piece may have to be lifted and attached independently.

CAUTION

When erecting these structures in the vicinity of energized lines, care should be taken to ground these pieces before any workers come in contact with them.

It is very important to note that in the case of framed structures each joint must be loosely connected until all parts of the structure are installed. This is necessary to allow adjustments while positioning and attaching each subsequent part.

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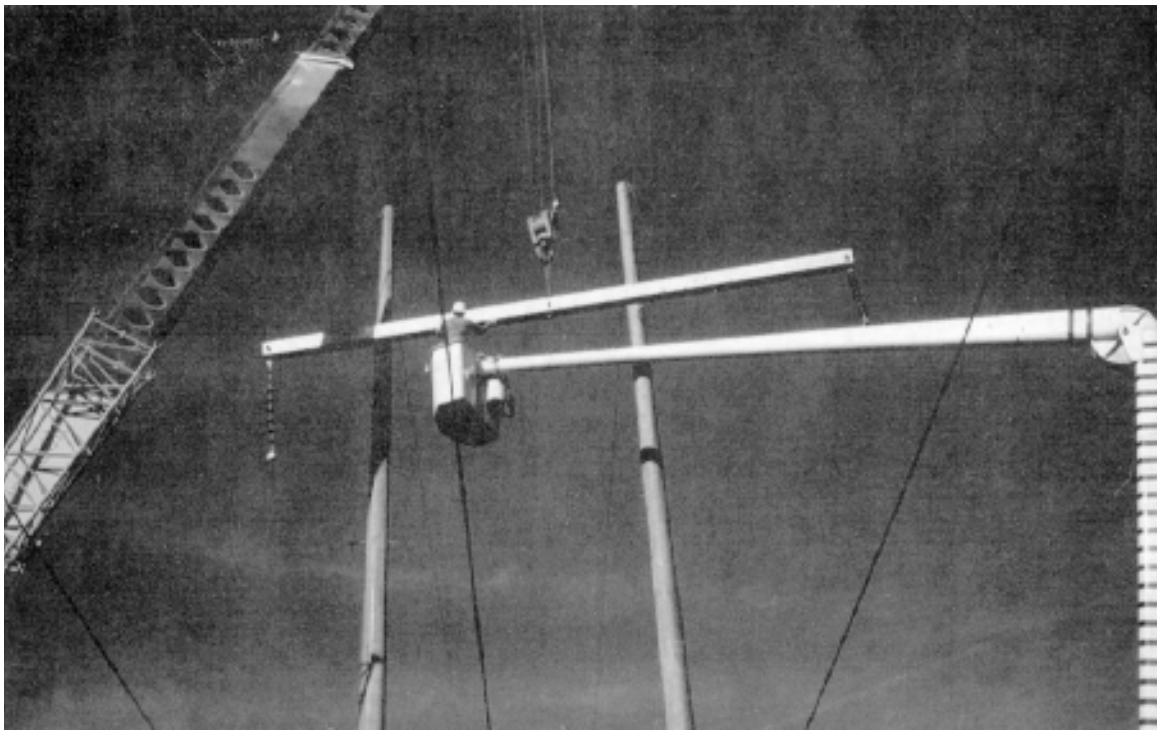


Figure 13—Aerial assembly of cross-arm

The bolt-tightening operation should begin only after all parts are assembled and all bolts are installed. Methodically tighten joints while continually checking the plumb, level, and orientation of each part. Refer to 6.2.2.1 for flange joints.

6.4 Helicopter erection

The use of helicopters to erect concrete pole structures has not been in common use due to the weight of these structures. This method may be required when the line route, terrain, or environmental regulations limit the access of heavy construction equipment.

Helicopters have proven to be a useful construction tool. However, with their high hourly cost, the planning and scheduling of construction become very critical. In addition, a larger marshalling yard may be required due to the assembly of a large number of structures prior to erection. Structures or sections can be flown from marshalling yards or lifted into position at the structure site.

The location of the marshalling yards should be as close as possible to the line to reduce flight time and suitably located for helicopter access. Yards should be prepared to prevent flying debris.

In order to lift the structure, a sling is attached to an electrically operated hook on the underside of the helicopter. A dynamometer can be connected to monitor the flying weight of the load as the load is affected by rotor down wash and drag. The electrically operated hook is controlled by the pilot.

When lifting the structure, slings should be attached to avoid overloading or distorting the structure.

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On guyed structures, the guy tails can be rolled up and the coils can be tied to the bottom of the structure to prevent them from catching on trees and fences during takeoff and landing. Each guy can be marked to identify the proper anchor location during the landing operation.

If possible, helicopter operation should be scheduled during cooler periods of the day to increase the lifting capacity since lift capacity is a function of air temperature.

Normally the pilot brings the structure to the site into the wind to maintain more lift on the rotor blades.

CAUTION

The structure may need to be grounded to discharge any electrical charge before workers come in contact with the structure.

Good communication is essential during helicopter erection. Dual-frequency radios should be used. The flying operation is kept on one channel and the ground operation on the other to prevent any communication interference.

Helicopter erection is facilitated by the use of guides and chutes that are installed on the structure prior to erection. Design and attachment of the guides and chutes should be coordinated between the constructor and the owner. These devices can eliminate the need for workers to be under the structure as it is being erected. Structure components should be secured as soon as possible after the helicopter releases the load. On guyed structures, all necessary guys must be secured prior to releasing the load from the helicopter.

6.5 Attaching pole structures to various foundations

The most common foundation type for concrete pole structures is the direct embedment method. Variations on this concept include setting the pole into a pile or a cavity within a drilled-pier, reinforced concrete foundation.

Foundations for concrete pole structures will vary based on the groundline moment carrying capacity of the soils. For many concrete pole applications, both self-supporting and guyed poles, direct embedment backfilled with native soil may be adequate. Further foundation design considerations may be required for weak soils, large groundline moment carrying capabilities, restricted deflections, rotation and translations of structures, and for foundation, structure, or line reliability. Oversized holes may be excavated, and controlled backfill of crushed stone, soil, cement, or concrete may be placed or compacted around the embedded section of the pole.

When the concrete pole foundation has a large groundline moment carrying capacity, it should be treated as a structural foundation. The capacity of the soil in the foundation design becomes an important factor. In some extreme cases, installation of piles or spread foundations may be necessary.

6.5.1 Direct embedment

Direct embedment of concrete poles is the most common type of installation. The constructor should review the foundation specifications to verify proper depth of embedment, diameter of the hole, preparation of the bottom of the hole, type of backfill material, and installation method of the backfill material (see figure 14). The excavation should be of sufficient diameter to allow accurate placement of the pole and adequate space to place, tamp, or vibrate the backfill. Loose material in the bottom of the hole will be compressed due to the weight of the concrete pole. The bottom of the hole should be made flat and firm prior to taking final depth measurement.

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Figure 14—Direct embedment

Soil borings are often taken at random locations along or near the right-of-way. These borings may not accurately represent all soil conditions encountered during actual hole excavation. Significant soil variances should be reported to the owner for review. If a very poor soil condition is unexpectedly encountered, it may be necessary to provide additional bearing capacity and enhance the quality of backfill to achieve adequate support. Conversely, better soil conditions or rock may be unexpectedly encountered that may also require revisions to the foundation.

Once the pole structure has been lifted, it should be safely guided over the hole without dragging or knocking excavated material into the hole. Care should be taken, while slowly lowering the pole into the hole, not to cause caving or sloughing of the walls of the hole. The pole should be checked for orientation and alignment just prior to it touching the bottom of the hole. Allow the pole to seat firmly in the bottom of the hole. The pole should be secured in a properly oriented and plumbed position before backfilling the hole.

The backfill material is normally native soil, improved backfill material, or sometimes concrete depending on the foundation design requirement and existing soil conditions. Generally, the backfill is placed uniformly around the circumference of the hole in predefined amounts. The backfill is tamped or vibrated in accordance with the foundation specifications. This process is repeated until the annular void is completely filled. The placement of the backfill should be constantly monitored to ensure that the pole is not being moved out of position. Care should be taken during the placement and compaction process to avoid damage to the embedded portion of the pole.

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Once the foundation is completed, the pole may be released. Foundations needing additional time to cure, such as concrete, may require temporary bracing or guying until the backfill is fully cured.

In some areas the soil may be too weak to adequately support the weight of the pole and the wire loads. Such conditions can exist in swamps, marshes, landfills, and river basins. Bog shoes are often used to provide additional bearing capacity. Bog shoes are normally rectangular, reinforced concrete beams that are placed below the pole or attached to the sides of the direct embedded portion of the pole.

A typical arrangement is shown in figure 15. A hole is augered to the required depth. A hydraulic hoe then digs the required trench to accept the bog shoe(s). The pole and bog shoes are set into the foundation and attached to each other as required by design. Backfilling commences after the structure is checked for correct alignment.

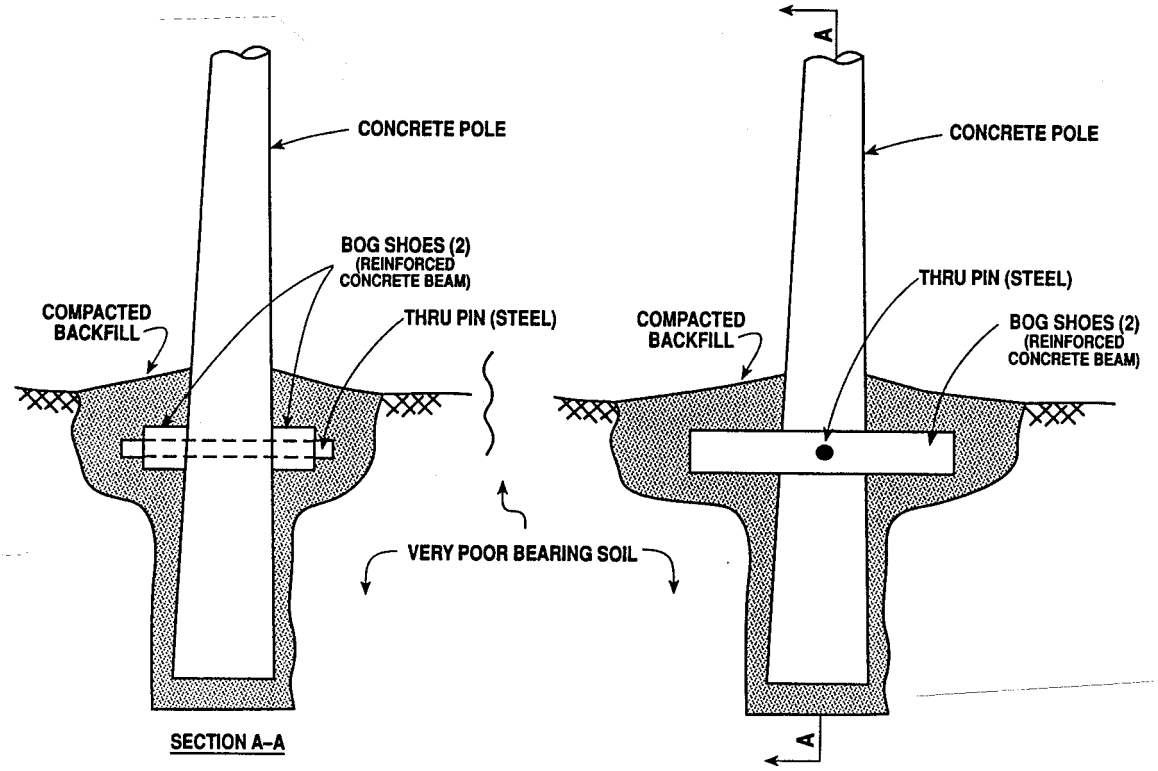


Figure 15—Bog shoes

If the space between the bottom of the base plate and the top of the concrete foundation is left open, the concrete foundation should be designed and finished such that no water or debris can collect in that space.

The foundation holes should be checked to verify that the bottom of each hole has the same elevation and level. If they are not the same, sufficient backfill should be placed and tamped firm and level in the deepest hole until both holes are at the same elevation.

The H-frame cross arm should be checked to verify that it is level after installation.

6.5.2 Anchor bolt/base plate

In the case of the anchor-bolted, concrete type foundation with a base-plated structure, the structure is simply lifted onto the anchor bolts.

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The levelling nuts should be threaded on each bolt sufficiently down on the threads to allow for the addition of the base plate and top nut. These lower nuts should be positioned so that when the base plate is set on top of them the base plate will be level and as close as practical to the foundation. After adding the top nuts, check the structure to ensure that it is oriented and aligned correctly. If the structure requires raking to allow for load deflections, the nuts above and below the base plate can be readjusted to move the structure out of plumb to the required position.

When tightening anchor bolt nuts, all nuts on the top side of the base plate should be brought to a “snug tight” condition, then the nuts on the bottom side of the base plate should be brought to a “snug tight” condition and checked to make sure that they are bearing completely against the base plate. It is important that the bottom nuts under the base plate be tightened. If required, final tightening of the nuts may proceed as specified. It is common practice to secure anchor bolt nuts (by applying a small tack weld to the edge of the nut and the mating surface of the base plate), thus preventing unauthorized turning or removal.

Upon completion of pole erection, the void between the base plate and the concrete foundation may be filled with nonshrinking, flowable grout or dry packing with a sand/cement mixture or left open.

Special care should be used when installing grout, if specified, so that the pole drains will not be dislodged or plugged. After the grout has set and the forms have been removed, each drain should be cleared to ensure that it is open and free to allow drain water to flow.

6.6 Post-erection

As soon as possible after erection, the constructor should connect the previously installed ground wire to the grounding attachment on the pole. The wire should be shaped to fit closely to the foundation and the base of the pole; any excess length should be trimmed.

Structures should be completely assembled with all bolts securely tightened before the start of conductor or shield wire stringing operations. Steps or ladders should be removed from the lower portions of all structures after completion of construction to discourage unauthorized climbing.

6.6.1 Concrete repair

Minor repair may be performed by the constructor. The constructor should follow the recommended repair procedure furnished by the manufacturer that has the owner’s approval. In general, all loose concrete and powder should be removed to provide a clean repair area. Exposed steel should be cleaned (degreased, no rust) and properly coated to protect against corrosion. It is recommended that the concrete repair patch compound have: (1) approximately the same expansion coefficient as the parent concrete, (2) nonshrinking drying characteristics, and (3) dry-to-blend-in color that will blend well with the original concrete surface (see figure 16). Most repair compounds are a type of epoxy grout, nonshrinking grout, or a polymer concrete mix. Normally, the concrete pole supplier has patch kits available that meet these requirements. The constructor should notify the owner, prior to repair, if major or extensive damage exists. Special inspection and repair procedures may be necessary in these cases. Some chemical grouts may exist that are toxic in nature and special handling techniques may be required.

6.6.2 Galvanized coating repair

The damaged area should be cleaned using a wire brush and solvent, if necessary, to remove rust, grease, and other foreign matter. When dry, the area should be coated, using a brush or spray can, with a cold galvanizing compound approved by the owner. As many coats as necessary should be applied to obtain a minimum dry thickness as specified by the owner (see ASTM A780-90).

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Figure 16—Field repair

6.6.3 Painted coating repair

The damaged area should be cleaned using a wire brush, scraper, and/or solvent, if necessary, to remove rust, grease, and other foreign matter. It may be desirable to lightly sand the edges of the area to be repaired to feather the touch-up paint into the existing coating. The damaged areas should be dry prior to coating. If damage is confined to the finish coat, apply one coat of properly mixed paint to attain the minimum dry film thickness required. If damage is through the coating to bare steel, the appropriate primer should be applied to the required dry film thickness and allowed to properly cure prior to top coat application. Care should be taken to ensure that the paint manufacturer's recommendations are observed during field application.

7. Assembly and installation of insulators and hardware

This clause covers the suggested procedures for the handling, inspection, assembly, and installation of insulators and hardware.

7.1 Assembly of insulators and hardware

Insulator and hardware assemblies for both conductors and shield wires should be assembled and installed as specified on the drawings. Care should be taken in handling and assembling insulators to avoid impact loads that may cause internal damage, to avoid chipping or cracking the ceramic or glass surface, and to avoid excessively deforming or marking the sheds of synthetic insulators. Any insulator having a damaged surface should be removed and disposed of after inspection.

Insulators and hardware, when properly aligned, should fit together easily (see figure 17). Care should be taken to ensure that compatible hardware (i.e., conforming to applicable ANSI or IEC standards) is used at the interface between insulators and hardware. It is advisable to preassemble one of each assembly type prior to actual installation to ensure compatibility and fit of components. Nuts which do not run freely on bolts

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should not be used. All nuts should be torqued or otherwise secured as specified on the drawings. All cotter keys should be inserted and properly spread where required.



Figure 17—Hardware assemblies installed prior to pole erection

7.2 Installation of cotter keys

In all cases, hardware should be installed so that cotter keys or bolts can be removed with the use of hot sticks. All cotter keys in suspension insulator units and hardware should be oriented to meet the maintenance requirements of the owner. In general, the cotter keys are turned so that the eye is toward the structure or upward. All cotter keys should be properly installed and spread, if required, to prevent accidental uncoupling of insulator units. The heads of all bolts and clevis pins used in the vertical position on hardware should be oriented in accordance with the owner's requirements.

Self-locking or humped-back cotter keys should not be inserted into a bolt or clevis pin by hammering the head of the cotter key or by other means that can cause deformation of the cotter key. If deformed, these cotter keys may lose their self-locking characteristics.

When cotter keys, bolts, or clevis pins are replaced, a cotter key, bolt, or pin supplied by the manufacturer of the insulator or hardware should be used since the cotter keys, bolts, and pins of different manufacturers are not necessarily interchangeable.

An inspection should be made of each assembly to ensure proper assembly installation and proper cotter key placement.

7.3 Installation of assemblies

Extreme care should be exercised in the installation of all insulators and hardware to prevent damage of any kind. During construction, loads may be inadvertently imposed on insulator strings in excess of their tension-proof load rating. Any insulators subjected to these overloads should be removed and replaced.

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Special care should be exercised with extra-high-voltage (EHV) hardware since surface damage of components may increase line noise.

The surface of the insulators should be clean and the metal portions should be free of contaminants and corrosion. Ceramic, glass, and metal surfaces should be wiped clean with a hard cotton canvas cloth prior to installation. Wire brushes or abrasive material should not be used to clean the surfaces.

Insulator strings or assemblies being installed should be supported or restrained in a manner to prevent the possibility of bending of ball or pin shanks or deformation of cotter keys in order to prevent subsequent uncoupling of the joints. Suitable cradles or other alignment supports should be used for this purpose where necessary. If the lower end of the insulator strings are to be tied to the structure during erection, particular care should be exercised to ensure that the weight of the insulators and hardware does not cause bending of the ball shanks.

Bolt heads or nuts should not bear directly on the concrete surface (i.e., bolts through the pole). A washer of adequate capacity should be placed between the bolt head or nut and the concrete surface. The washer may be flat or curved depending upon the concrete surface contour.

If post or strut insulators are used, care should be taken to avoid loads that induce bending or impact. Lifting the post or strut insulators with the structure can produce impact loads on the insulators and should be avoided. If post or strut insulators are installed on poles with joints, care should be taken to ensure the proper engagement of the joint and that no further joint movement will occur prior to installing the insulators.

If travelers are to be installed with the insulators and hardware, care should be taken to ensure that they are in proper working order and are oriented correctly, and that any finger lines are placed. Where required, dampers and spacers may also be temporarily positioned on the structure for final installation.

8. Quality assurance

Complete inspection during assembly and erection of each concrete pole structure is recommended. The owner should make inspections of both materials and workmanship at each stage of the work, focusing attention on such items as:

a) Cracks and spalls in concrete surface
b) Exposed reinforcing steel or steel strands
c) Material, weld, and test certifications
d) Material coatings
e) Missing or incorrect items
f) Fit or engagement of members and bolts
g) Bent, deformed, or otherwise damaged items (e.g., deformed members may reflect mislocated footings)
h) Field modifications and repairs
i) Bolt and nut tightness
j) Installation of locking devices
k) Length and type of bolts
l) Plumb of the pole and its orientation
m) Pretension of guys
n) Installation of structure ground
o) Installation of miscellaneous attachments (i.e., signs, anticlimbing devices, climbing devices, insulator washing pipe, etc.)

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