Special Research Topic Report on Current Practice in Utility Distribution Poles and Light Poles

Adam Crosby

Date 5/05/11

1.0 Objective

The objective of this report is to present a summary of the current practice of the structural design of utility distribution poles and light poles, including the poles and foundations. This summary includes design and safety standards and codes, material specification, material selection, foundation design, design liability, and maintenance.

Two common genres of poles are discussed in this report. The first genre is utility poles. Utility poles are grouped into two kinds – utility transmission and utility distribution. The second genre includes poles for lighting, traffic, homeland security, and intelligent traffic structures. The two genres of poles are analyzed and designed by the same structural principles, but they differ in governing codes and common industry practice. This report focuses on poles for utility distribution and lighting. Because they of their differences, they are treated as two separate topics in this report. The first section of the report addresses utility distribution poles and the second section addresses poles used for lighting.

1.1 Utility Poles and Structures

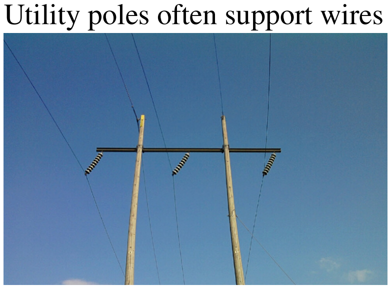


Figure 1: Transmission Structure (Crosby, 2011)

Utility poles often support wires and other components for many utilities such as electric power, telecommunications, cable television, and fiber optic. Transmission lines typically carry the electric power from the source to substations where distribution lines branch off to supply the surrounding businesses and homes with power. Figure 1 shows a typical transmission structure. In some cases there is difficulty in making a distinction between utility transmission lines and utility distribution lines. Distribution lines can best be distinguished from transmission lines by their smaller rights-of-way. In addition to having taller poles and structures, a transmission line is accompanied by rights-of-way ranging from 75-200 feet and voltages around or above 69 kV. (RUS Bulletin 1724E-20). Regarding utility poles, this report focuses on distribution. See Figure 4 for a typical distribution pole.

1.2 Lighting, Traffic, and Homeland Security

From the genre of poles including lighting, traffic, and homeland security, this report focuses only on lighting. Light poles are typically freestanding poles with light fixtures at the top. Figure 2a shows a typical light pole.

Figure 2: a) Light Pole, b)Traffic Mast Arm Pole (a and b from www.valmont.com)

Traffic poles include those supporting traffic signals and signs as shown in Figure 2b.

Types of homeland security and intelligent traffic structures are message signs, surveillance cameras, and traffic sensors. See Figure 3 for examples.

Figure 3: a) Message Sign, b) Surveillance Pole, c) Surveillance Pole with solar panels (a, b, and c from www.valmont.com)

2.0 Utility Distribution Poles

Utility distribution poles, sometimes called power poles or telephone poles, are components in distribution lines. Other components include various utility wires spanning from poles to pole, guy wires, transformers and other equipment. Figure 4 shows a typical wood distribution pole.

2.1 Types of Utility Companies

Four types of utility companies are involved in the ownership, design, installation, and maintenance of distribution lines:

1. Investor Owned Utility (IOU) such as the Southern Company which includes Georgia Power.
2. Electric Membership Cooperatives (EMC)
3. Municipalities- Cities or counties providing electricity distribution.
4. Telecommunication Companies – AT&T, Verizon, Sprint, etc.

Figure 4 Typical Wood Distribution Pole (Bingel, 2011)

Figure 5 shows the assigned service areas for Georgia Power, Electric Membership Cooperatives, and Municipalities. Note that very few poles are owned, designed, or installed by telecommunication utility companies.

2.1.1 Investor Owned Utilities

Investor owned utilities are a type of utility company owned by private investors for profit. Currently the only investor owned utility in Georgia is The Southern Company, which includes Georgia Power. Historically Georgia Power has supplied over 50% of the residential, commercial, and industrial customers and (www.gefa.org).

2.1.2 Electric cooperatives

Forty-three electric cooperatives, also known as electric membership corporations, coops, or EMCs service 73% of the land area of Georgia. These member-owned utility companies serve a little less than 50% of Georgia's residential customers and about 13% of Georgia's commercial and industrial customers combined. See Figure 5 for a map of EMC service.

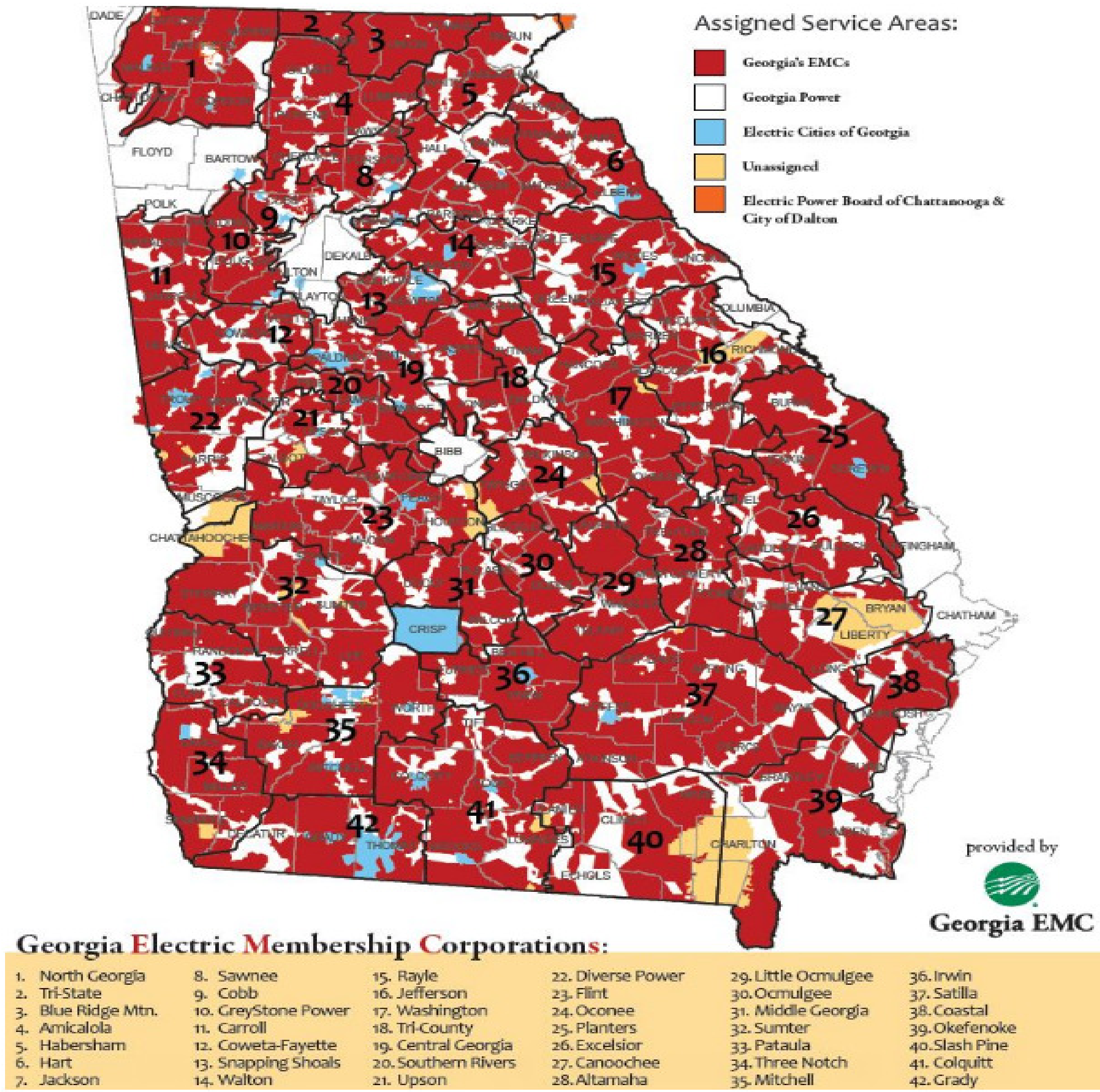


Figure 5: Assigned service areas by utility company type (www.georgiaemc.com)

Most electric cooperatives receive funding in the form of loans from the Rural Utilities Service (RUS). Because of this, the borrowers (EMCs) are required to adhere to the Rural Utilities Service guidelines in addition to the governing codes.

2.1.3 Municipalities

In the early 1900's Georgia Power, then called Georgia Railway, was not able to build distribution lines. Towns would build coal fired or oil powered power plants to supply their area with electricity and longer power lines with no nearby towns were owned and operated by electric cooperatives. In Georgia, there are currently (2011) 52 electric cities – municipalities that own and operate their own electric distribution systems. The number of electric cities in Georgia remains virtually constant. It would be difficult for a city such as Macon, which is not an electric city, to become one. A city would have to buy the existing electric distribution system from Georgia Power. Because of money and politics, it is unlikely that Georgia Power would make this transaction. The same reasons keep electric cities in the electricity business. Figure 6 shows all 52 of these electric cities.

Acworth, GA	Grantville, GA
Adel, GA	Griffin, GA
Albany, GA	Hampton, GA
Barnesville, GA	Hogansville, GA
Blakely, GA	Jackson, GA
Brinson, GA	LaFayette, GA
Buford, GA	LaGrange, GA
Cairo, GA	Lawrenceville, GA
Calhoun, GA	Mansfield, GA
Camilla, GA	Marietta, GA
Cartersville, GA	Monroe, GA
Chickamauga, GA	Monticello, GA
College Park, GA	Moultrie, GA
Commerce, GA	Newnan, GA
Covington, GA	Norcross, GA
Crisp County	Oxford, GA
Dalton, GA	Palmetto, GA
Doerun, GA	Quitman, GA
Douglas, GA	Sandersville, GA
East Point, GA	Sylvania, GA
Elberton, GA	Sylvester, GA
Ellaville, GA	Thomaston, GA
Fairburn, GA	Thomasville, GA
Fitzgerald, GA	Washington, GA
Forsyth, GA	West Point, GA
Fort Valley, GA	Whigham, GA

Figure 6 Map of Municipalities providing their own power (A. Crosby and Google Maps, 2011)

While some of these cities have large enough engineering departments to design most or all of their own distribution poles, the majority rely on private consulting engineers or an organization called Electrical Cities of Georgia (ECG). ECG is a not for profit organization that provides engineering services and safety training. Currently, almost all of the 52 electric cities subscribe to Electrical Cities of Georgia's training, engineering services, or both. The majority of these subscribe to ECG's engineering services to design some or all of their distribution lines.

2.1.4 Telecommunications

A very small percentage of the utility distribution poles in Georgia are owned, designed, and maintained by telecommunication companies like AT&T, Verizon, Sprint, and Cox. When a utility pole carries only telephone line, the telecom company most likely owns and operates it. However, in most cases, a Telecom company wants to add their utility lines and equipment to an existing utility pole owned by a power company. Sometimes power companies will require the telecom company to check the design to ensure adding the extra components will not cause the pole to be under-designed.

2.2 Standards for design of distribution lines

Any utility company, whether it is investor owned, cooperative, municipal, or telecommunications, will probably have its own way to design distribution lines. While there are differences from company to company, the design methods will likely be similar because they have been built from the same standards. There are two typical standards for distribution pole design – National Electrical Safety Code (NESC) and the American National Standards Institute (ANSI O5.1). There are additional guidelines for Electric Cooperatives imposed by the Rural Utilities Service.

2.2.1 National Electric Safety Code (NESC)

The National Electric Safety Code is a standard containing minimum safety requirements for distribution lines and for distribution poles of any material. It specifies loading criteria such as wind, ice, loading factors, etc. The NESC clearly states that it is not a design guide or a design code but merely a set of safety requirements to be strictly followed.

The National Electric Safety Code specifies minimum required loading for pole design. Among other factors, the loading depends on the grade of construction of a pole. The grades are B, C and N, where B is the most stringent design and N is the least. Grade B includes poles located on limited access high-ways (such as interstates), railroad tracks, and navigable waterways requiring waterway crossing permits. Probably over 90% of the poles in Georgia are considered to have a grade of construction of C.

The horizontal and vertical loading from various combinations of ice and wind on poles, wires (conductors), transformers and other components are specified in this code. The worse probable effect of ice and wind loading is meant to be captured by the rules in the National Electric Safety Code.

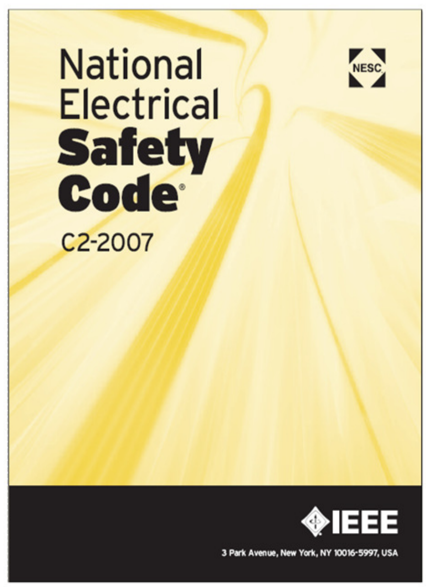
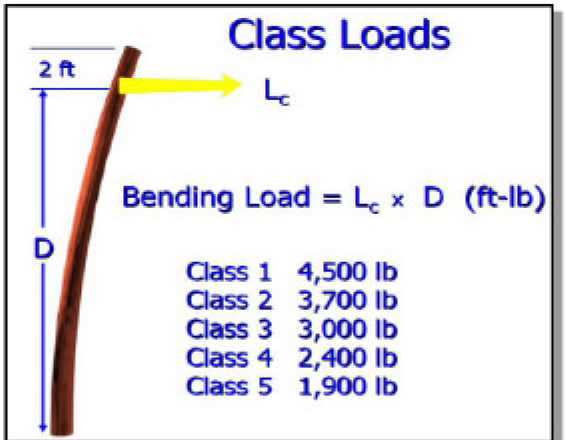


Figure 7: National Electrical Safety Code (Bingel, 2011)

The NESC references the American Society of Civil Engineers (ASCE7) for environmental loading information such as ice and wind loads. In regards to wood, the National Electrical Safety Code references the ANSI O5.1 for dimensions, tolerances, grades of materials and the like. While the National Electric Safety Code specifies loads for analysis, the American National Standards Institute O5.1 establishes the capacity of the poles.

2.2.2 American National Standards Institute (ANSI O5.1):

The ANSI 05.1 lists minimum pole dimensions for each class of pole. The classes are tabulated in Figure 8a from largest to smallest. ANSI 05.1.2008 Table 8 for Southern Pine or Douglas Fir (recreated in Figure 8b) shows that a Class 5 pole has a minimum top circumference of 19 inches, and the circumference 6 feet from the butt ranges from 23-34 inches based on total pole lengths from 20-50 feet, respectively. The same table shows that a Class 1 pole is required to have a minimum top circumference of 27 inches, and the minimum circumference 6 feet from the butt varies from 31-63.5 inches with respect to total pole lengths ranging 20-125 feet. Usually a pole's height and class are abbreviated as follows: “35-6” is a 35 foot long, class 6 pole.



Class	Tip Load (lbs)	Class	Tip Load (lbs)
H6	11,400	3	3,000
H5	10,000	4	2,400
H4	8,700	5	1,900
H3	7,500	6	1,500
H2	6,400	7	1,200
H1	5,400	9	740
1	4,500	10	370
2	3,700		

Class		1	5
Min. Circumference at top (in)		27	19
Length of pole (ft)	Approx. Groundline distance from butt (ft)	Min. circumference at 6ft from butt (ft)	
20	4	31.0	23.0
25	5	33.5	25.5
30	5.5	36.5	27.5
35	6	39.0	29.0
40	6	41.0	31.0
45	6.5	43.0	32.5
50	7	45.0	34.0
55	7.5	46.5	--
60	8	48.0	--
65	8.5	49.5	--
70	9	51.0	--
75	9.5	52.5	--
80	10	54.0	--
85	10.5	55.0	--
90	11	56.0	--
95	11	57.0	--
100	11	58.5	--
105	12	59.5	--
110	12	60.5	--
115	12	61.5	--
120	12	62.5	--
125	12	63.5	--

Figure 8: a) Class Load for Wooden Poles per ANSI 05.1 (Bingel, 2011), b) ANSI O5.1.2008 Table 8 for Southern Pine or Douglas Fir

Pole classes are defined so that poles of different species are approximately equal in load-carrying capacity (ANSI 05.1 2008, Annex B). A pole of a species of wood with lower fiber strength would require larger dimensions to be considered the same class pole. For instance, a Class 3 Western Red Cedar (6000 psi fiber strength) has a larger circumference than a Class 3 Southern Pine (8000 psi fiber strength) of the same length. The dimensions in Tables 3 through 10 of ANSI O5.1 are calculated such that the groundline stresses for a given class do not exceed the fiber strength of the wood. The groundline stress is calculated by applying a horizontal load tip load, 2 feet from the top of the pole to simulate the force transferred from the wires due to wind load. There is a different tip load for each class of pole as shown in Figure 8a.

2.2.3 Rural Utilities Service guidelines

In addition to governing standards (National Electric Safety Code and American National Standards Institute O5.1), Electric Cooperatives must comply with the Rural Utilities Service guidelines. These guidelines specify acceptable pole and component materials, pole embedment, treatment, and inspection schedules. In addition to wood, Rural Utilities Service also specifies requirements for use of concrete, steel, and fiber reinforced polymer poles. The Rural Utilities Service is more stringent than the National Electric Safety Code, thus a design per RUS guidelines may be more conservative than a design by utility company which does not have the extra guidelines.

2.3 Types of utility distribution poles

Three types of utility poles are used on typical distribution lines:

1) Tangent poles

2) Guyed poles

3) Self-supporting poles

2.3.1 Tangent poles

Tangent poles (almost always wood) can be identified as the poles that do not have down guy wires and are in a straight line with other poles. Tangent poles act as simple cantilever beams and/or slender columns. According to Rural Utilities Service construction standards, tangent poles may have a maximum line angle of 5 degrees (RUS Bulletin 1724E-150). Because tangent poles are not to be located at a sharp angle turn in the line they typically resist only the forces due to wind, ice, gravity, and the forces from unbalanced tension in the conductors or other utility wires. Tangent poles do not typically have any back fill material other than the native soil.

2.3.2 Guyed poles

In addition to horizontal forces and their resulting moments caused by wind and vertical forces from dead load, guyed poles must resist loads in both horizontal and vertical directions due to guywires. Guying forces are the biggest contributors to vertical forces in guyed poles. Like tangent poles, guyed poles do not make use of backfill or concrete to transfer forces to the soil.

2.3.3 Self-supporting poles

Self-supporting poles, typically made of concrete or steel, are used where tangent poles and guyed poles will not work. For instance, self-supporting poles may be located at corners of distribution lines where guy wires cannot be used, where sidewalks prevent guying, where a property owner will not allow guying, where an obstruction prevents guying, or many other reasons. Self-supporting poles are not common on distribution lines, but are required where there is no guying option.

Another instance when self-supporting poles are used in lieu of tangent or guyed poles is where the grade of construction increases from the typical grade C to the more stringent grade B – such as crossing of distribution lines. The higher strength is required because of the increase in grade of construction may make a self-supporting pole the most cost effective option.

In any of these cases, the field technician or senior designer may recognize that the pole is reaching the limitations of a typical wood pole and decide to have a self-supporting pole designed. Almost all self-supporting poles are designed by pole manufactures. Design criteria are given to the manufacturers and they design the poles. The designer of responsible charge (i.e. the utility company) typically designs the foundation for the pole, or contracts the design out - which may involve a geotechnical soil investigation.

Figure 9: a)Tangent pole (Bingel, 2011), b) Guyed pole (Crosby, 2011), c)Self-supporting concrete distribution pole (Crosby, 2011)

According to the Rural Utilities Service guidelines, unguyed poles may have a maximum pole line angle of 5 degrees. There are many unguyed wood poles that have an between 0 and 5 degrees. These may also be called self-supporting poles.

2.4 Distribution pole foundations

Typical tanget poles and guyed poles have setting depths based on a rule of thumb: 10% of the total pole length plus 2 feet. That is, if the pole is 40 feet long, approximately 6 feet is buried while 34 feet is above ground. ANSI O5.1 tables 5 through 8 list the “Approximate groundline distances from butt” (in feet) for varying lengths of poles. These distances basically follow the '10% plus 2 feet' rule. The ANSI foot note explains that these values are not intended to be recommended embedment depths. Even so, pole designers have used these values for embedment depth as an industry standard for tangent and guyed poles in the United States, regardless of soil conditions, wind speed, pole diameter, span lengths between poles, guying forces, gravity forces, and other factors.

This rule of thumb, for the most part, is working. However, engineering methods exist for such foundation types. For instance, AASHTO DTS has a nomagraph design aid based on the equivalent horizontal load, allowable soil bearing pressure, and width of pole at embedment.

Also, The International Building Code has a similar design aid in the form of an equation (International Building Code 2006, Eqns 18-1, 18-2, or 18-3 based on level of constraint at ground line). Equation 18-1, the unconstrained case (most common, most conservative) involves variables such as width of pole at embedment, equivalent lateral force on pole, lateral bearing resistance of soil, and lateral sliding resistance of soil. In the absence of a soil investigation (which is not feasible for utility distribution poles), these soil characteristics may be assumed to be minimum values from IBC 2006, Table 1804.2 (Figure 10).

The vertical loads from guying and dead weight may be designed to be resisted by the assumed minimum allowable foundation pressure in the same table. Thus, only the class of soil material needs known to design the foundation with the International Building Code Equation. If this classification is unclear to pole technician in the field, the worst case may be assumed.

In addition to these methods, there are more sophisticated engineering methods for modeling soils. In the design of tangent and guyed poles, a simple equation or nomograph seems more feasible than a detailed analysis.

Class of Materials	Allowable Foundation Pressure (psf)	Lateral Bearing Pressure (psf/ft below natural grade)	Lateral Sliding	
			Coeff. Of Friction	Resistance (psf)
Crystalline Bedrock	12000	1200	0.7	--
Sedimentary and foliated rock	4000	400	0.35	--
Sandy gravel and/or gravel	3000	200	0.35	--
Sand, silty sant, clayey sand, sitly gravel and clayey gravel	2000	150	0.25	--
Clay, sandy clay, silty clay, clayey silt, and sandy silt	1500	100	--	130

Figure 10: International Building Code 2006 Minimum Soil Pressure Values

2.5 Design of spans

The distance between poles (span) depends on several factors. In design of a new distribution line, first the designer takes note of the control points – locations that must have a pole. These include road intersections, point of tangency of a road, near a house or building that needs power, and many others. Then the designer fills in the other poles between these control points based on maximum allowable span of the wire.

On a long straight segment of distribution line, the span is often times controlled by the span of the wires, not the strength of the pole. That is, spans are determined based on clearances between wires, clearances above ground topography, etc.

2.6 Common practice

Most utility poles are not designed new each time from the National Electric Safety Code and ANSI 05.1, but rather a pole is selected by a field technician from the company's customized handbook given a maximum span, pole height, electrical conductor wire information, and electrical accessories. An experienced field technician will often know these company specific tables and charts well.

For non-typical pole design applications, the field technician may need to evaluate the pole with software. Georgia Power field technicians have a copy of PoleForman software at their disposal. This software is one of the most commonly used for distribution pole design. If the pole is abnormally tall or has an especially large transformer, the technician will design it using the PoleForman software. In difficult design cases, the field technicians refer to their senior designers. Of the field technicians (also called field engineers), few are professional engineers – a certification that is more common among senior engineers.

Rules of thumb will vary between utility companies. A simple example of a utility company's rule of thumb is as follows:

40 feet Class 5

45 feet Class 4

50 feet Class 3

2.7 Commonly used distribution pole design software

Some of the most common software for designing common wood utility distribution poles are PoleForman with SagLine, O-Calc, and SPIDACalc. These three programs have a library of common poles, conductors, crossarms, guys and anchors. They perform analysis based on the NESC including wind and ice loads. PoleForman is the most commonly used and is advertized for its ease of use, but lacks some functionality that the other programs provide. In addition to typical pole analysis and design, O-Calc and SPIDACalc have features that Pole Forman does not. For instance, O-Calc has the ability to consider imperfections (like rot) of poles in the design of existing poles.

2.8 Materials used in distribution poles

Utility distribution poles are made of wood, steel, concrete, fiber reinforced polymers, or laminated wood.

2.8.1 Wood distribution poles

Over 90% of Georgia's distribution poles are made of wood. Southern pine is the most common in the southeastern United States, including Georgia. Douglas fir is mainly used west of the Rocky Mountains, but is sometimes used in the southeast when taller poles are needed. This is because southern pine is not typically harvested in lengths greater than 60 ft. Wood is the most common because it is generally the most cost effective and functional material. When codes, cosmetics, or conditions are an influence factor, the engineer may use a material other than wood.

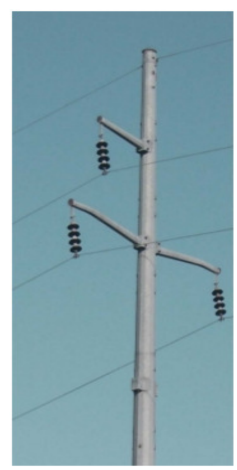


Figure 11: Steel Distribution Pole (www.unionmetal.com)

2.8.2 Steel distribution poles

Depending on cost of steel versus wood, steel poles can be price competitively with wood poles. While steel poles are subject to some corrosion, it stands to reason that there would be less maintenance required than on wood poles. Poles made of steel, fiberglass, concrete and laminated lumber do not fit with the common mode of operation. That is, these poles are not nearly as easy to climb as traditional wood poles. Steel poles are most often used as self-supporting poles. A designer would supply the pole manufacturer the forces, moments, and design criteria for the manufacturer to design the pole itself. Steel poles are sometimes fastened to a circular reinforced concrete pier by anchor bolts. Other times they are simply backfilled with gravel.

2.8.3 Concrete distribution poles

Concrete poles are most commonly used in distribution lines as self-supporting poles, but are sometimes guyed. There is very little maintenance for concrete poles. Concrete may be very costly to transport depending on the distance from the concrete plant to the installation site.

Class	Tip Load (lbs)	Class	Tip Load (lbs)
C	1,200	J	4,500
D	1,500	K	5,400
E	1,900	L	6,400
F	2,400	M	7,500
G	3,000	N	8,700
H	3,700	O	10,000

Figure 12 Concrete Pole Classes

Concrete Poles can may be static cast or spun cast. Spun cast is different than static cast because it is spun while curing to consolidate the concrete better, giving more compressive strength to the concrete.

Concrete poles have different classification than wood poles. While wood poles use a numbering system, concrete poles use the alphabet. If a utility company tries a large wood pole in PoleForman or similar software, the company will often ask the concrete manufacture to design an equivalent pole for comparison of cost. For instance, a class 2 wood pole, with a 3700 lb tip load may be considered equivalent to a Class H concrete pole. It is also possible to use a ratio of the material strength reduction factors to get a Class G concrete pole, for instance.

2.8.4 Fiber reinforced polymer distribution poles

Fiber reinforced polymer (FRP or fiberglass) poles are very light and thus can be carried by hand to remote locations where a vehicle cannot go – such as the side of a mountain. Fiberglass poles have few maintenance issues, but because fiberglass not a commonly used material, it requires installers who have experience with fiberglass. Conversely, wood construction is well known.

Currently the Rural Utilities Service requires its borrowers (Electric Cooperatives) to submit for approval to use fiberglass poles. This approval submittal includes calculations, reasons for using fiberglass, cost analysis, etc. Currently (2011), RUS is developing a guide specification for use of fiberglass distribution poles which borrowers could use to purchase and use fiberglass poles without Rural Utilities Service approval. (RUS, July 2008)

2.8.5 Laminated wood distribution poles

Laminated wood poles, not typically used in Georgia, are sometimes used as self-supporting poles where wood poles are not strong enough to withstand the loads. As with self-supporting steel poles, the utility company designer would give the design criteria to the laminated wood pole manufacture (i.e. E-LAM) to design the pole. These poles are typically set deeper than ordinary wood poles, and the holes are backfilled with gravel.

2.9 Installation of poles

If a pole is installed deeper than it was designed, the circumference is less than it was designed for. Thus the pole is not as strong as the designer intended. One can usually tell when a pole is buried too deep because the birthmark of the pole is low to the ground. The birthmark is a descriptive marking of the pole class and material (See figure 13). It should typically be at shoulder level.

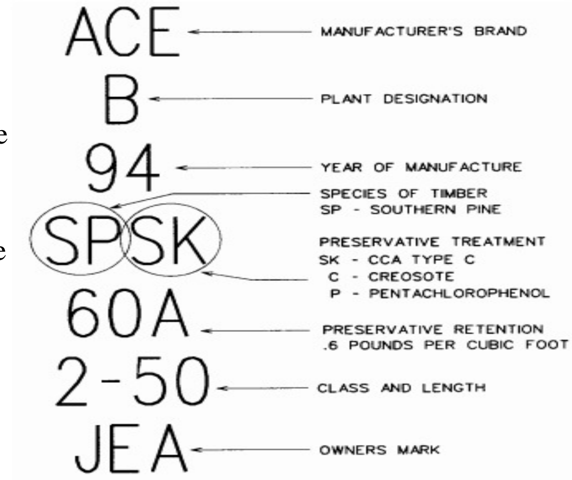


Figure 13: Pole Birthmark (www.jea.com)

2.10 Wood pole issues

The main maintenance issue for wood is decay. Decay at the groundline almost exclusively occurs within a zone from 6 inches above the groundline to 18 inches below. For decay to occur four things must be present: 1. food (the wood pole) 2. oxygen 3. water and 4. a certain temperature range. At 6 inches above the surface not enough oxygen is present to facilitate decay. The moisture that causes decay is wicked from the soil up the pole, but the wicking only occurs up to 18 inches below the soil. Thus the poles remain virtually decay free, above and below this zone. See Figure 14 and 15.

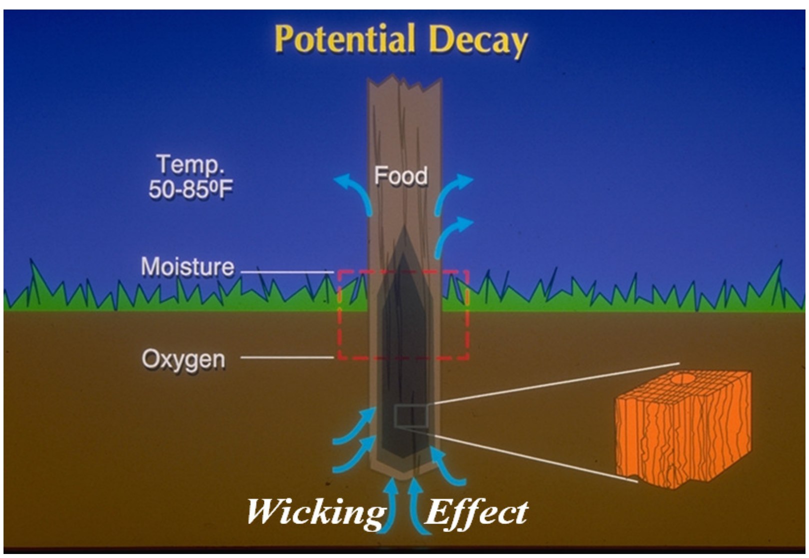


Figure 14 Factors for potential decay in wood poles (Bingel, 2011)

In order to prevent decay, wood poles have historically been pressure treated with oil based chemicals such as creosote and pentachlorophenol (penta). Creosote, which is not allowed in the majority of modern timber, is fading in its use even in distribution poles. Pentachlora phenome is less detrimental to the environment than creosote, even though it is still subject to leaching. Most utility companies in Georgia are exclusively using poles treated with Copper chromium arsenate (CCA), the newest alternative to these historical treatments. These poles have a green color and they last much longer because this chemical does not leach like the oil based treatments.

2.11 Inspection and maintenance of wood poles

Two common modes of failure in wood poles are decay near the ground line and decay at the top of the pole as treatments leach down the pole. Figure 15 shows failure of a pole due to decay in the section of the pole that 18 inches deep below the groundline .

Figure 15 Pole Failure due to Decay in 18 inch decay section (Bingel, 2011)

Utility companies usually inspect a percentage of their poles in a given time period. Companies that are borrowers of RUS money are to follow the suggested pole inspection schedule described in RUS Bulletin 1730B-121. For Georgia, this bulletin recommends that 12.5% of the total poles be inspected each year. The initial inspection is to be within 8-10 years of placement, and the subsequent reinspections are to be every 8 years. Companies that do not subscribe to RUS often follow some sort of inspection schedule. Osmose Utilites, a company that inspects poles for utility companies, reports that there could be a large cost savings if poles were more frequently inspected. If a pole is inspected sooner, it may be repaired

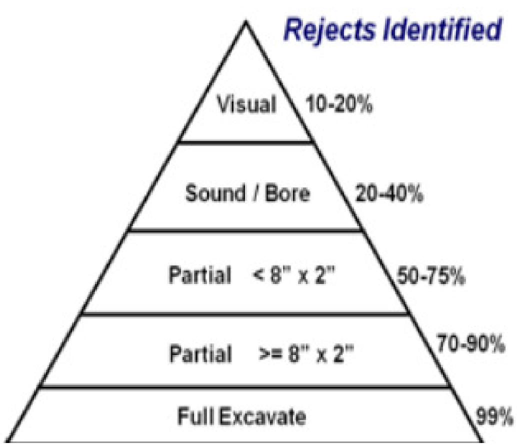


Figure 16: a) Identifying rejects (Bingel, 2011), b) Applying treatment (Bingel, 2011)

and/or retreated with preservative to give it more years of service. RUS Bulletin 1730B-121 also states the importance of periodic inspection and maintenance (Section 7.3 Groundline Treatment):

"All treated poles eventually lose resistance to decay, and groundline treatment provides and economical extension of their useful life. Experience has shown that groundline decay can be postponed almost indefinitely in cases where periodic inspection and maintenance programs are in effect."

A pole is rejected if it is less than approximately 67% of the required strength. Rejects may be identified in a number of ways: visual inspection, striking the pole with a hammer and listening, boring into pole, fully excavating to the 18 inch depth all around the pole, and partially excavating. Figure 16a shows what percentage of rejects is identified with varying levels of investigation. For example, quick visual inspections will identify up to 20% of the poles that are actually rejects. With more extensive investigation a higher percentage of rejects will be discovered.

If a pole is not rejected, it may be retreated with preservative like the paste shown in Figure 16b. If a pole is rejected, it may be strengthened or completely replaced.

3.0 Light Poles

There are a wide variety of light pole types including high mast, roadway, residential, area lighting, and sports lighting. These poles are available in many styles and may be decorative or standard.

High mast poles are usually found lighting interstates. These poles are used most often by the Department of Transportation. These are very tall slender poles with fixtures that can be lowered to the ground with a hoist system for maintenance. High mast poles are rarely decorative, but they are very functional as they may light a large area.

Roadway lighting may be used on interstates, highways, and other streets. These are not as tall as high mast poles and may have a standard or decorative style. Valmont Industries groups roadway poles and residential poles into the same type because their uses overlap.

Area lighting is used to light areas like parking lots but may be used in residential areas, parks and similar places. A typical standard (non-decorative) pole may be square or round in cross-section and may be tapered or not.

Figure 17: a) High mast (www.suryaroshilighting.com), b) Roadside (www.valmont.com), c) Residential (www.valmont.com), d) Area lighting (A. Crosby), e) Sports lighting (www.valmont.com)

3.1 Criteria, Standards and Guidelines for Light Pole Design

Light poles may be designed by three different criteria or standards:

1) AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals (AASHTO LTS)

2) State specific DOT Standard

3) Commercial criteria

The majority of the light poles are designed by the pole manufactures such as Valmont or Lithonia Lighting. Often the manufacturer will be given a specification with design criteria such as design loading or a specific wind speed and code to design by. Other times the pole buyers may simply tell the manufacturer which pole they want. In the former case, several competing manufacturers may bid on a job based on the specifications. When the specification does not specify a code by which to design the poles, such as AASHTO LTS-4, the manufacturer may design by its own criteria - called commercial criteria. In addition to any of these standards, poles may be subject to the specific requirements of the state, county, city or region in which the pole is located.

3.1.1 AASHTO LTS

Approximately every 7 years, the American Association of State Highway and Transportation Officials produces a new edition of the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals. This standard, often called AASHTO LTS, has several editions. The latest versions are:

1) LTS-3, published in 1994

2) LTS-4, published in 2001 and revised in 2003

3) LTS-5, published in 2009 and revised in 2010

This design reference is the basic standard for all light pole design. The other design standards are essentially made up of part or all of the AASHTO with some modifications. The Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals is a design standard specifying general requirements, loads, methods of analysis, and material-specific design requirements for light poles and other highway specific structures. AASHTO considers dead, live, ice, and wind loads.

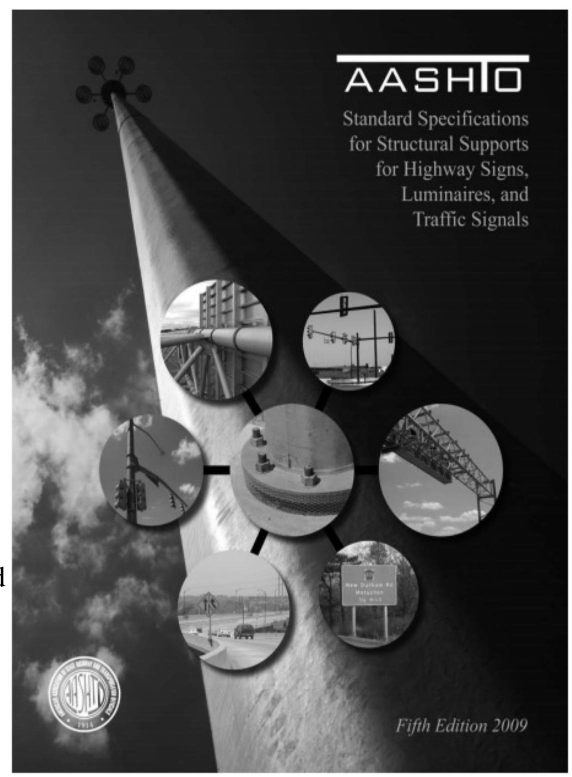


Figure 18: AASHTO LTS-5 (www.techstreet.com)

The 2001 LTS and later versions include a very big change in design from previous revisions. Fatigue design due to galloping, vortex shedding, natural wind gust, and truck induced wind gust are to be considered in certain circumstances. Poles and structures designed by this code for fatigue must be assigned a fatigue category I, II or III, ordered from most to least stringent.

3.1.2 State specific Department of Transportation standard

Each State's Department of Transportation has the authority to decide what standard the poles shall be designed by. Almost all Departments of Transportation adopt a version of AASHTO they are most comfortable with and modify it as they choose.

3.1.3 Commercial criteria:

When designing by commercial criteria, manufactures may not design as robustly as an AASHTO LTS standard would require because they are trying to underbid their competitors. For instance, fatigue design which often controls pole design per newer versions of AASHTO LTS would most likely not be taken into account with a design done by commercial criteria. Another way to lighten the design is to design to a safety factor of 1, instead of the larger safety factors required by the AASHTO LTS.

Manufacturers have product literature available for their commonly used poles. It is not uncommon for a pole to be selected from a manufacturer's literature. This literature contains charts for selecting poles that are pre-designed based on the manufacturer's design. Some of this product literature is based on AASHTO LTS design, and others are based on commercial criteria. The poles that are almost exlusively used by the Department of Transportation, such as the high mast poles, are most likely designed per AASHTO LTS. Poles, such as area lighting that may be found in a retail store parking lot, would often be designed per the company's own criteria. Poles are typically selected from manufacturer's product literature by the following procedure (from Manis, p 1):

1. Select the light fixture and obtain its effective projected area (EPA) and weight. The effective projected area is the area that is loaded by the wind. This information is located on the fixture cut sheet.

2. Determine the number of light fixtures and any special mounting methods (arm or bracket) to be installed on the pole. Obtain the effective projected area and weight for any arms or brackets from the corresponding cut sheets.

3. Total the effective projected area and the weights of all fixtures, arms and brackets.

4. Select the design wind speed for the project location from the light pole manufacturer's wind map, which may be based on fastest mile wind speed or 3-second gust wind speed, like current building code.

5. Select a pole and compare the EPA and fixture weights with the allowable EPA and fixture weights for that pole. If the actual effective projected area and fixture weights are less than the allowable EPA and maximum weight listed on the cut sheet, the pole meets the manufacturer's requirements.

SSS Square Straight Steel Poles

TECHNICAL INFORMATION													
					EPA (ft²) with 1.3 gust								
Catalog Number	Nominal shaft length (feet)	Pole Shaft Size (in x ft)	Wall Thickness (inches)	Gauge	80 mph	Max. weight	90 mph	Max. weight	100 mph	Max. weight	Bolt Circle (inches)	Bolt Size (in. x in. x in.)	Approximate ship weight (pounds)
SSS 10 4C	10	4.0 x 10.0	0.125	11	30.6	765	23.8	595	18.9	473	8--9	3/4 x 18 x 3	75
SSS 12 4C	12	4.0 x 12.0	0.125	11	24.4	610	18.8	470	14.8	370	8--9	3/4 x 18 x 3	90
SSS 14 4C	14	4.0 x 14.0	0.125	11	19.9	498	15.1	378	11.7	293	8--9	3/4 x 18 x 3	100
SSS 16 4C	16	4.0 x 16.0	0.125	11	15.9	398	11.8	295	8.9	223	8--9	3/4 x 18 x 3	115
SSS 18 4C	18	4.0 x 18.0	0.125	11	12.6	315	9.2	230	6.7	168	8--9	3/4 x 18 x 3	125
SSS 20 4C	20	4.0 x 20.0	0.125	11	9.6	240	6.7	167	4.5	150	8--9	3/4 x 18 x 3	140
SSS 20 4G	20	4.0 x 20.0	0.188	7	14.0	350	11.0	275	8.0	200	8--9	3/4 x 30 x 3	198
SSS 20 5C	20	5.0 x 20.0	0.125	11	17.7	443	12.7	343	9.4	235	10--12	1 x 36 x 4	185
SSS 20 5G	20	5.0 x 20.0	0.188	7	28.1	703	21.4	535	16.2	405	10--12	1 x 36 x 4	265
SSS 25 4C	25	4.0 x 25.0	0.125	11	4.8	150	2.6	100	1.0	50	8--9	3/4 x 18 x 3	170
SSS 25 4G	25	4.0 x 25.0	0.188	7	10.8	270	7.7	188	5.4	135	8--9	3/4 x 30 x 3	245
SSS 25 5C	25	5.0 x 25.0	0.125	11	9.8	245	6.3	157	3.7	150	10--12	1 x 36 x 4	225
SSS 25 5G	25	5.0 x 25.0	0.188	7	18.5	463	13.3	333	9.5	238	10--12	1 x 36 x 4	360

Figure 19 Lithonia Lighting- Square Steel Non-Tapered Pole (www.lithonia.com)

While manufacturers have differences in company specific commercial criteria, some poles usually have virtually the same design. Lithonia Lighting and Valmont Structures manufacture some of the same poles with the the same maximum effective projected area and maximum weight. For instance, Lithonia model SSS 20 5C is identical to Valmont's model S500Q200. Both are 4" square diameter non-tapered 20 ft tall, 11 gauge steel poles weighing 185 lbs. (See Figures 19 and 20) For this pole, both manufacturers came to the same design conclusion: the maximum allowable EPA and weight for this pole in a 90 miles per hour wind zone is 12.7 square ft and 343 pounds, respectively. On the other hand, when comparing Lithonia's RTA 39 10J, a tapered aluminum pole, to its identical competitor Valmont's 3808 – 60108T4, Lithonia has smaller allowable effective projected areas (See Appendix). In other words, Lithonia's design is more conservative for this pole. This may be due to a difference in each manufacturer's design criteria and methods.

LOAD AND DIMENSIONAL DATA											
	DESIGN INFORMATION						POLE DIMENSIONS				
	80 MPH w/1.3 GUST		90 MPH w/1.3 GUST		100 MPH w/1.3 GUST						
NOMINAL MOUNTING HEIGHT	MAX EPA[1] (SQFT)	MAX WEIGHT[1] (LBS)	MAX EPA[1] (SQFT)	MAX WEIGHT[1] (LBS)	MAX EPA[1] (SQFT)	MAX WEIGHT[1] (LBS)	BASE SQUARE OD (IN)	TOP SQUARE OD (IN)	WALL THK (IN)	STRUCTURE WEIGHT[2] (LBS)	MODEL NUMBER
10'-0"	30.6	765	23.8	595	18.9	473	4.00	4.00	11	75	S400Q100
12'-0"	24.4	610	18.8	470	14.8	370	4.00	4.00	11	90	S400Q120
14'-0"	19.9	498	15.1	378	11.7	293	4.00	4.00	11	100	S400Q140
16'-0"	15.9	398	11.8	295	8.9	223	4.00	4.00	11	115	S400Q160
18'-0"	12.6	315	9.2	230	6.7	168	4.00	4.00	11	125	S400Q180
20'-0"	9.6	240	6.7	167	4.5	150	4.00	4.00	11	140	S400Q200
	17.7	443	12.7	343	9.4	235	5.00	5.00	11	185	S500Q200
	28.1	703	21.4	535	16.2	405	5.00	5.00	7	265	S500W200
25'-0"	4.8	150	2.6	100	1.0	50	4.00	4.00	11	170	S400Q250
	10.8	270	7.7	188	5.4	135	4.00	4.00	7	245	S400W250
	9.8	245	6.3	157	3.7	150	5.00	5.00	11	225	S500Q250
	18.5	463	13.3	333	9.5	238	5.00	5.00	7	360	S500W250
30'-0"	6.7	168	4.4	110	2.6	65	4.00	4.00	7	291	S400W300
	4.7	150	2.0	50	N/A	N/A	5.00	5.00	11	265	S500Q300
	10.7	267	6.7	167	3.9	100	5.00	5.00	7	380	S500W300
	19.0	475	13.2	330	9.0	225	6.00	6.00	7	520	S600W300
35'-0"	5.9	150	2.5	100	N/A	N/A	5.00	5.00	7	440	S500W350
	12.4	310	7.6	190	4.2	105	6.00	6.00	7	540	S600W350
40'-0"	7.2	180	3.0	75	N/A	N/A	6.00	6.00	7	605	S600W400

Figure 17: Valmont Lighting- Square Steel Non-Tapered Pole

3.2 Light Pole Jurisdictions

The jurisdiction the pole is in determines what design methods or standards it will be designed by. A pole may fall in one or more of the following jurisdictions:

1) The State DOT
2) Municipality
3) Private property

3.2.1 The State Department of Transportation

In Georgia, the design of a large number of the poles is the responsibility of the Department of Transportation (DOT). Poles fall in the Department of Transportation's jurisdiction if the department is administering money to design, install, or maintain the pole. This is the case for lighting along all interstates and state routes. Because the Georgia Department of Transportation is required to return a percentage of the gas tax to city street projects, city streets and county roads receive some funding from the Department of Transportation. In these cases, the poles would be designed and installed per GDOT guidelines and standards.

Every state's DOT may be different in their requirements for design of light poles. They have the freedom to choose if they want the poles in their jurisdiction to be designed by a certain edition of AASHTO or a customized standard for that state's Department of Transportation, which is typically a version of the AASHTO LTS with some modifications. In addition, the state Department of transportation may dictate if a pole's foundation is required to be designed (and sealed) by a professional engineer and whether a geotechnical soil analysis is required. Each state's DOT may also dictate several other factors such as the types of foundations allowed, the pole shape, the pole height, and more.

For example in 2006, the Florida Department of Transporation moved from using the AASHTO 1994 edition to the 2001 edition (LTS-4). Instead of using the windspeed maps in the 2001 AASHTO, Florida used a simplified windspeed map based on American Society of Civil Engineers ASCE7 3-second gust maps. It also opted to not adopt Section 11 of LTS-4 on fatigue design until further studies had been done. If a state has has no problems with its poles designed by the earlier versions of the LTS, it has the freedom not to adopt a newer code. Georgia's Department of Transportation is in the process of switching from the AASHTO LTS-3 (1994) to the most current LTS.

Because each state's Department of Transportation is typically staffed with engineers, they may design most of the foundations for the light poles within their jurisdiction. They also perform the majority of the soil testing, when needed.

3.2.2 Municipalities

When no Department of Transportation money is administered to a city lighting project, the poles fall completely in the municipality’s jurisdiction. In this case the city, county, or region may choose which standard, if any, the pole shall be designed by. Georgia municipalities typically specify the poles to be designed by Georgia Department of Transportation standards even though the DOT is not involved in any way. However, the municipality may choose for each pole to be designed by any edition of AASHTO or commercial criteria. In addition, they may choose to design for fatigue or not.

The Georgia Department of Transportation often has agreements with municipalities which want interstate lighting in their town to attract business. The DOT will buy the poles and pay construction costs and the local government pays the initial design fees to the illumination engineer and pays for energy costs and maintenance for 50 years.

Municipalities may also choose if pole foundations are required to be professionally engineered and if a geotechnical soil reports are required. Some cities like Alpharetta, GA also require specific styles of light pole to be used.

Some big municipalities may have an engineering staff that designs poles and/or pole foundations.

3.2.3 Private Properties

When a light pole is on private property, such as a retail store or a strip mall, it may fall into any of the three jurisdictions. A light along the road way, for instance, may be in the Department of Transportation’s jurisdiction. On the other hand a parking lot light may fall into the municipality’s realm of responsibility. The private property developer should check with the Georgia Department of Transportation and municipality, and if neither the municipality nor the Department of Transportation are involved in decision making, the developer should check with the building department to see if there are any guidelines or standards that are required. For instance, a building department may require the developer to have the foundation engineered, have a soil report done, or may limit the types of poles that may be used.

If there are no guidelines or standards, the developer may choose how the pole and foundation are designed. That is, the developer chooses if a pole is designed by AASHTO, State DOT standards, or commercial criteria and may decide whether the pole foundation shall be engineered. This means a situation could arise where a retail store owner may be in full control of the light pole structures put up in his parking lot. Because of the great liability involved, hopefully this store owner would have a contractor with experience in pole installation and would rely on the expertise of the pole manufacturer to select the right pole for the location-based wind load.

3.3 Light Pole Materials

Most light poles are made of steel, namely ASTM A595 Grade A or A572 Grade 50, 55, 60, or 65. Aluminum poles, which are more expensive, are usually made of 6063 T6 aluminum. Concrete poles are either spun cast concrete or regular precast concrete. Concrete poles are often shipped in a few pieces and assembled as interlocking pieces on site. Some light poles are made of wood. This would be mostly southern pine in Georgia, just like the utility poles in this report. Fiber reinforced polymers are used sometimes in the United States when it is necessary to transport the poles by hand.

3.4 Joint use poles

While this report is segregated into utility distribution poles and light poles, many times these utilities share a pole. Figure 20 shows a wood distribution pole being used to support a light and traffic signals.

Figure 20: Wood joint-use pole (Crosby, 2011)

3.5 Pole Foundations:

The pole manufacturers design light poles and anchor bolts and will usually give base reactions if requested, and they recommend having a professional engineer design the foundation. The responsible party may have an engineer design the pole; others like the Florida Department of Transportation have a typical foundation design for every standard pole. Figure 21 shows a typical metal pole foundation from Florida's Department of Transportation. Florida utilizes a 30 inch diameter auger drilled pier with a reinforcing bar cage in an 8-10 feet deep precast or poured concrete pier. The Georgia Department of Transportation uses a 24” diameter, 6 ft deep, reinforced concrete, auger drilled pier for all poles under 50ft tall.

Most light poles are constructed like the auger drilled foundation in Figure 21, but some light poles are directly embedded. With directly embedded poles the setting depth is usually 10 percent of the total pole length plus 2 feet. This is the same rule of thumb used for tangent or guyed distribution poles. Others, like the Florida Department of Transportation may have other guidelines.

In Georgia, 100-120 ft tall, high mast structures are typically accompanied by a 4 ft diameter, 20 ft deep, auger drilled pier with reinforcing steel.

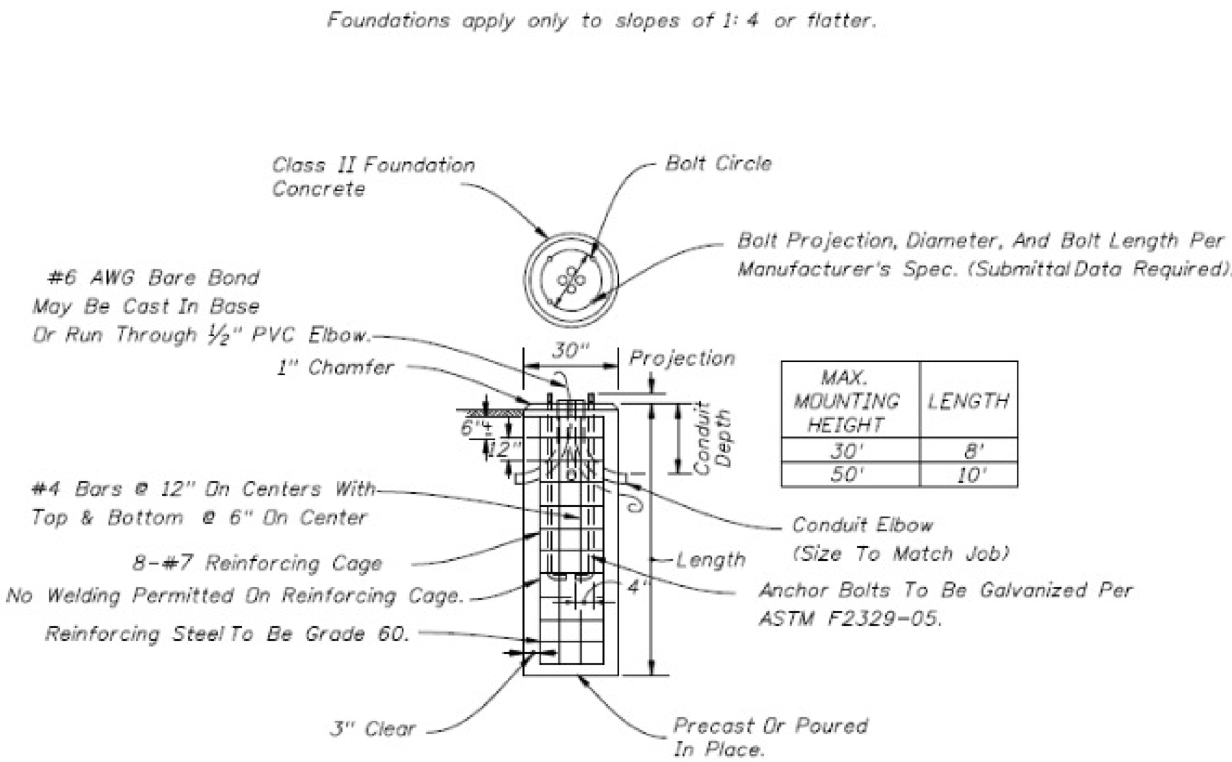


Figure 21: Florida Department of Transportation Auger Drilled Pole Foundation

3.6 Wind induced vibrations on light poles

Under certain circumstances, extra measures may be necessary to prevent wind-induced vibrations on light poles. In steady low wind speed situations, (20-40 mph) with poles 25 feet or higher, with fixtures that have an effective projected area of less than 2 square feet, poles have a higher probability of wind induced harmonic vibrations. This may cause poles to fail because of the fracture of the weld between the pole and the base plate. Light pole manufactures sometimes have information on this phenomenon, but they warn that they do not warranty poles that fail in this way. It seems that the most cost effective way to prevent this type of failure is to select poles, pole heights, and fixtures that do not lend themselves to this type of vibration. Tapered poles, round poles, and octagonal poles are less likely than square straight poles to experience this phenomenon. Furthermore, geographical location may contribute to the steady slow wind speeds that cause this type of vibration. Open flat lands, places where wind may be channeled through a valley, and airplane runways may be the most susceptible (Manis, Reference 1).

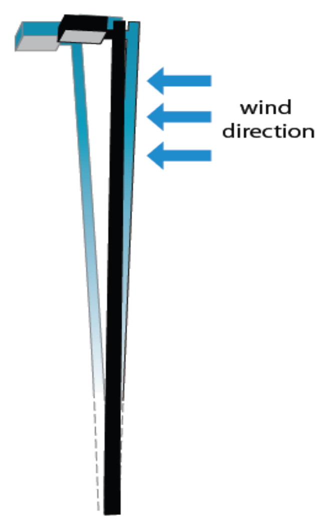


Figure 22: Harmonic Vibration due to Wind (Manis, 2008)

3.7 Light pole maintenance and inspection

Light poles require typical maintenance like changing bulbs, painting the steel, and inspecting the electrical components. From a structural perspective special attention may be needed to recognize potential failure due to wind induced vibrations. Lithonia Lighting literature explains that it is important to inspect regularly, about every 3 months, for signs of fatigue. This is because fatigue failure comes quickly after signs appear and the results of failure can be catastrophic (www.lithonia.com).

Inspectors should look for hairline cracks just above the weld from the pole to the base plate. Rust will typically be apparent at the fatigue area. Aluminum poles, which do not show rust, may need to be inspected by a red die penetration test.

3.8 Conclusions

In conclusion the author presents a few possible points of interest for readers of this paper who are involved in utility distribution pole or light pole design:

For utility distribution pole designers, this report presents basic concepts that most utility companies are well versed in. These utility companies may want to consider a few things: Firstly, there may be considerable cost savings with increase in wood pole inspection and treatment as explained in this report. Secondly, the 10% + 2 ft rule for setting depth appears to work fine in soils that are well consolidated. Regarding poles set in questionable soil, one may consider using one of the foundation design methods explained in this paper to determine setting depth. Thirdly, when a wood pole is required to be very large to withstand the loads, the utility company may consider providing a concrete or steel manufacturer with either a loading diagram or specify a wood-pole-equivalent. Regarding the latter, one may choose to utilize the differences in material over strength factors for cost savings.

It may be prudent for any private property developer, city or county to know its options when buying light poles. One may specify a certain wind speed, fatigue category (I, II or III - if any), and standard for design (AASHTO-LTS, the state Department of Transportation standard or commercial criteria). If the lighting project has any Department of Transportation oversight or funds involved, the design will be per the Department of Transportation's standard, which is usually some version of the AASHTO-LTS code. If the project requires no DOT oversight, one may specify to use commercial criteria for a minimal cost solution, but some liability exists because the poles are not designed by a code. One may also select poles by the manufacturer's product literature as detailed in this report.

Engineers who are consulted to design foundations for self-supporting utility poles or light poles may pay attention to current methods of foundation design and typical Department of Transportation pole foundations as addressed in this report. In regards to light pole design, the manufacturer will supply base reactions upon request.

References:

1. American National Standards Institute, Inc.; American National Standards for Wood Poles and Wood Products; ANSI 05.1 2008, Specifications & Dimensions

2. Bingel, Nelson of Osmose Utilities; Interview on February, 2011.

3. Crosby, Adam; author's photos; 2011

4. Florida Department of Transportation website; http://www.dot.state.fl.us/

5. Georgia Electric Membership Corporation website; http://www.georgiaemc.com/

6. Georgia Environmental Finance Authority website; http://www.gefa.org/Index.aspx?page=328

7. Guidelines for RUS Approval to Use Fiber Reinforced Polymer (FRP) Poles (July 2008)

8. Jacksonville Electric Authority website; http://jea.com/

9. Lithonia Lighting technical bulletin; Light Standards, Effects of Vibration, 2002

10. Lithonia Lighting website; http://www.lithonia.com/

11. Manis, P., Structure Magazine, March 2008, "Wind Induced Vibrations on Light Standards"

12. National Electrical Safety Code C2-2007

13. Surya Roshni Limited website; http://suryaroshnilighting.com/

14. Techstreet of Thomas Reuters websits; http://www.techstreet.com/

15. Union Metal website; http://www.unionmetal.com/

16. United States Department of Agriculture: Rural Utilities Service: Bulletin 1730B-121

17. United States Department of Agriculture: Rural Utilities Service: Bulletin 1724E-150

18. United States Department of Agriculture: Rural Utilities Service: Bulletin 1724E-20

19. Valmont Industries, Inc. website; http://www.valmont.com/

Appendix:

RTA Round Tapered Aluminum Poles

TECHNICAL INFORMATION

Catalog Number	Nominal shaft length (ft.)	Wall pole shaft size (in. x in. x ft.)	Thickness (in.)	EPA (ft²) with 1.3 gust: 80 mph	90 mph	100 mph	Max. weight	Bolt circle (in.)	Bolt size (in. x in. x in.)	Approximate ship weight (pounds)
RTA 20 5C	20	5 x 3 x 19.66"	0.125	3.9	2.5	1.6	100	7.5-9.5	.75 x 18 x 3	62
RTA 20 5G	20	5 x 3 x 19.66"	0.188	7.4	5.2	3.8	100	7.5-9.5	.75 x 18 x 3	72
RTA 20 6G	20	6 x 4 x 19.66"	0.188	12.2	9.2	7.2	214	9-10	.75 x 30 x 3	107
RTA 20 7E	20	7 x 4 x 19.66"	0.156	15.0	11.4	9.0	256	9.875-11.25	1 x 36 x 4	103
RTA 25 6E	25	6 x 4 x 24.66"	0.156	5.3	3.6	2.6	114	9-10	.75 x 30 x 3	106
RTA 25 7E	25	7 x 4 x 24.66"	0.156	9.5	7.0	5.4	162	9.875-11.25	1 x 36 x 4	120
RTA 25 8E	25	8 x 4.5 x 24.66"	0.156	14.2	10.9	8.5	220	11-12	1 x 36 x 4	130
RTA 25 8G	25	8 x 4.5 x 24.66"	0.188	18.0	13.8	10.9	261	11-12	1 x 36 x 4	153
RTA 30 7E	30	7 x 4 x 29.66"	0.156	5.5	3.8	2.7	111	9.875-11.25	1 x 36 x 4	135
RTA 30 8E	30	8 x 4.5 x 29.66"	0.156	9.4	7.0	5.3	151	11-12	1 x 36 x 4	150
RTA 30 8G	30	8 x 4.5 x 29.66"	0.188	12.4	9.4	7.3	179	11-12	1 x 36 x 4	175
RTA 30 10G	30	10 x 6 x 29.66"	0.188	23.8	18.3	14.3	377	14.25-16.25	1 x 40 x 4	235
RTA 35 8E	35	8 x 4.5 x 34.66"	0.156	5.8	4.1	2.9	119	11-12	1 x 36 x 4	185
RTA 35 8G	35	8 x 4.5 x 34.66"	0.188	8.3	6.0	4.5	141	11-12	1 x 36 x 4	220
RTA 35 8J	35	8 x 4.5 x 34.66"	0.250	12.9	9.7	7.5	183	11-12	1 x 36 x 4	251
RTA 35 10G	35	10 x 6 x 34.66"	0.188	17.9	13.6	10.4	295	14.25-16.25	1 x 40 x 4	268
RTA 39 8G	39	8 x 4.5 x 38.66"	0.188	5.6	3.9	2.7	122	11-12	1 x 36 x 4	250
RTA 39 8J	39	8 x 4.5 x 38.66"	0.250	9.7	7.1	5.4	158	11-12	1 x 36 x 4	280
RTA 39 10G	39	10 x 6 x 38.66"	0.188	14.2	10.5	7.8	253	14.25-16.25	1 x 40 x 4	295
RTA 39 10J	39	10 x 6 x 38.66"	0.250	20.4	15.5	11.9	300	14.5-16	1.25 x 48 x 5	373
3RTA 8 4C	8	4 x 3 x 8	0.125	12.1	9.3	7.3	75	6.5-7.25	.75 x 18 x 3	23
3RTA 10 4C	10	4 x 3 x 10	0.125	8.8	6.7	5.2	75	6.5-7.25	.75 x 18 x 3	27
3RTA 12 4C	12	4 x 3 x 12	0.125	6.6	4.8	3.6	75	6.5-7.25	.75 x 18 x 3	31
3RTA 14 4C	14	4 x 3 x 14	0.125	4.9	3.4	2.4	75	6.5-7.25	.75 x 18 x 3	34
3RTA 16 4C	16	4 x 3 x 16	0.125	3.5	2.3	1.5	75	6.5-7.25	.75 x 18 x 3	38
3RTA 16 5C	16	5 x 3 x 16	0.125	6.9	5.0	3.8	75	7.5-8.5	.75 x 18 x 3	43
3RTA 18 5C	18	5 x 3 x 18	0.125	5.0	3.5	2.5	150	7.5-8.5	.75 x 18 x 3	47
3RTA 18 5E	18	5 x 3 x 18	0.156	7.0	5.0	3.7	150	7.5-8.5	.75 x 18 x 3	57
3RTA 20 5C	20	5 x 3 x 20	0.125	3.8	2.5	1.6	150	7.5-8.5	.75 x 18 x 3	50
3RTA 20 5E	20	5 x 3 x 20	0.156	5.5	3.8	2.6	150	7.5-8.5	.75 x 18 x 3	62

Appendix Figure 1: Lithonia Lighting -Round Tapered Aluminum Poles

DIMENSIONAL AND LOAD DATA

TYPICAL WEIGHT AND ALLOWABLE SIZE OF LUMINAIRES*							DIMENSIONS OF POLES				
NOMINAL MOUNTING HEIGHT	TYPICAL LUMINAIRE WEIGHT (LBS.)	EFFECTIVE PROJECTED AREA IN SQUARE FEET AT: 70 MPH	80 MPH	90 MPH	100 MPH	110 MPH	POLE HEIGHT	TOP	BASE	WALL	MODEL NUMBER**
30'	150	10.0	6.5	4.5	3.2	2.4	29'8"	4'	7"	.156"	+2908 - 40705T4
30'	150	15.5	11.1	8.2	6.2	4.8	29'8"	4.5'	8"	.156"	+2908 - 45805T4
30'	150	20.2	14.6	11.1	8.6	6.7	29'8"	4.5'	8"	.188"	2908 - 45806T4
30'	150	28.8	21.2	16.2	12.8	10.2	29'8"	4.5'	8"	.250"	2908 - 45808T4
30'	200	37.3	28.0	21.5	16.8	13.3	29'8"	6'	10"	.188"	2908 - 60106T4
30'	300	50.7	38.2	29.6	23.5	18.8	29'8"	6'	10"	.250"	2908 - 60108T4
33'	150	12.1	8.4	6.0	4.5	3.3	32'8"	4.5'	8"	.156"	+3208 - 45805T4
33'	150	16.4	11.5	8.5	6.5	4.9	32'8"	4.5'	8"	.188"	3208 - 45806T4
33'	150	24.0	17.4	13.2	10.2	8.1	32'8"	4.5'	8"	250"	3208 - 45808T4
33'	200	31.5	23.5	18.0	14.0	10.8	32'8"	6'	10"	.188"	3208 - 60106T4
33'	300	43.5	32.7	25.2	19.9	15.8	32'8"	6'	10"	.250"	3208 - 60108T4
35'	150	10.2	6.8	4.8	3.4	2.5	34'8"	4.5'	8"	.156"	+3408 - 45805T4
35'	150	14.0	9.8	7.1	5.3	4.0	34'8"	4.5'	8"	.188"	3408 - 45806T4
35'	150	21.3	15.2	11.4	8.8	6.9	34'8"	4.5'	8"	.250"	3408 - 45808T4
35'	200	28.4	21.1	16.0	12.2	9.4	34'8"	6'	10"	.188"	3408 - 60106T4
35'	300	39.4	29.5	22.7	17.6	13.9	34'8"	6'	10"	.250"	3408 - 60108T4
37'	150	12.0	8.1	5.8	4.2	3.1	36'8"	4.5'	8"	.188"	+3608 - 45806T4
37'	150	18.7	13.3	9.9	7.5	5.8	36'8"	4.5'	8"	.250"	3608 - 45808T4
37'	200	25.4	18.7	14.1	10.7	8.0	36'8"	6'	10"	.188"	3608 - 60106T4
37'	300	35.8	26.7	20.4	15.8	12.2	36'8"	6'	10"	.250"	3608 - 60108T4
39'	150	10.1	6.6	4.6	3.2	2.1	38'8"	4.5'	8"	.188"	+3808 - 45806T4
39'	150	16.5	11.4	8.4	6.4	4.7	38'8"	4.5'	8"	.250"	3808 - 45808T4
39'	200	22.8	16.7	12.4	9.2	6.8	38'8"	6'	10"	.188"	3808 - 60106T4
39'	300	32.4	24.0	18.2	14.0	10.7	38'8"	6'	10"	.250"	3808 - 60108T4
48'	300	19.6	14.1	10.4	7.6	5.4	47'8"	6'	10"	.250"	4708 - 60108T4
50'	300	17.5	12.5	9.1	6.5	4.5	49'8"	6'	10"	.250"	4908 - 60108T4

Appendix Figure 2: Valmont Structures -Round Tapered Aluminum Poles