ENGINEERING WITH TIMBER POLES

Part 2 - Elements of Design

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1. Elements of Design

The design of pole structures is perfectly conventional and only the requirement regarding poles is the analysis of poles themselves for depth of embedment and then for bending and direct loading.

In pole type structures, excessive deflections or side sway can be eliminated by having a bracing system which could be provided at the top of the base of the pole in order to reduce bending moments at the base of the pole and to distribute loads.

1.1 Foundation

Design for foundations for poles involves investigation of soil properties. Direct bearing under vertical loads is dependent on the bearing capacity of the soil against the end of the pole and the frictional resistance between the pole and the soil, together with the sheer strength of the soil in which the post is embedded. The depth of embedment must resist the lateral wind forces and any moment on the supporting poles as well as sufficient skin friction to bear the vertical weight of the structure. Vertical forces are transferred to the soil by skin friction between the soil and the upper portions of the embedded length of the pole, without producing much end-bearing pressure at the butt-end. Back filling of the hole with compacted soil, sand or gravel, soil cement or concrete can develop a more effective pole diameter, hence reducing the required depth of embedment, and concrete encasement of the pole in the ground enlarges the frictional surface and thus increases the bearing capacity. Skin friction is also effective where uplift due to wind may act on a pole through its connections to the roof framing.

Normally concrete footings are used in order to increase the bearing capacity under pole butts. These footings should be designed to withstand the punching shear of the pole and any bending moment due to the pole load. The thickness of concrete footings should never be less than 12 in and may need be greater depending on the loads.

The depth of embedment for a pole may be calculated using the allowable lateral pressure determined by a soil investigation or other source. Assuming a typical value for prleiminary design of 250 psf. per foot of depth, the following formula may be used for determining the approximate depth—

$$d = \sqrt[3]{\frac{12hP}{bp}}$$

Where d = depth of embedment.
P = applied horizontal force on pole in pounds.
h = height from ground line to point of application of force in feet.
b = butt diameter of pole or diameter of concrete casing in feet.
p = allowable lateral passive soil pressure psf. per foot of depth.

Using this formula to obtain a value for d which is regarded as approximate, d is recalculated by the equation (Timber Construction Manual (1974).).

$$d = \frac{A}{2}\left[1 + \sqrt{\frac{4.36h}{A}}\right]$$

Where $A = \frac{2.34\,P}{S_1 b}$

and $S_1 = \frac{pd}{3}$

This formula may be used in determining the required embedment depth where no constraint such as rigid floor or surface pavement is provided at the ground line. Where pole structures are built so that the poles project through a concrete floor slab restraining at the ground line, the computation of the depth of embedment is determined by the following formula:

$$d = \sqrt{\frac{4.25\,Ph}{S_3\,b}}$$

Where $S_3 = pd$

When poles are restrained at the cave line or have some degree of fixity, the point at which the horizontal force P acts, is the point of inflection of the pole. For round tapered poles, the point of inflection is assumed to be at two-thirds the distance from the ground line to the point of restraint. When poles have no restraint, the value for the height to the top of the pole is used as h.

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1.2 Checking the Pole Bending Stress

The stress at the point of maximum bending moment is determined by the formula,

$$f_b = \frac{32 \cdot \pi^2 M}{C^3}$$
$$= \frac{32\,M}{\pi D^3}$$
$$\leq F_b$$

Where F_b = allowable bending stress in pounds per sq in adjusted for duration of load.

f_b = actual bending stress in pounds per sq in

C = circumference of pole at the point of maximum moment in inches.

M = Maximum moment in lb in.

The point of maximum bending moment for a round tapered pole is assumed to occur at one fourth the depth of embedment below the ground line, unless special restraint at ground level such as poured concrete slab is used. The value of the bending moment becomes a maximum at the bottom of the roof bracing or at the connection to knee braces. Hence this moment should be checked against the allowable bending stress. For poles acting as cantilevers without top end moment, the distance 'h' is measured from actual ground level to the point of loading, usually the top, and for poles fixed at top-end, the distance 'h' is measured to the point of inflection which for round tapered poles is two-thirds the distance from the ground line to the point of restraint (the knee-brace or the lower chord of truss).

1.3 Checking of Pole Compression

In addition to applied line loads, snow loads and the dead load of the structure, the vertical loads on one pole include the vertical component of wind load and one-third the weight of the pole. The maximum compressive stress in the pole may be determined by the formula

$$f_c = \frac{P}{A} \leq F_c^1$$

Where f_c = maximum compressive stress in pounds per sq in

P = direct compressive load.

A = area of top of pole or at level where stress is greatest in sq in

F_c^1 = allowable compressive stress (parallel to grain) in pounds per sq in

And
$$F_c^1 = \frac{3.6\,E}{\left(\frac{l}{r}\right)^2}$$
$$= \frac{0.225\,E}{\left(\frac{l}{d}\right)^2}$$

Where E = modulus of elasticity of the pole in pounds per sq. in.

l = unsupported length of pole in inches.

r = least radius of girgrtion of pole at one-third the length from the top in inches.

D = diameter of the pole taken as the sum of minimum diameter and one-third the difference between the minimum and maximum diameters but in no case shall it be assumed as more than 1.5 times the minimum diameter

and
$$r^2 = \frac{D^2}{16}$$

The ratio l/d should not exceed 44 for round columns.

A reduction in the unsupported length can be made by bracing in both directions at approximately the point of inflection of the pole. The actual compressive stress (F_c) parallel to grain should not exceed the allowable unit stress for a short column wheie

$$f_c = \frac{P}{A}$$

P = total vertical load on the pole in pounds

A = cross sectional area at the top of the pole in sq in

Concluded