

Transmission Line Design (Volume IV) - Structural Considerations

An Online Continuing Education Course for Engineers

Course Number: E-3064

Credit: 3 Hours / 3 PDH / 3 CPD

Transmission Line Design (Volume IV) – Structural Considerations

Lee Layton, P.E.



Introduction

The primary purpose of this series of courses is to furnish engineering information for use in designing transmission lines. Good line design should result in high continuity of service, long life of physical equipment, low maintenance costs, and safe operation. These courses present a generalized “how to” guide for the design of a high voltage transmission line.

The engineering information in this course is for use in design of transmission lines for voltages 230 kV and below. Designs should be adapted to various conditions and local requirements. Engineers should investigate local weather information, soil conditions, operation of existing lines, local regulations, and environmental requirements and evaluate known pertinent factors in arriving at design recommendations.

This course is based on the requirements of the National Electrical Safety Code® (NESC®). However, since the NESC is a safety code and not a design guide, additional information and design criteria are provided in this course as guidance to the engineer. The additional design criteria are based on practices of many utilities in the United States.

This series includes five volumes. For the best understanding of the material, they should be studied in order. The volumes are generally divided into the following categories.

Volume I. This volume is an introduction to transmission line design and addresses siting issues, plan and profile drawings, loading, and distribution underbuild.

Volume II. This volume is all about clearances. Ground clearances, horizontal clearances, clearances from other live parts, and clearances to supporting structures are addressed.

Volume III. This volume discusses the materials involved in transmission line design and construction including insulators, conductors and hardware.

Volume IV. This volume in the series is concerned with the structural aspects of transmission line design and includes foundations and guyed structures.

Volume V. The final volume in the series is concerned with the structural aspects of transmission line design and includes single-pole structures and H-frame structures.

Chapter 1

Foundation Stability of Direct-Embedded Poles

Every structure standing above ground is subjected to lateral and vertical forces. In the case of direct-embedded wood, steel or pre-stressed concrete transmission structures, it is desirable to depend on the earth to resist these forces. The embedded portion of a pole provides this resistance by distributing the loads over a sufficient area of soil. A properly selected embedment depth should prevent poles from “kicking out”. With time, single poles may not remain plumb. Leaning of single pole structures is sometimes permitted, provided excessive angular displacements are avoided, pole strength is adequate considering additional loads from the pole being out of plumb and adequate clearances are maintained.

The lateral forces to which wood transmission structures are subjected are primarily forces due to wind and wire tension loads due to line angles.

Longitudinal loads due to dead-ending or uniform ice on unequal spans should be examined to see how they affect embedment depths. Normally, flexible transmission structures are stabilized longitudinally by the overhead ground wire and phase conductors.

Bearing and lateral earth capacity of soils depend on soil types and soil characteristics such as internal friction, cohesion, unit weight, moisture content, gradation of fines, consolidation and plasticity. Most soils are a combination of a cohesive soil (clay) and cohesion-less soil (sand).

Site Survey

Soil Borings

Depending on the transmission line and knowledge of the soil conditions along the corridor, the need for soil borings must be determined. If the line is composed of H2 or higher class wood poles, or equivalent strength steel or concrete poles, the need for soil borings may be greater. The decision to take borings will also depend on existing soil information. Variation of the soil will determine the frequency of the borings. Borings should be considered at locations where additional lateral loads will occur, such as un-guyed angle structures and dead end structures composed of steel or concrete poles.

For transmission line projects that are a few miles in length to ones that are longer, a geotechnical report, which includes soil borings and subsurface analysis, is usually a small

percentage of the overall cost of the project. A few borings appropriately placed along the route of the line can provide valuable data to analyze the most economical and stable embedment depths. This is particularly true when CAD programs include a function for analyzing subsurface soil data for embedment depths.

Embedment Depths

In deciding embedment depths for many typical wood pole lines, economics may dictate that few, if any, soil borings be taken when data and experience from previous lines are available. Numerous soil conditions will be encountered in the field. Although the soil conditions may closely resemble each other, the soils may have a wide range of strengths. The engineer, therefore, must identify areas or conditions where pole embedment depths in soil may have to be greater than the minimum depth of 10 percent of the pole length, plus 2 feet.

Areas where the designer needs to consider additional embedment depths include (but are not limited to):

- Low areas near streams, rivers, or other bodies of water where a high-water table or a fluctuating water table is probable. Poles in a sandy soil with a high-water table may "kick" out. Due to the submerged weight of soil below the water table, frictional forces along the surface area of embedded poles are reduced along with reduction in the strength of the soil to resist lateral and vertical forces. The legs of H-frames may "walk" out of the ground if neither sufficient depth nor bog shoes are provided to resist uplift. Guy anchors may fail if the design capacity does not consider the submerged weight of the soil.
- Areas where the soil is loose such as soft clay, poorly compacted sand, pliable soil, or soil which is highly organic in nature.
- Locations where higher safety is desired. This may be at locations of un-guyed small angle structures where a portion of the load is relatively permanent in nature, or at river, line, or road crossings.
- Locations where poles are set adjacent to or on steep grades.
- Locations where more heavily loaded poles are used.

- Locations where underground utilities such as water or sewer will be located next to the pole.

Subsurface soil conditions may exist that are so poor that direct embedment is not the appropriate option for support of the structure. In these cases, actual soil boring information may be needed to determine alternative foundation options and structure types.

Field Survey

A field survey is a method that can be used to estimate whether a soil is "good," "average," or "poor." It should be noted that embedment depth design based on field survey data is subject to a wide variation in results. The location for obtaining the most reliable soil data using field survey methods would be at the depth where the pole would bear and at any transition between soil layers along the depth of embedment of the pole. There are several economical methods to make a field survey for wood transmission lines. The engineer may use a hand auger, light penetrometer, or torque probe. The meaning of terms such as firm, stiff, soft, dense, and loose may not always be clear. Table 1 will help to clarify these terms.

Table 1	
Classification of Soils Based on Field Tests	
Term	Field Test
Very soft	Squeezes between fingers when fist is closed
Soft	Easily molded by fingers
Firm	Molded by strong pressure of fingers
Stiff	Dented by strong pressure of fingers
Very Stiff	Dented only slightly by finger pressure
Hard	Dented only slightly by pencil point
Loose	Easily penetrated with a 1/2 in. reinforcing rod pushed by hand
Firm	Easily penetrated with a 1/2 in. reinforcing rod driven with a 5-lb. hammer
Dense	Penetrated 1 ft. with a 1/2 in. reinforcing rod with a 5 lb. Hammer
Very dense	Penetrated only a few inches with a 1/2 in. reinforcing rod driven with a 5-lb. hammer

Pole Stability

Wood Poles

In addition to local experience with wood poles, the graphs in Figures 1 through 3 may be used to approximate embedment depths. To use the charts, good, average, and poor soils must be defined. The following are proposed as descriptions of good, average, and poor soils:

- Good: Very dense, well graded sand and gravel, hard clay, dense, well graded, fine and coarse sand.
- Average: Firm clay, firm sand and gravel, compact sandy loam.
- Poor: Soft clay, poorly compacted sands (loose sand), wet clays and soft clayey silt

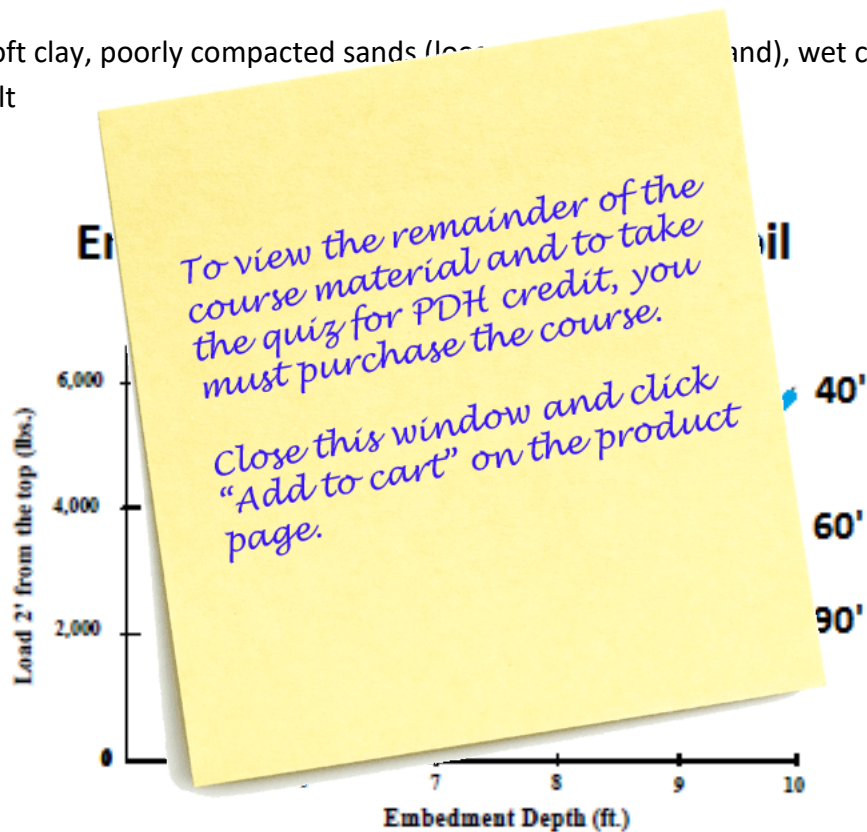


Figure 1