Hurricane Wind Forces on Utility Poles and Foundation Support in Various Soils

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Abstract

In this study the wind load is calculated using National Electrical Safety Code 2007 (NESC) for electrical poles greater than sixty feet. The calculated wind load from NESC were taken for modeling the pole using a commercially available software PLAXIS. The parameters embedment depth (D), height of the pole (H), cohesion (c), angle of friction (ϕ) were varied with a controlled deflection of 2.7 ft at the top of the pole. D/H ratio is plotted against cohesion for different friction angles (ϕ) values and in the entire study modulus of elasticity (E) is kept constant.

1. Introduction

Self-supported direct-embedded poles are widely used by the utility industry in the United States to support high voltage transmission lines. These poles are subjected to lateral loads caused by wind and gravity loads due to the weight of the wire and ice that forms around the wire. For a typical tangent transmission pole the lateral loads govern the design of the pole and foundation. In the case of self-supported poles, these lateral loads are resisted by the soil along the depth of the pole below ground level. Although close attention is paid to the design of the pole itself, the design of the foundation is often based only on empirical methods in current practice. According to the Rural Utility Service (RUS), the standard of practice, or rule of thumb (ROT), is to embed the pole 10% of the total length of the pole plus 2 ft into the ground Rural Utilities Service RUS (2004). The current design methods for transmission pole foundations do not take into consideration the pole or soil properties. It has been shown that the methods used in current practice do not yield consistently reliable pole foundation embedment depths in all soil types and for all possible pole classes, lengths, species, and pole loading scenarios. When the embedment depth specified is not adequate for the combinations of applied loads and in situ soil conditions, the transmission poles will lean as the soil around the pole yields and deforms. In some cases, the poles may even fall over, causing costly power outages and creating a potential risk to human life. On the other hand, in competent soils, the current methods yield over conservative embedment depths that are unnecessary and uneconomical. Despite the consequences of transmission pole foundation failures, only a few studies have been performed on direct-embedded self-supported transmission pole foundations (Meador 1997; Keshavarzian 2002). According to NESC the extreme wind loads were carried out using the following equation. Where V = Wind speed, K_Z= velocity pressure exposure co-efficient, G_{RF} = gust response factor, C_d = coefficient of drag and A= projected wind area.

$$\text{Wind load in pound} = 0.00256\, V^2.\, K_Z.\, G_{RF}.\, C_d.A \text{ --------- (1)}$$

2. Objective

The objective of this paper is to provide a required embedment depth for the utility poles depending upon the soil parameters cohesion (c) and angle of friction (ϕ).

3. Analyses

Analysis of wind loads on poles is carried out using National Electrical Safety Code, considering the structure is in Houston Texas with a design wind speed of 100 mph. The height of the pole above the ground level is 70 feet, having three wires above the ground line at 73 feet (one wire) and 67 feet (two wires) with a wind span of 300 feet. The conductors and pole are assumed to be round in shape. The combined extreme wind load calculated using equation1 on the pole and conductors is 3230 lb-f. The calculated wind load from the analysis were taken and modeled using a commercially available finite element software PLAXIS. Form the Rural Utility services ROT the embedment depth (D) of the pole is taken as 10ft for initial depth, later on the embedment depth (D) is varied along with cohesion (c) and friction angle (ϕ) keeping height of the structure (H) and modulus of elasticity of soil (E) are kept constant throughout analysis.

4. Discussions

The D/H ratio is plotted against the cohesion for different friction angles (ϕ) with a controlled deflection of 2.7 ft at the top. Fig.1 shows a schematic diagram used for the calculation of wind loads and analysis, where as Fig.2 represents a plot between D/H ratio and Cohesion for different angle of friction (ϕ) values with controlled deflection of 2.7 ft at the top. From the plot it is clear that according to rural utility services ROT the D/H ratio is independent of soil parameters and it is also seen that friction angle (ϕ) is same for soils whose cohesion is greater than 2.8 ksf.

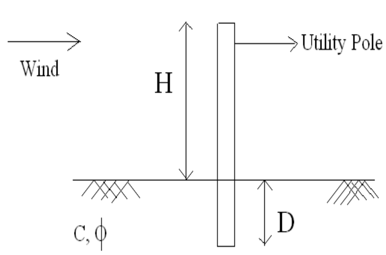

Fig.1 Schematic Diagram used for Analysis

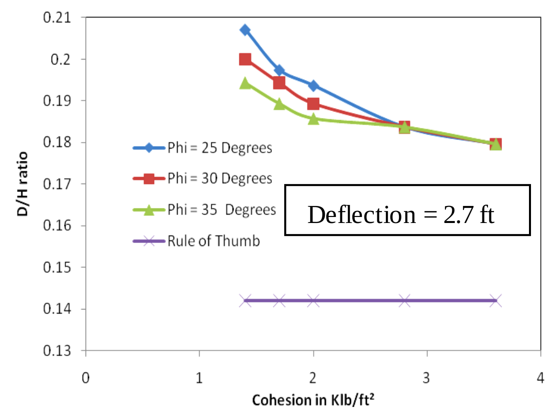

Fig.2 D/H ratio vs Cohesion

5. Conclusions

Based on this study it is clear that rural utility services ROT is independent of soil properties and this study shows that embedment depth (D) depends upon the soil properties cohesion and angle of friction.

6. Acknowledgement

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7. References

1. Keshavarzian, M. (2002). "Self-supported wood pole fixity at the ANSI ground line". Practice Periodical Structural Design and Construction, vol 7(4), 147-155.

2. Meador, N. F. (1997). "Mathematical models for lateral resistance of post foundations." Trans. ASAE, 40(1), 191–201.

3. The Institute of Electrical and Electronics Engineers, Inc. "National Electrical Safety Code". New York, NY 10016-5997, USA.

4. David J. Marne P.E., "National Electrical Safety Code 2007 Hand book", McGraw-Hill Professional Publishing.