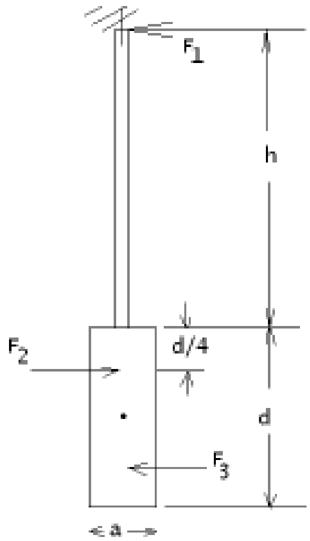
Simple Antenna Tower Base Calculation



For those interested in understanding some tower base designs for freestanding (i.e self-supporting, non-guyed) ham antenna towers. Why do they specify so much concrete in such a large hole?

Consider the tower, mast, beam antenna, and tower base, as poorly drawn above. The top of the tower is at a height, h, above ground level. A force, F1, from the wind, acts on the tower.

The tower is mounted securely on a concrete tower base, which is of square cross section (i.e. a x a) and it extends to a depth, d, below the surface.

The dot in the center of the tower base is assumed to be the center of rotation in the soil. In reality, because the soil characteristics vary with depth, this assumption may or may not be suitable.

Summing the forces,

F2 = F1 + F3. (1)

Computing the torques about F2,

(F1)(h+d/4) = (F3)(d/2). (2)

Substituting (1) into (2),

(F1)(h + d/4) = (F2 - F1)(d/2) = (aPd/2 - F1)(d/2), (3)

where

(F2) = aPd/2, and P is the average soil pressure, which acts on the tower base in line with the wind force, down to the center of rotation.

Rearranging (3),

4(F1)h + (F1)d = aPd^2 - 2(F1)d, (4)

further, (4) becomes,

$$aPd^2 - 3(F1)d - 4(F1)h = 0. \qquad (5)$$

Solving the quadratic, (5), and keeping the meaningful root, we arrive at a result for the depth, d,

$$d = \{3(F1) + \sqrt{9(F1)^2 + 16aPh(F1)}\}/(2aP). \qquad (6)$$

A couple of things to point out:

1. The weight of the concrete tower base is not the primary force that keeps the tower from overturning in the wind. The soil pushes back on the tower base to keep the tower base upright in the wind and it is the soil pressure that counteracts the wind. The tower base does not need to be concrete, but it should be of sufficient strength, size and depth to counteract the overturning force.

2. From (6), it is clear that "deeper" is better than "wider." Note that if the tower base did not have square cross section, one could easily assign a proper value for the base "width" in the case of a rectangle or cylinder.

For some cases of practical interest to hams, (6) can be rewritten for rough estimates,

$$d \sim 2\sqrt{(F1)h/aP}, \qquad (7)$$

and throughout, I have not introduced any factor of safety. Tall towers in windy locations with poor soil need wide and deep tower bases. Unless you measure the soil properties at a prospective site, you really do not know how to design the tower base.

Example:

An EZ Way RBS40 self-supporting, crankup and tiltover tower (no Wonder Post, but the ground-mounted steel tilt base). Back in the 1960's, the manufacturer specified a concrete base with dimension, 1.83' x 1.83' x 4' deep. The tower is 42 feet tall, and a WAG is that the design wind force is about 100 pounds (they spec'ed it at 50 MPH, 12 sq. ft. of antenna plus the tower and mast). Let's assume rather poor soil at P = 1,000 pounds/sq.ft.

Using (7), $d \sim 3$ feet deep, so it appears that EZ Way put a factor of safety of about 1.75 on (F1)/P to arrive at the 4 foot deep hole. (Note that the force of the wind increase as the square of the wind velocity.)

This note should not be used to design a tower base. However, it might be a useful tool in reviewing tower base designs created by engineers for amateur radio operators.

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