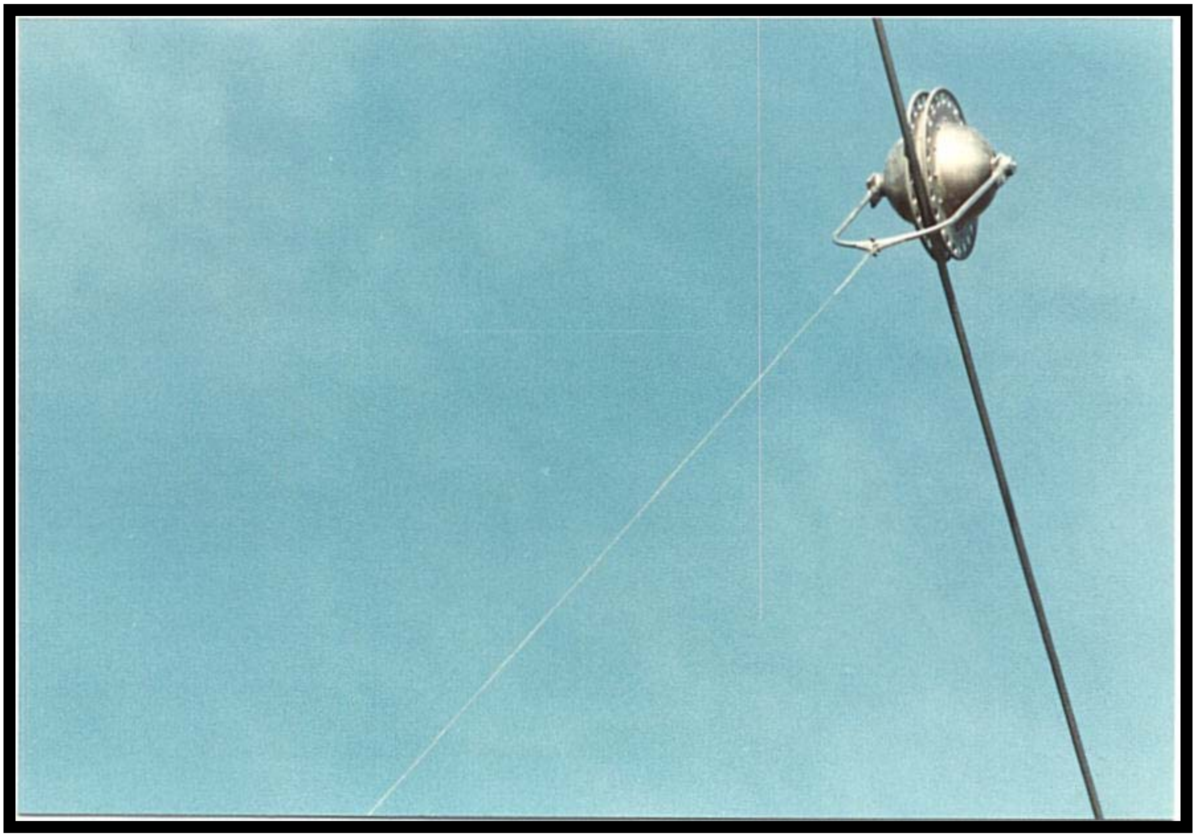

Limiting the Dynamic Loads on Tall Towers

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Introduction

Dynamic loads on tall towers result from extreme conditions. Among these are: (1) earthquake loads, (2) ice dropping loads, (3) wind loads, and (4) galloping loads. In the case of the earthquake loads the tower is driven by the base motion of the ground in a horizontal direction. The tower response to earthquake motion is not unlike the response of a tall building to an earthquake. While the dynamic motion of the base may only be in a range of 0.1 to 0.2 g's, motion at certain points along the tower can be 0.3 to 0.4 g's or more. This is because many of natural modes on the tower contribute to the dynamic response. These modes depend upon tower mass distribution, stiffness, guy tension, and the like.

In the case of ice dropping loads, the ice that drops creates a sudden loss of guy tension. In heavy ice a condition of guy unloading occurs that may actually reduce the guy tension to zero. At that instant the guy becomes weightless due to vertical acceleration. If tension loss occurs only on one side of the tower, and the guys on the opposite side remain loaded, dynamic bending load distribution along the tower may cause tower collapse. This situation did occur near Raleigh, North Carolina on December 10, 1989. Two towers failed, while one remained standing. All three towers were within one mile of each other, and were all 2,000 feet high. The one that did not fail had an anti-gallop device on the guy cables.

In the case of wind loads, the tower is usually designed for maximum wind loads without ice. While the equivalent wind speeds are in the range of 140MPH, the loads are applied as static loads, but include gust factor to account for dynamic loading. In the U.S. the design code is the EIA – 222 D/E. This has replaced early codes EIA – 222A, 222B, 222C. Many towers were built under the old codes, and have been subject to changes over the years as well. The result is that some towers, designed under the old code, may not now satisfy the new code safety factors. Further, some of these towers are now being equipped with anti-gallop devices for the control of low frequency vibration. In some of these cases, protection against high dynamic loading has increased.

The gallop loads are the result of combinations of ice and strong wind, but neither the ice nor the wind needs to be excessive for severe galloping to occur. In a typical case, ice of only 1/2 in. (or less) accompanied by 50MPH wind (or less) has caused guy cable galloping and in some cases tower collapse.

There is a need to relate the static loads on a tall tower with dynamic loads, and/or the effect of load control devices. These are subjects for future study and research. This present report provides some tentative insight to the question.

Dynamic Tension

The dynamic loads on the mast are generated by changes in guy tension, which are caused by guy motion. Thus, if one controls the motion, one also controls the dynamic loads on the mast. The control of guy motion is not easy under all of the previously identified conditions. Firstly, the motion of the guy cables is made up of vertical and horizontal components. The latter does not generate dynamic tension, but the former does. Hence, a method that controls only the horizontal component will not limit dynamic tension.

The amount of tension change due to vertical motion depends on guy mass, initial tension, guy elevation angle, guy length and the ratio of the first two natural frequencies. The last factor is a dominant influence. For example, if the first two natural frequencies are close to each other, the dynamic tension can exceed the initial tension.

In a vertical gallop tension could reduce to zero on the up stroke, and increase to twice its initial value of the down stroke.

The mode shape of the first mode is usually a single loop, or one-half sine curve, while the shape of the second mode is a full sine curve. When the two frequencies come together, the shape of the first mode changes. If the first frequency is larger than the second, there are three loops in the first mode instead of one. Each tower must be carefully analyzed to establish dynamic characteristics. An analysis has been performed to illustrate the process.

Needham Tower

The tower in Needham, Massachusetts has experienced some galloping problems in past years. It is located near an office park and a hotel, and the owners decided to equip it with the SANDAMPER anti-gallop system. These devices are located on the guy cables and control the vertical guy motion. The tower has three major UHF channel antennae located on top, and thirty additional radio antennae and dishes along the tower.

The physical features of the tower guy cables are seen in Table (1). The tower has six guy levels up to 1,100 ft., and the start platform for the three top UHF antennae are stabilized by six guy cables. Because of the tight space at ground level the SANDAMPER cables could not be anchored to the ground, but are tied back to the tower legs.

Table 1. Candelabra Tower Characteristics, Height = 1100 feet

Guy Level	Diameter (inches)	Tension (Kp)	F1(Hz)	F2(Hz)
1	1.125	14.0	0.61	1.01
2	1.437	14.3	0.46	0.62
3	1.812	21.3	0.36	0.47
4	1.875	35.8	0.29	0.47
5	2.187	52.0	0.25	0.41
6	1.875	42.1	0.22	0.36

Analysis

The tower has an unusually low guy tension at the second and third guys. A normal design tension is in the range of 10% to 12% times the breaking strength. Here the initial tensions at theses levels are respectively 5.4% and 5.1%. The natural frequencies of the first two modes are also closer than any other guy. This is a signal that large dynamic loads may occur.

The analysis of the tower by static loads, by the EIA-222E code method reveals that some members are overloaded.

In the case of loading into the apex of the tower, the factor of safety on all guy levels is in the range of 2.7 to 3.2 as compared to breaking strength. In the code o minimum of 2.5 is recommended.

In the case of loading parallel to a tower face, the factor of safety is 2.1 at the top guys, and 3.0 or more at the lower guys.

In the case of the loading into a flat face of the tower the factor of safety at levels 4 & 5 are respectively 2.2 and 2.1

The maximum deflection of the tower is about 14 feet at the top, and the deflection curve may be closely approximated by a straight line.

Effect of Damper

The damper used on this tower is the SANDAMPER. It is a device that rides on the guy cables, one per guy. Inside the damper is loose, dry sand, sealed against the elements. It moves up and down the guy cable as the cable moves up and down. Damping is applied to the motion by this method. The damper is also a snubber. If there is ice and the damper becomes frozen to the guy cable, any motion will create an increased load in the damper tether cable. This increased load pulls against the guy up to a maximum of 4,000 pounds at which point a safety link breaks and limits the tether load on the guy.

The analysis has included the effect of all damper simultaneously loaded on one side of the tower to a maximum of 4,000 pounds. The analysis shows that:

- load reactions on the tower by the SANDAMPER device reduce the shear reactions at damper tether attachment points by up to 9%.

- tower deflection is reduced by 10%

- damping of galloping motion is increased by up to seven times the guy able damping at levels two and three, and up to four times at other guy levels.

Conclusions

Dynamic loads on tall towers are often not considered in design, yet dynamic loads can be severe. Large amplitude motion of guy cables can develop dynamic tension loading on the tower mast when the natural frequency of the first mode is close to the frequency of the second mode.

Analysis of the Needham tower by the new EIA-222E code has shown that loads applied on the tower mast itself can be diminished by an anti-galloping device that is attached back to the tower legs at one end, and to the guy cable at the other end.