PLANNING ADVISORY NOTICE

Topography (TOPO)

This PAN is focused on what in telecommunications is commonly referred to as TOPO: short for topography. As the engineering knowledge has improved over the years it has been found that a proper understanding of topography can have a significant impact on the proper performance of a structure. Improper application can lead to the structure not performing as designed or greatly increases the cost of the structure or its modifications with no material benefit. The force wind exerts on a structure can be affected by a variety of factors including, but not limited to, the geographic location, wind exposure category, elevation of the site, and the topography of the site. If you have ever gone on a road trip and stopped at a scenic view you have experienced this when you came to the overlook, the wind seems to blow harder and faster as you approach the overlook. This PAN will focus on the effect the topography has on the basic wind speed for a site-specific structure location.

The equation to determine the velocity pressure of wind at a specific height is given in Equation 1.

$$qz = 0.00256K_zK_{ZT}K_dK_eV^2$$

(Eq-1) (ANSI/TIA-222-H Section 2.6.11.6)

Where:

q_z = velocity pressure at a given height z.
K_z = velocity pressure exposure coefficient
K_{ZT} = topographic factor
K_d = wind directionality factor
K_e = ground elevation factor
V = basic wind speed (mph)

Topographic effects influence the gusted wind pressure based on the wind speed-up effect produced by the topographic feature upon a structure. Code based structural analysis/design is contained in the ANSI/TIA-222 Standard and requires engineers to account for topography in the surrounding region of the structure to modify the minimum design wind to fully account for site specific effects of Topography on the structure. When wind meets a topographic feature such as a hill or an escarpment, it accelerates as it travels up the feature and results in a higher wind speed impacting the structure. This wind speed-up effect is illustrated in Figure 1.

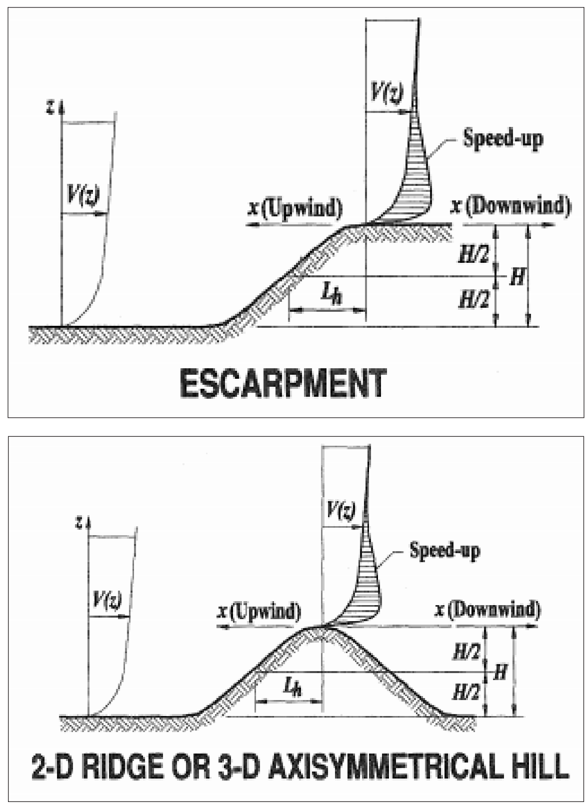

Figure 1
Wind Speed-up Effects at a Topographic Feature (Ch 26.8, ASCE 7-16)

Certain site-specific minimum criteria must be met for a topographic feature to be considered to result in a wind speed-up effect

Authors: **Justin Kline, Gilberto Martinez, Kyle Thorpe,** and **Michelle Kang**.

PAN Advisory Group: Michelle Kang, Scott Vance, Scott Stekr, Dale Heath, Brandon Chapman, Carlo Franceschino, Joshua Huff, and Scott Kisting.

on the structure. These criteria have been more clearly elaborated on since the release of ANSI/TIA-222-G and must always be satisfied regardless of the methodology used to calculate the topographic factor (K_{ZT}). There are times where topographic effects are applied to a structure when it is not required. This has a potential adverse impact to society. It may be affecting the ability of those procuring tower sites to be able to add additional sites to improve network redundancy, as it improperly requires the structure to perform in higher wind speeds than required per code which translates into increased and unnecessary costs. All the following criteria must be met for topography to be considered on a site:

1. Tower point elevation exceeds the mid-point elevation of the topographic feature;
2. The slope of the topographic feature is 10% or greater;
3. The height of the topographic feature (H) is greater than or equal to 60 ft for Exposure B or greater than or equal to 15 ft for Exposure C and D; and
4. The topographic feature is considered isolated.

In the event that the minimum criteria discussed above are met, the requirements of ANSI/TIA 222 must be met as it is the governing standard for telecommunications structures as adopted by the International Building Code (IBC). With the 2005 release of ANSI/TIA-222-G, the requirements for consideration of topographic effects were more effectively communicated. The procedure provided in ANSI/TIA-222-G was a direct adoption of the method provided in ASCE 7-02. With the release of ANSI/TIA-222-H, this is now known as Method 1. ANSI/TIA 222-G also provided for the reasonable allowance of alternative methods “based on recognized published literature or research findings”. This allowance for alternative methods resulted in the emergence a more refined methodology introduced by the Structural Engineers Association of Washington (SEAW). The SEAW Rapid-Solution Methodology (RSM) introduced a refined method that included, among other factors, the effect of the slope of the topographic feature on a structure. ANSI/TIA-222-H codified the methodology introduced by the SEAW RSM-03 and established this as Method 2. Please note, most engineers will default to Method 2.

ANSI/TIA-222-H also allows for a third method, “site specific topographic procedure”. This method is the most rigorous and costly to undertake but in certain situations it may provide the best understanding for the needs of the structure. Properly applied, this is a long-term investment in understanding the site-specific topographic effects on a structure. This allows the engineer to potentially arrive at a more accurate, and perhaps lower, site-specific wind speed than what can be applied to the structure through Method 1 or Method 2. The engineer should clearly communicate to the structure owner the potential benefits of using Method 3 for specific sites where this investment may result in a pass/fail difference.

If we think back to the example of the scenic overview, the shape of the feature and surrounding terrain really do make a difference to the wind speed experienced by the structure.

> *The ANSI/TIA–222 Standard has evolved to account for how topography impacts the wind speed applied to telecommunications structures.*

To recap on the three methods for determining TOPO effects per TIA-222-H they are:

Method 1 – Simplified Topographic Factor Procedure (ANSI/TIA-222-H Section 2.6.6.2.1):

$$K_{ZT} = (1 + K_c K_t / K_h)^2 \qquad \text{(Eq-2)}$$

Where:

K_c = terrain constant
K_t = topographic constant
K_h = height reduction factor = $e^{fz/H}$
e = 2.718
f = height attenuation factor
z = height above ground level at base of structure
H = height of crest above surrounding terrain

Method 2 – Rigorous Topographic Feature Procedure (ANSI/TIA-222-H Section 2.6.6.2.2):

$$K_{ZT} = (1 + K_1 K_2 K_3)^2 \qquad \text{(Eq-3)}$$

Where:

K_1 = topographic feature factor adjusted for slope
$K_1 = \beta\, K_1'$

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β = slope modifier
K_1' = topographic feature factor
K_2 = horizontal distance factor
K_3 = vertical distance factor

Method 3 – Site Specific Topographic Procedure (ANSI/TIA-222-H Section 2.6.6.2.3):

Wind speed-up criteria shall be based on a site-specific investigation.

The slope of the topographic feature can have a significant impact on the topographic factor, K_{ZT}. When the slope of the topographic feature with respect to the structure location is less than 10% (aka K_{ZT} = 1.0), there is no topographic wind speed-up effect and therefore no reason to consider increases in wind speed to the structure as a result of topography.

When the slope of the topographic feature with respect to the structure location is between 10% and 25%, K_{ZT} will be > 1.0 per Figure 2 below. Any feature with a slope greater than or equal to 25% will have the same K_{ZT} value as Method 1, as this method does not consider the actual slope of the topographic feature. It applies the worst-case wind speed-up for the site based on the crest height of the feature. Figure 2 below demonstrates the differences in the topographic factor (K_{ZT}) derived from Method 1 vs. Method 2 as impact by the change in slope.

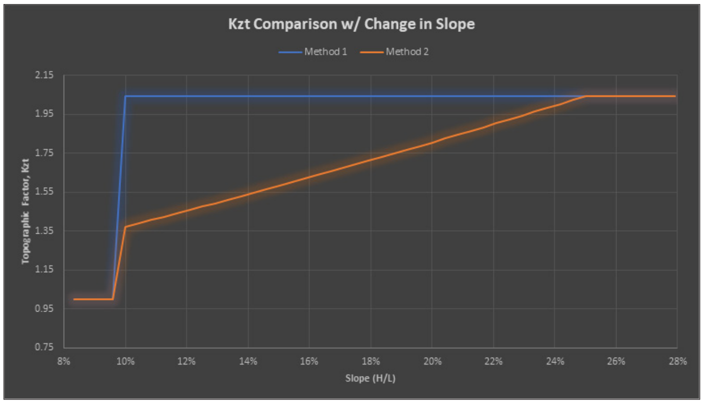

Figure 2
K_{ZT} derived from Method 1 vs. Method 2 for a ridge feature in Exposure C as defined by ANSI/TIA-222-H

While the consideration of slope was a major addition to Method 2, there are several other factors introduced by this methodology that furthered the evolution from Method 1. The topographic constant (K_t) as defined in Method 1 was limited to three topographic features (Escarpment, Hill, and Ridge). The topographic feature factor (K_1), as defined in Method 2, introduced two additional topographic features (Flat Topped Ridge and Flat-Topped Hill).

Method 2 further refines the analysis by considering the horizontal distance of the structure location relative to the crest of the topographic feature. This horizontal distance factor (K_2) is a reduction factor that decreases the further away the structure location is from the crest of the topographic feature. An additional reduction factor is applied in the form of the vertical distance factor (K_3) that decreases the further the structure being analyzed is to ground level. Therefore, when K_2 and K_3 are applied in Method 2, there are significant reductions in the wind speed-up effect applied to the structure the further away it is from the topographic feature and the higher it is off the ground.

As discussed above, the introduction of Method 2 significantly refined the methodologies available to engineers in the telecommunications industry. The consideration of slope, additional types of topographic features, and structure location relative to the crest of the topographic feature are all factors that improve the accuracy of the consideration of topographic effects on a structure. Engineers now have the ability to move away from the limited approach of Method 1 and move towards the more accurate Method 2. Using Method 2 for analysis and design of telecommunication structures will ensure the structures remain code compliant while eliminating the cost associated with the more conservative Method 1.

In closing, it is our hope that this PAN provides a high-level introduction to topography and the way in which the telecommunications industry has continued to develop its standards in this area. These advancements provide more comprehensive design guidance to allow for refined wind speed-up effects based on topography and the opportunity to have a more strategic investment in the telecommunications infrastructure.