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Wind loads on roof mounted telecommunications equipment: a structural perspective

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Abstract

A significant risk to reliability of the telecommunications network is damage to equipment in severe wind events. To a lesser extent underestimates of wind loads can result in excessive deflections and antenna rotations being experienced more often than specified in design criteria with subsequent reduction in network reliability. Research and experience has shown that roof mounted equipment can be subject to significantly higher wind loads due to wind being diverted over and around buildings. This paper presents information on the subject based on a search of literature and discusses the cause of the higher loads, the relative magnitude of these loads, provisions in overseas codes, and a possible method for design for Australian sites.

Background

The author worked in design of antenna mounts on buildings several years ago for a consulting firm in Brisbane and practice at the time was to design for wind speeds calculated from terrain height relationships as shown in the code.

Returning to the telecommunications industry after working in other areas the author was looking at a wall mounted antenna and noted that it was in an area where edge vortices could be expected and hence higher wind speeds might apply. This led to a search via two common internet search engines for information on the topic.

Results of literature search

The literature on this subject is not extensive, at least on the internet. The result was confirmation that this did happen and it applied to roofs as well and over a greater extent than anticipated. In fact the literature applied exclusively to roof mounted equipment.

Following Hurricane Katrina the FEMA report noted

> 5.6.2 Electrical and Communications Equipment
>
> Rooftop electrical and communications equipment was also observed to be inadequately protected and anchored. Problems included flooded generators, antenna collapse, blown over satellite dishes and displacement of LPS.

A fairly complete overview of the then current situation was provided by Reinhold in “Calculating Wind Loads and Anchorage Requirements for Rooftop Equipment,” 2006. He noted that "While the American Society of Civil Engineers (ASCE) Standard 7-05, Minimum Design Loads for Buildings and Other Structures, finally has begun to formally address wind loads on rooftop equipment, the current guidelines are quite limited."

Reinhold helpfully provides some extracts from ASCE 7 codes to illustrate progress on the issue.

The ASCE 7-02 Commentary states, "ASCE 7-02 has been modified to explicitly require the use of Figure 6-19 for the determination of the wind load on equipment located on a rooftop. Because there is a lack of research to provide better guidance for loads on rooftop equipment, this change was made based on the consensus opinion of the Committee."

The ASCE 7-05 Commentary states, "There is now a very limited amount of research to provide better guidance for the increased force ... Based on this research, the force of Eq. 6-28 should be increased by a factor of 1.9 for units with area less than (0.1 Bh). These provisions were continued in ASCE 7-10."

Erwin et. al. published results from a "Wall of Wind" experiment in 2011 where they found a lateral peak force coefficient 50% higher than the ASCE 7-10 provisions, i.e. a load factor of about 3.0.

In 2013 the Insurance Institute for Business & Home Safety (IBHS) published a report “Wind Loads on Small Roof-Mounted Air-Conditioning Units” which shows that awareness of the issue has moved beyond professional circles. Provisions now appear in at least the ASCE and IBC loading codes. We can anticipate that similar provisions will appear in Australian and New Zealand Codes in the near future.

The effect on telecommunications equipment

The first obvious effect is the if loads during extreme events are much higher than designed for the mounts could fail resulting in failure of the communications system.

Taking region B as an example this could, in the case where a load factor of 3.0 might apply, effectively reduce the design life from 50 years (500 year ARI) to 10 years (100 year ARI).

Not that all mounts will fail under these loads but at any wind speed we can expect a higher rate of failure, and failure will begin at lower wind speeds.

Serviceability for communications equipment is normally calculated as a rotation limit depending on the type of antenna. Typically, ‘outages’ are required to be limited to 0.1% of the time for broadcasting (TV, radio) services (about 9 hours per year), and 0.001% for telecommunication services (about 5 minutes per year).

Generally this is significantly lower than the serviceability wind speed of 25 years ARI typically used for buildings.

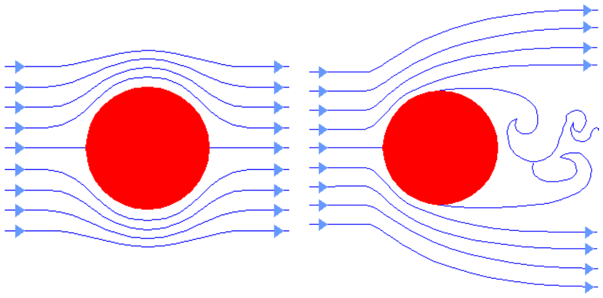
In many cases the calculated rotation at serviceability is well within the specified limits and even an increased wind load of 2-3 times will still produce satisfactory service.

Causes of increased loads

The general properties of flow around objects are well known.

Ideal flow around a cylinder results in increased wind speed where streamlines are closer on the sides. Real flow around a cylinder also produces higher wind speeds around the sides but a separation zone forms causing a wake region.

These higher wind speeds can affect equipment mounted on the sides of tanks and reservoirs but this will not be considered further here.



Ideal flow around a cylinder Real flow around a cylinder

Figure 1. Air flow around a cylinder.

Flow around a bluff body such as a building also results in higher wind speeds over and around the body but at leading edges we get separation zones and vortices.

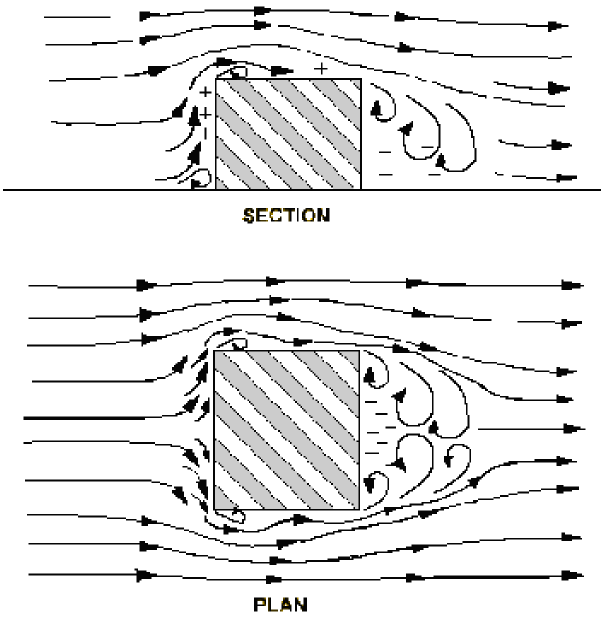


Figure 2. Wind flow around a bluff body with higher speeds and separation zones

We are already familiar with some of the effects of these as higher negative coefficients of pressure and local pressure factors near leading edges. These flow regimes will also cause significantly increased load on equipment installed within these zones.

Magnitude of peak force coefficient

In ASCE 7-10 the wind force is generally determined by the formula

$$F = q_z \, G \, C_f \, A_f \qquad (1)$$

where G=0.85

Based on wind tunnel tests the load on rooftop equipment is expressed in ASCE 7-10 Section 29.5.1 as

$$F_h = q_h \, (GC_r) \, A_f \qquad (2)$$

where $(GC_r)=1.9$

It is convenient to define a wind pressure multiplier

K_e = external equipment pressure multiplier,

$$K_e = F_h/F = 1.9/(0.85C_f) \qquad (3)$$

Taking C_f as a typical value of 1.2 we get $K_e = 1.86 \approx 1.9$

In ASCE 7-10 these loads are applied to equipment anywhere on the roof, although the peak pressure factor decreases where $A_f > 0.1$ B h. Usually telecommunications equipment will have $A_f < 0.1$ B h and this reduction will not be considered further.

However Erwin et. al, 2011, found loads about 50% higher and notes "the largest measured and estimated wind loads occurred when the rooftop equipment was placed near the roof edge". They found $GC_r = 3.1$ which gives $Ke=3.04 \approx 3.0$

So in assessing wind loads on roof mounted telecommunications equipment we can generally expect Ke ≈ 1.9, and close to the roof edge up to Ke ≈ 3.0

Limitations of the method in ASCE 7 are;

- it abruptly cuts out at a building height of 18m
- it combines effects of increased wind speed and coefficient of drag so that equipment shape or streamlining has no effect
- it does not allow for any change in load factor according to position on the roof
- it has no provisions for equipment on building walls. It applies the load as a single factor

None of the references found cover wall mounted equipment however we can expect Ke > 1.0 and it is not unreasonable to suggest similar magnitudes to roof mounted equipment.

What do we do about these loads?

Option 1. Ignore them. They're not specifically required in the AS1170 loading codes, and nobody else is doing it. This however would not generally be regarded as professional practice. As stated in the scope of AS1170.0 "Normal design practice is that all likely actions be considered. Any actions considered in design that are not in the above list should be the subject of special studies, as they are not covered by this Standard."

Option 2. Adopt the provisions of ASCE 7-10 (or some other source). As noted above and in the references these provisions appear to be inadequate for several reasons and could lead to significat underestimation of loads.

Option 3. Find a design procedure which is rational, can be consistently applied, and gives reasonable results consistent with the available information. A proposed procedure that meets these requirements is presented in the next section.

A proposed method for buildings

Considering the situation of an object on the roof of a building with low height/width ratio this can be viewed as similar to an object on a cliff or escarpment with a vertical face. This leads us to consider using the appropriate topographic multiplier to estimate design loads.

When we consider a tall building however it is likely that most of the wind flow will be around rather than over the building. Considering a plan view we can also look at this as analogous to a cliff with the axis of symmetry corresponding to the ground line so that the "height" is half the building width.

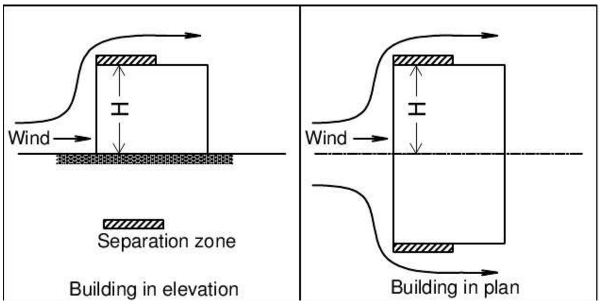


Figure 3. H = the lesser of the height of the building and half the building width.

Combining these observations leads to the proposition that we can use a topographic multiplier where the escarpment height, H, can be taken as the lesser of the building height or half the width.

Since the building on which the antenna is situated might be on a hill we need to distinguish the wind speed multiplier for building effects from that for topographic effects. We will define this multiplier as

Me = wind speed external equipment multiplier,

(i) Within the separation zone

$$M_e = 1 + 0.71[1-|x|/L_2] \qquad (4)$$

(ii) Elsewhere within the equipment multiplier zone

$$M_e = 1 + (H/(3.5(z + L_1))(1-|x|/L_2) \qquad (5)$$

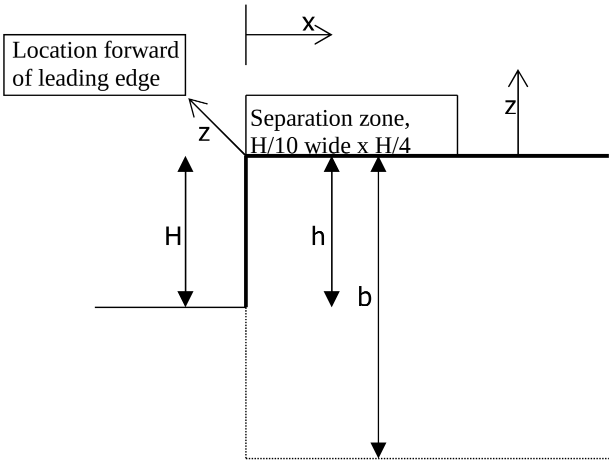


Fig 4. Parameters for calculating external equipment multiplier

where

H = the lesser of the height of the building and half the building width.

L_1 = length scale, to determine the outwards variation of Me, to be taken as 0.4 H

L_2 = length scale, to determine the horizontal variation of Me, 10 L_1 downwind from the leading edge

x = horizontal distance downwind of the structure leading edge

z = reference height on the structure normal to the building surface, or where x<0, the radial distance from the leading building edge

Expressing this as a wind pressure multiplier

Ke = external equipment pressure multiplier, where Ke = Me^2

Since from (4) the maximum value of Me = 1.71 we get Ke,max = 3.0 which is consistent with values measured by Erwin et. Al.

As in ASCE 7 these wind speed or wind pressure factors are used with the free stream speed or pressure applying at the building roof, or appropriate height for wall mounted equipment.

Results from application of the design method

At the leading edge within the separation zone we get Me = 1.71 and hence Ke = 3.0. This is the upper limit of increased wind pressure on equipment. Ke decreases as the equipment is located outwards beyond the separation zone and also with increasing distance from the leading edge.

This method has now been used for a number of antenna designs. Generally it has been found that in our work a roof mounted antenna is on a mount 2-3m above the roof level. This is usually outside the separation zone and typically we find Ke~=2.0.

Conclusions

A design method has been developed from existing provisions of AS1170.2 that corresponds well with available information. This can only be regarded as a best estimate until further research is published which will allow an improved method to be formulated.

The expected outcome is not over design of telecommunications equipment supports but designs that meet client strength and serviceability requirements.

Disclaimer

The views expressed in this paper are those of the author and not necessarily those of any employer, past, present, or future.

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