The 2002 Australian and New Zealand Wind Actions Standard –
A first step in an international harmonization process for wind loading codes?

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Abstract
This paper presents the rationale behind the new combined Australia and New Zealand Standard for Wind Actions. Instead of merely updating the previous 13-year-old standard, the radical step of reformatting the code into an ISO format document was taken. This process was driven by a quasi-governmental process to harmonize engineering codes of practice, at least in the Asia-Pacific region, so as to remove them as real or potential barriers to the free trade of services. Comparisons of results from the new Standard and from the rules in ASCE 7 on wind loads are given.

1. Introduction

For over 30 years, the authors of the Australian Wind Loading Standards have been at the forefront of codifying research data and techniques into procedures for estimating wind loads on all manner of structures. The previous edition, AS1170.2 [1], was published in 1989 and has been employed as a model for a domestic wind load standard by Malaysia, Singapore and South Africa, as well as Mexico. The prescribed decennial review process for this code sought to produce a revised version for the beginning of the 21st Century. However, instead of incorporating additional data and updating some procedures, a somewhat radical approach was adopted – a new format, based on the International Standard for Wind Loads ISO 4354 [2]. This approach was partially driven by a quasi-governmental process to harmonize engineering codes of practice, at least in the Asia-Pacific region, so as to remove them as real or potential barriers to the free trade of services. In addition, this revision also sought to align the wind and indeed other loading codes between Australia and New Zealand as an important first step in the realization of a 'universal' wind load code [3,4].

In the following sections, the code format and results are presented and compared with existing wind load codes and in particular the recently released ASCE7-02 [6].

2. Code Format

Standards Australia and the committee charged with the task of drafting the new Standard aimed to adopt as far as possible the model code format and terminology laid out in the current International Standard for Wind Loads, ISO 4354 [2]. In this model standard, the reference velocity pressure (q_{ref}) is combined with 3 factors, C_{exp}, C_{fig}, and C_{dyn} to produce a design wind pressure as shown in Equation 1.

$$p = q_{ref} C_{exp} C_{fig} C_{dyn} \qquad (1)$$

q_{ref} (=(1/2)ρ_{air} v^2) is the basic velocity pressure at standard height (10m) and standard terrain (open country) with a specified probability of occurrence and is <u>unique to each</u>

country / region and ρ is the air density. However the Committee of Standards Australia chose to use the more fundamental basic regional wind *speed*, V_R, rather than velocity pressure as the basis of AS/NZS1170.2:2002.

The ISO model can employ either a mean or a gust wind speed as the basic wind speed with appropriate compensation in the other factors. The ISO Standard then sought to generalize the characteristics of the wind that are universal: namely the variation with height, terrain and topography through the C_{exp} factor, the bluff body aerodynamics that lead to pressure coefficients through the C_{fig} factor and finally, for flexible structures with a dynamic response the C_{dyn} factor.

2.1 Regional Wind Speed (V_R)

In AS1170.2-1989 [1] and indeed ASCE7-98 & 02 [5,6], an Importance Multiplier was applied to wind speed in the former and wind pressure in the later to vary the risk for different types of structures. In the new Australian/New Zealand Standard [3], the importance factor has been replaced with variable probability of exceedences that have been arrived at from up-to-date analyses of the *gust* wind speed climate of Australia and New Zealand [7]. These gust speeds are the maximum wind speeds measured by various anemometers that have been assessed at having a frequency response of approximately 0.15Hz or a 3second averaging time before a 50% step change in gust wind speed is registered. For most of the Australian continent, designated Region A, Holmes [7,8] found that a single Type III extreme value distribution fitted the basic *gust* wind speed (V_R) data well with Equation (2), in which R is the return period, or mean recurrence interval, in years:

$$V_R = 67 - 41R^{-0.1} \tag{2}$$

For a 50year return period this gives V_R = 39.3m/s, while for 1000years V_R = 46.5m/s. The previous code had given the 1000year return period wind speed for this same region as 50m/s. This reduction has come about through the availability of more wind speed data (~10-15 years) and the adoption of the type III extreme value distribution, which is bounded [7,8]. Note as $R \rightarrow \propto$, the upper limit of wind speed in Region A is 67m/s. With this explicit formulation for basic gust wind speed and return period, the engineer, in consultation with the Building Code of Australia, which specifies annual probabilities of exceedence for various importance levels, can assess the appropriate level of risk for design. Note that, in the Australian and New Zealand Standards, a wind load factor of 1.0 is applied to design for ultimate limit states – hence design wind speeds with estimated return periods of 500 to 2000 years, are typically used to calculate wind loads.

In drafting AS/NZS1170.2:2002 it soon became clear that C_{exp} contained a variable that was tied to region, namely the directionality of the basic wind speed. Thus independence of C_{exp} to location was unable to be achieved and instead a directional site wind ($V_{sit,\beta}$) speed is first calculated that employs the above mentioned exposure multipliers for height, terrain, topography, shielding and wind direction as shown in Equation 3.

$$V_{sit\beta} = V_R M_d (M_{z,czt} M_s M_t) \qquad (3)$$

V_R is the regional 3s gust wind speed for an annual probability of exceedence of 1/R, M_d, wind speed directional multipliers for the 8 cardinal directions (β), $M_{z,cat}$ the terrain height multiplier, M_s, a shielding multiplier, and M_t, a topographic multiplier. The term in brackets corresponds to the 'universal' C_{exp} exposure factor of ISO, but in this case is generally a function of wind direction.

In the 1989 version of AS1170.2 [1], directional wind speed information (M_d) was provided for 6 major cities in Australia, outside of the tropical cyclone region. Holmes has re-analyzed directional gust wind speed data for the whole of the non-tropical cyclone region of Australia and all of New Zealand and determined 8 regions for which directional wind speed multipliers over 45^o sectors may be applied. These multipliers, M_d, range from 0.8 to 1 and apply directly to the gust wind speed so upon squaring, taking account of directional wind speed data can reduce the design wind (velocity) pressure by 36% for some wind directions. In ASCE 7-98 & 02 [5,6] a blanket directionality factor, K_d applied to velocity (wind) pressure of 0.85 (except for some circular shapes) is applied. This corresponds to a 15% reduction in wind load, but may only be employed in conjunction with load combinations specified in that standard. The K_d factor does not have any basis in terms of analysis of directional gust wind speed distributions, unlike the Australian/New Zealand factor.

However, for Regions B, C and D in Australia, which have varying degrees of influence from tropical cyclones (the term used in the Southern Hemisphere to denote the equivalent of hurricanes), and for which directional influences are small or indeterminate, a 'statistical' value of M_d equal to 0.95 may be applied to compute wind actions on 'major structural elements'. This is equivalent to a value of K_d in ASCE 7 $(0.95)^2$, or 0.90, applied to pressures – i.e. somewhat higher than the ASCE 7 value. In considering these values, it should be noted that several recent studies have shown that M_d and K_d increase with the return period at which they are calculated, and approach 1.0 at very high return periods.

2.2 Terrain, shielding and topography Multipliers (C_{exp})

The multipliers to take in account the variation of gust wind speed with height, exposure ($M_{z,cat}$), shielding (M_s), and topography (M_t) are essentially unchanged and still apply to velocity, not pressure as is the case with ASCE 7 [5,6]. Four terrain categories from very smooth (Category 1) to very rough (Category 4) have been retained, Category 2 is the open country terrain. This contrasts with ASCE 7-02 [6], in which the very rough category, typified by inner city New York, (Exposure A) has been dropped. Exposure C is the open country terrain. The comparison of the gust speed Multipliers ($M_{z,cat}$ and $K_z^{0.5}$) for the two recent editions of the codes are shown in Figure 1. It is seen that the gust speeds are in agreement up to about 100m for each terrain, where after the ASCE 7 values are higher due to the power law assumption of that profile. Different profiles are provided in [3] for tropical cyclones, with basically the wind speed varying up to 100m and thereafter remaining constant. No such distinction is currently made in ASCE 7.

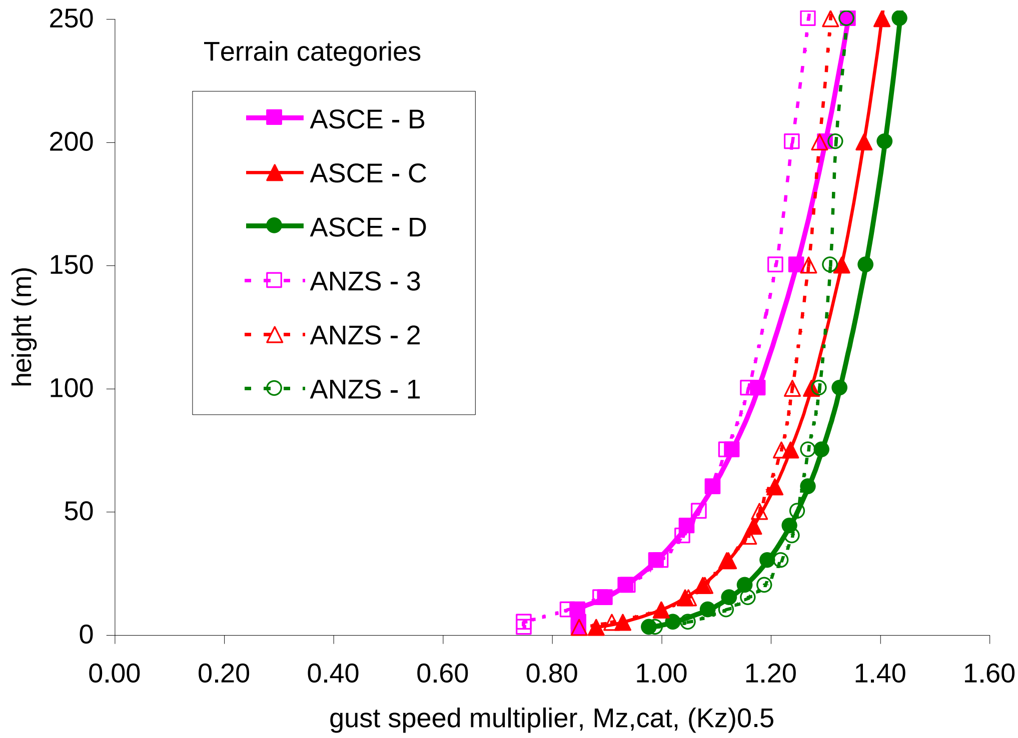

Figure 1. Comparison of AS/NZS and ASCE gust speed terrain/height multipliers.

The existing procedure for establishing the variation of wind speed across a change in terrain has been simplified in [3], while ASCE 7-02 [6] now permits the use of '…a rational analysis method defined in the recognized literature.' One such method is in fact detailed in the Commentary to ASCE 7-02.

The shielding multiplier (M_s) remains unique in wind load codes. It attempts to account for the localized shielding afforded by surrounding objects as opposed to the general retardation of the atmospheric boundary layer flow over a rougher terrain, represented by the 'equilibrium' terrain categories (1 to 4 or Exposures C to D). For a typically Australian suburb, a value of $M_s = 0.85$ has been determined.

The topographic multiplier (M_t) has been enhanced to deal with not only speed-up effects over hills (M_h), but also lee wave effects (M_{lee}), principally generated by the mountain chain on the South Island of New Zealand, and the increase in wind speed at high elevation (E). The hill shape component (M_h) of the topographic multiplier has been put in equation form, not unlike ASCE 7-98 & 02, and the previous linear interpolation with height has been replaced by an inverse relationship. A separation zone behind the crest of steep hills has been defined which lowers the speed-up effect in this region.

2.3 Aerodynamic Shape Factor (C_{fig})

The aerodynamic shape factor, C_{fig}, basically encompasses all the pressure coefficients, C_p, in the earlier standard [1]. The major modification to this coefficient has been the selection of the average roof height as the reference height for calculation of the relevant dynamic pressure. No modification of actual pressure coefficients, previously determined for eaves height reference pressure, was undertaken. The issue driving this change was the underestimation of some wind loads on steeply pitched roofs and the requirement for defining two reference heights for pitched roofs depending on whether the wind was parallel or perpendicular to the ridgeline. Additional coefficients or shape factors have been provided for flags, spheres and open hyperbolic paraboloid roofs. As with the earlier standard, all coefficients represent the compilation of many wind tunnel tests, which have reported mean and pseudo-mean pressure coefficients to be applied with gust wind pressures. C_{fig} is defined for external pressures by equation (4), with somewhat similar equations for internal pressures and frictional drag forces.

$$C_{fig} = C_{p,e}\, K_a\, K_c\, K_l\, K_p \tag{4}$$

The philosophy in Australian wind load standards has been to provide overall surface pressure coefficients, $C_{p,e}$, for buildings surfaces, eg., windward, leeward and side walls, windward and leeward roof surfaces, for main frame design. These are then modified depending on the situation/design case by the K factors.

To account for the decreasing correlation of fluctuating pressures over larger areas, an area reduction factor, K_a, is applied and it is purely a function of tributary area (m^2). The minimum value of K_a is 0.8 for areas in excess of $100m^2$. To determine cladding loads, a local pressure factor K_l is applied and depends on the location and size of the area under consideration. In a new feature the influence of parapets on local cladding is derived through a separately evaluated K_r – parapet reduction factor. The K_l factor varies from 3 on small areas near leading sidewall edges of taller buildings (>25m) to 1.25 on windward wall areas. Typical roof values for K_l are 2 near leading edges with a total of 10 different regions specified for the application of K_l. K_p is a porous cladding reduction factor and only applies to suction pressures on surfaces with porosities less than 1%, ie., 99% solid surfaces.

A new combination factor, K_c has been introduced and it aims to account for the lack of correlation of fluctuating pressure over two or more building surfaces that contribute to a framing load (rather than K_a which is for a single building surface). The minimum value of K_c is 0.8 and it applies for such cases as combining pressures on windward and leeward walls together with roof pressures.

This whole approach differs markedly from ASCE 7 where two separate pressure calculations are made, one for main wind force resisting systems (framing) and one for components and cladding (local loads). Here, for framing loads K_a is applied with $K_l = 1$, while for cladding loads, normally $K_a = 1$ and $K_c = 1$ and appropriate K_l values are chosen.

The main body of AS/NZS1170.2:2002 provides external and internal shape factors only for rectangular enclosed buildings. Values for other structures are provided in a series of Appendices. These are : Appendix C – additional enclosed buildings (multi-span roofs, curved roofs, circular bins, silos, tanks); Appendix D – freestanding walls, hoardings and canopies (data is given as a net pressure coefficient across a surface rather than as external / internal pressure coefficients) ; Appendix E – exposed structural members, frames and lattice towers; Appendix – flags and spherical shapes.

2.4 Dynamic Response Factor (C_{dyn})

The calculation of dynamic along-wind response – C_{dyn} – has been simplified and is now based on a 3 second gust wind speed rather than an hourly mean wind speed, which was the case in the previous wind load code. This is in fact consistent with the approach used in ASCE 7 for the gust effect factor for dynamic structures. This is not the same format as the previous 'gust factor' formulation, being based on a peak gust envelope pressure distribution with height, as discussed by Holmes [8]. However the differences in base bending moments for tall buildings from the previous Standard, are mainly caused by the changes in regional design wind speeds as previously discussed, not by the change in format.

The 1989 edition of AS1170.2 was one of the very few in the world to give a method for calculating the *cross*-wind response of tall buildings (ASCE-7 still does not do this). The method has been retained for AS/NZS1170.2:2002 with mathematical equations provided for the 'cross-wind force spectrum coefficient' as well as the graphical form. Methods for calculation of accelerations at the top of tall buildings in both along- and cross-wind directions are given in an Appendix.

A 'diagnostic'method for calculation of cross-wind tip deflections of masts and chimneys of circular cross-section due to vortex shedding, is given in AS/NZS1170.2:2002. There is no pretence of accuracy in this method, which is based on simple sinusoidal excitation theory. However for small structures it is usually advisable to 'design out' the cross-wind vibration problem by adding mass, damping, guy wires or strakes, so that accurate calculations are often not required.

3. Comparisons with ASCE7-02

Australia – a large continental country has many geographical similarities with the United States, and these similarities extend to the extreme wind climate. For example, both countries suffer from hurricanes/tropical cyclones and severe thunderstorm winds. Construction practices are generally quite similar in the two countries. This has led to wind loading standards that are advanced by world standards in both places.

A fairly detailed comparison of the previous Australian Standard AS1170.2-1989 with ASCE7-98, and four other major international standards, was given in [8]. Most of that comparison is still valid with the new versions of both the Australian and U.S. Standards, with the main differences arising from the new format of AS/NZS1170.2:2002. Over recent years, the U.S. and Australia / New Zealand Standards have become more similar in several ways.

Notable points of similarity are :

- Both Standards are based on peak gust (2-3 second) wind speed
- A similar regional system is used for the basic wind speeds in non-hurricane (non-tropical cyclone) regions
- Definitions of terrain/exposure categories are similar
- The method of calculating dynamic along-wind response for tall structures is similar

Points of difference are :

- Directional wind speed multipliers by compass point are not given in ASCE-7 (although a global wind directionality factor, K_d, is given)
- Contours of basic wind speed are given along the hurricane-affected coastlines in ASCE-7, whereas a two regional system is used in AS/NZS1170.2
- Multipliers for exposure and topography in ASCE-7 are applied to velocity *pressure*, whereas in AS/NZS1170.2 they are applied to the velocity itself
- The exposure/terrain categories are defined in reverse order of roughness. i.e. Exposure Categories A to D in ASCE-7 correspond to Terrain Categories 4 to 1 in AS/NZS1170.2:2002 (see Figure 1).
- Local pressure effects (for cladding design near corners and edges etc.) are treated differently in the two Standards as discussed previously
- There are significant differences in the tables of external pressure coefficients for many building types (some of these were discussed in [8])

However, the two standards are more similar to each other than are other international codes and standards, and there may be some mutual benefit in the respective sub-Committees pursuing alignment of wind loading rules in the future.

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6. References

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