Introduction of AS/NZS1170.2 wind actions into New Zealand

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ABSTRACT: This paper discusses issues relating to the introduction of the joint Australia/New Zealand loading standard, AS/NZS1170:2004 into New Zealand, with particular reference to the implications of the new wind loading provisions contained in Part 2 thereof.

The paper outlines the changes that have been introduced with the new wind design standard, how these have come about and what the impact they are having, and are expected to have, as the standard moves towards being a cited means of compliance with the New Zealand Building Code.

KEYWORDS: New Zealand, standard, buildings, wind, safety, regulations

INTRODUCTION

The Building Act [1] and the associated Building Code of New Zealand (NZBC) that was published within the regulation associated with the Act, provide the regulatory framework within which buildings are approved in New Zealand. The structural engineering provisions relating to system safety (ultimate limit state – ULS) and amenity retention (serviceability limit state – SLS) are presented in Clause B1 of the NZBC. The New Zealand Loading Standard NZS 4203:1992 [2] is cited within this clause as the basis for determining the applied actions. Similarly the various structural material standards such as NZS 3101 – Concrete, NZS 3404 Steel and NZS 3603 Timber are cited as acceptable means of determining acceptable stress limits for structural members and sectional properties for the calculation of system deflections under those imposed actions.

For the past 10 years, the loading standard has been under review. For New Zealand, this process was completed in December 2004 with the publication of the joint Australia and New Zealand loading standard, AS/NZS 1170 [3]. A responsibility of the Department of Building and Housing (DBH) (the government agency with responsibility for administering the NZBC) is to undertake a Regulatory Impact Statement (RIS) so as to satisfy the public (and industry) that the standards proposed are consistent with public expectations and that the economic benefit matches any additional costs. This process has been underway through most of 2005, and is now reaching a point where recommendations will be made to adopt or amend AS/NZS 1170 early in 2006.

Since the Standard was published (December 2004) it has been available as an alternative solution to designers who wish to engage its use for either current design or for review of existing buildings. In addition DBH has commissioned several consultants to redesign existing work so as to ascertain the economic impact that the new standard may have and hence form the basis of their regulatory impact statement. This paper has evolved as a result of those assessments and through the use of the standard in developing a wind design guide [4] and associated wind calculation software [5] that is now available to assist designers using AS/NZS 1170.

AS/NZS 1170.2 Wind Actions - Issues Arising

General

The format used in 1170.2 is similar in many regards to that used previously in NZS 4203 and as such is expected to be readily adopted by the design community. There are, however, many subtle, and some significant differences and these need careful watching as they can create confusion. Overall, however, design wind speeds have increased by approximately 10%, and in some cases by up to 50% (although these are rare and are generally because previous ambiguities saw designers using values less than those intended (e.g. Wellington channelling effects are now included in the directional multipliers whereas they were often previously ignored as being unnecessary). This section identifies where significant changes in either value or presentational style are considered likely to cause either a change in design practice or a change in building practice.

Design Wind Speed Computation

Reference Building height: The provisions of clause 2.2 of AS/NZS 1170.2 prescribe the reference height that is to be used for determining the design wind speed for pitched roof buildings. This is defined as the average height of the building and differs from the previously defined reference height which was to building eaves. This is intended to be a simplification in that it avoids issues relating to varying reference height with sloping foundations and also where recessed plan footprints can result in various eaves elevations.

Site Wind Speed: The site wind speed, $V_{sit,B}$, is given in AS/NZS 1170.2 by equation 1.

$$V_{sit,B} = V_R M_d (M_{z,cat} M_s M_t) \quad (1)$$

Where

V_R = Regional Wind Speed for the region and the recurrence interval of interest

M_d = directional multiplier

$M_{z,cat}$ = height/terrain multiplier

M_s = Shielding multiplier

M_t = topographic multiplier

The equivalent equation within NZS 4203:1992 is given by equation 2.

$$V_\theta = V M_{z,cat} M_s M_t M_{ls} M_r \quad (2)$$

Where

V = basic wind speed for direction θ

M_{ls} = Limit State Multiplier (between 0.9 & 0.95 for ULS)

M_R = Risk Multiplier (relating to building importance class and ranging from 1 to 1.3)

$M_{z,cat} M_s M_t$ as for equation 1

While the presentational style is only slightly different, for New Zealand there is an increase of approximately 6 % in wind speed as the ULS reference period has changed from 350 to 500 years.

Changes in Wind Zone boundaries: The zones of similar wind character were reconsidered and the wind zone boundaries adjusted. This has resulted in the removal of two of the lower wind speed zones from NZS 4203 (around western North Island) which, although the data supported the presence of such zones, the number of data points of any duration was small and their justification over long time periods was suspect.

Terrain Height Multiplier and lag distances: Some minor changes were introduced at low elevations (<5m) as a means of accommodating the change in reference height definition (refer above). Otherwise the tabulated values of wind profile (speed variation with elevation) and ground roughness remains unaltered. There is, however, an attempt to rationalise the lag effect experienced by wind passage over ground of varying roughness. These effects will result in changes in the immediate vicinity of a site having no effect when considered at the reference height, whereas changes in roughness well beyond the nominal transition zone (1000m for ht<50m) will modify the wind profile at that height. These results are eminently rational, but do result in the need for the designer to consider roughness changes well beyond those previously considered. The simplified averaged roughness by length adjustment to $M_{z,cat}$ has been retained however.

Shielding Multiplier, M_s: This multiplier remains unaltered from that adopted previously. Two primary problems have been encountered when using this reduction factor, namely determining the number and breadth of qualifying up-wind obstacles and possible changes of use that may occur around specific building sites. The most common approach appears to have been to use a blanket factor (say 0.85 for all residential subdivision) rather than to attempt to compute 'true' values based on engineering principles. The rational, however, remains unchanged as does the value to be used for M_s.

Topographic Multiplier, M_t: Some significant simplification has been made in the manner that local hill and escarpment wind flow modification effects are to be accounted for. Although the formula to be used to compute the crest multiplier has changed, the maximum value remains at 1.7 and the transition length remains unaltered. Problems establishing the value floor and therefore the height of the feature have not been clarified within the standard but are now becoming more widely understood. The elevation factor and the lee zone factors applicable to New Zealand remain unaltered and have been extended to apply to Tasmania.

Channelling Multiplier: The channelling multiplier was previously included as a component of the topographic multiplier and reflected by amplified wind speeds as a result of funnelling effects caused by natural land forms. Difficulty was experienced by designers in understanding this concept and how far they needed to extend their consideration in such instances where channelling may have been relevant. The primary region in which this effect needed to be considered was Wellington, where in both northerly and southerly winds, the local hills are known to result in channelling phenomena. The directional multiplier for Wellington (region W) was therefore modified to reflect this local effect and the factor removed from the standard.

Aerodynamic Shape Factor Computation:

Presentation: The combination of the external and internal pressure coefficients into the aerodynamic shape factor, C_{fig}, was undertaken to align the standard with the ISO suggested approach. The underpinning external pressure coefficient, C_{ext}, and internal pressure coefficient, C_{int}, remain although some of the ambiguities encountered in the earlier standard have been addressed. Technical advances have also been included, although these are generally relatively minor in nature. The format of this section now has a clear focus on enclosed buildings, with the parameters for four other building configurations being included with Appendices C to F (viz circular bins, silos and tanks (C), free-standing walls and hoardings (D), exposed structural members and lattice towers (E) and flags and circular shapes (F))

Internal Pressure Coefficient, C_{pi}: The internal pressure coefficient, C_{pi}, remains largely as in the earlier standard. Attempts have been made to provide clarity regarding dominant openings and their positions relative to the windward face. The contribution of permeability and the effect of closing openings are both considered. Clarification that the internal pressures presented in Table 5.1A apply only to buildings with an open floor plan (as was always intended) has resulted in reduction design data required for the design of interior partitions and ceilings and also for elements which may form pressure compartments (e.g.

windows and doors). However, this was always the intent and the new standard simply provides clarity on the intended application.

External Pressure Coefficients, C_{pe}: The external pressure coefficients presented for windward (Table 5.2(A), leeward (5.2(B)) and side walls (5.2(C)) and for flat (5.3(A)) upwind (5.3(B)) and downwind (5.3(C)) roof planes remain largely unaltered from previously. The combination factors used to amplify the results for area reduction effects on side walls and roof elements (Table 5.4), and local pressures on claddings (5.6) remain largely unaltered. The effect of parapets on adjacent near-flat roof elements has been included (5.7) as has the much more significant combination factor, K_c, used to reduce peak effects that would apply across multiple surfaces. This factor is particularly significant when developing the overall structural actions on frame elements such as portal frames ($K_c = 0.8$) but is also helpful when considering combinations of internal and external pressure. The primary rationale for this factor is the time independence that exists as the wind pressure develops across various surfaces, and does compensate for the overall increase in wind pressures otherwise experienced by the revised standard.

Dynamic Response Factor Computation:

Presentation: The Dynamic Response Factor, C_{dyn}, again brings the new standard into alignment with ISO and is used to identify potential dynamic response characteristics that result from the dynamic response of a structure becoming sympathetic with dynamic wind turbulence effects. Within NZS 4203 such buildings were considered to be 'wind sensitive' and the designer, although being provided with New Zealand data on hourly wind speeds etc., was directed to use the provisions outlined in AS1170.2:1989. The detail of those 1989 provisions have been modified to enable the 3 second gust wind speed to be used as the basis for ascertaining dynamic response, rather than requiring the hourly mean and turbulence effects to be considered. This approach, although requiring some calibration of the factors presented, does provide a simplification to the designer.

Wind Sensitive Building Qualifiers: Of significance is the tightening of the criterion which results in buildings being considered 'wind sensitive' and therefore requiring the designer to compute C_{dyn} rather than using default value of 1.0. Firstly the criterion is based upon building frequency, which is somewhat of an anomaly for New Zealand designers who, for earthquake design reasons, most commonly consider building periods and response spectra resulting there from. A simple translation from period to frequency is however trivial and of little consequence. Of greater concern is that under the new criteria all buildings and towers with a frequency less than 1 Hz now require C_{dyn} to be computed. This compares to previous criteria developed for New Zealand which resulted in wind sensitive buildings being only those that had a period > 3 seconds and a height to square root plan area ratio >3.3. Those criteria were developed in the early 1990's from studies of wind sensitive structures in New Zealand but did not provide sufficient demarcation for wind sensitive buildings in Australia. Hence the more restrictive criteria were adopted in the revised standard. The effect of this is that many more buildings require C_{dyn} to be computed, in most cases only to find a slight (typically) downwards adjustment could be justified.

Along-Wind Response: A series of formula are presented within the standard, largely to enable the 3 second gust wind speed to be transcribed to reflect dynamic response. While designers have initially expressed concerns regarding these equations, they are able to be resolved and software is becoming available to facilitate easier determination of these values. One desirable side effect of undertaking this calculation is the determination of the dynamic response and hence the acceleration experienced from dynamic effects. This information is required to ascertain potential dynamic serviceability problems that have so far been neglected during most design.

Across-Wind Response: It is perhaps the cross-wind response that has caused most concern, at least in part because this effect is less intuitive and yet is still required to be computed for all buildings considered as wind sensitive. Some equations are provided for selected buildings of two height:breadth:depth ratios but these are too few in number to provide solutions to many buildings where the standard requires this computation. In addition the forces generated from such computation are generally relatively small and will usually be overshadowed by lateral forces generated from New Zealand's earthquake provisions. The resolution of this issue may become clearer as more design is undertaken in accordance with the new standard, but at this stage a committee review of both the criteria and the provision of additional points of interpolation (for cross-wind response) would be most helpful.

On the other hand, there are an increasing number of high aspect ratio buildings being proposed for the City of Auckland due to a change in the Local Body regulations, and an increase in the amount of floor area that is possible for a given land area. These buildings often have moderate heights of say 60 m, and relatively high natural frequencies. Calculations of accelerations using AS/NZS1170.2:2002 can often give values which are either unacceptable, or are bordering on unacceptable, and this is a relatively new situation for local designers. Thus requiring cross-wind calculations of designers has made them more cognisant of human comfort, and they are addressing those factors that can help reduce accelerations, which has been a positive outcome

CONCLUSIONS

The publication of AS/NZS 1170 and its path towards citation as a compliance method within the compliance documents that accompany the New Zealand Building Code are both well advanced and are expected to be completed early in 2006. At that time the design profession will be required to adapt to the use of the new standard. The decision of Standards New Zealand to publish the Standard as two separate volumes (Standard and Commentary) is to be commended and does provide the designer with a more complete set of loading definitions for practical design office use.

The new wind loading provisions also assist in clarifying several areas where previously confusion has arisen. Reducing the number of wind zones covering New Zealand has resulted in quite significant increases in design wind pressures in some areas. The justification of earlier lower directional wind speeds was unclear and the change therefore appropriate.

The introduction of the load combination factor to mitigate some of the increased wind pressures is again appropriate and effectively retains the status quo for primary structural elements, although this relief is not available for most claddings and windows, where an increase in wind pressure is expected. In the case of Wellington, where channelling effects are now included in the basic regional wind speed, and where the hilly terrain is likely to result in high topographic multipliers, this can be expected to result in much more robust building practices and stronger, stiffer elements being required.

REFERENCES

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