WIND LOADING

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SYNOPSIS

This paper is presented to outline the features of the revised Wind Loading Code NZS4203/303 and to give some background on the history of wind ByLaws in New Zealand.

1.0 LEGAL ASPECTS

Like other sections of the draft revision of the Loading Code, this Code aims at not only giving the designer guidance in the design of the building against wind forces but also gives the Local Authorities a By-law for enforcement to ensure that an acceptable standard of design is maintained. Before a local authority can make a Bylaw on any subject, there must be specific authority from Government to do this. The authority for the Loading Code comes from Section 386, subsection 14 of the Municipal Corporations Act (similar provision in the Counties Act) which states:-

> "..... Council may from time to time make such Bylaws as it thinks fit for all or any of the following purposes:
>
> (14) Regulating and controlling the construction and repair to buildings including the design and construction of buildings in relation to their resistance to earthquake shocks."

2.0 HISTORY

A perusal of some of the major local authority Bylaws of the 1920s indicates there is little or no reference to either wind or earthquake forces. It was not until after the Napier earthquake of 1931 that forces from wind and earthquake were specifically stated. The need for uniformity and expertise in the design of buildings was the conclusion of Government after that tragedy, and the Standards Institution was asked in 1934 to draft a Model Building Bylaw. Although the project arose from the proved inadequacy of the old Bylaws as regards earthquake resistance of buildings, provision for other forms of loading both vertical and horizontal were included in the Model Building Bylaw.

In December, 1935, the first Model Building Bylaw for New Zealand was published by the N.Z. Standards Institute. The only clause relating to wind loading was Clause 305, which read:-

> "Pressures on all vertical surfaces 15lb/sq.ft. below a level of 40 feet above the ground, and 20lb/sq.ft. above this level, except that 40lb/sq.ft. is to be taken on sprinkler tanks, sky signs and other exposed structures and their supports. Cylindrical surfaces are to be proportioned for the same pressure on 6/10ths of the projected area."

In 1955, this Model Bylaw was revised and the clause relating to wind forces was considerably extended. The New ByLaw gave 75 m.p.h. as the minimum design velocity with a proviso that in "very exposed position consideration shall be given for higher wind pressures in that design". The revision covered wind pressures to a building height of "200 ft. and more", distribution or external pressure on walls, wind pressures on sloping, curved and multi-span roofs, internal pressures and pressures on wall and roof sheeting.

The next revision and updating of the wind Bylaws came in 1965 with the publication of Chapter 8, N.Z.S. 1900. This revision was based on the Canadian Code which was considered to be the most up-to-date and comprehensive Code available. Whereas the previous Bylaws had referred to an undefined wind velocity of 75 m.p.h., the revision adopted the one minute mean velocity used by the Canadians. The one minute mean velocity used related to a return period of not less than 30 years. Because the extreme wind speeds extracted from automatic records in New Zealand are short-period (3-5 second) gusts and not one minute mean, an approximate conversion factor was given. The revised bylaw also had a refinement on the previous bylaws of three exposure conditions A, B, and C, with exposure A being the most severe with a one minute mean velocity of 81 m.p.h. corresponding to a gust velocity of 105 m.p.h. For the first time in the New Zealand Bylaw, diagrams of some thirty building shapes and structures were included giving the various pressure co-efficients for the different surfaces. At the time these were published, by courtesy of the National Building Code of Canada, it was accepted that further research would expand the series on a more practical line.

In 1970 the Loadings Committee of S.A.N.Z. was reconvened and consideration given to the updating of Chapter 8, NZS 1900.

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The Sub-Committee on wind consisted of members of the main committee with co-opted members. Representation on this Sub-Committee was from Meteorological Service (1), Building Research of N.Z. (1), Municipal Association (1), Building Industry (1) and Universities (4).

The Sub-Committee initially obtained copies of the latest wind codes of South Africa, England, Australia, America and Canada. At that time a number of these codes were either being revised or in draft form. The British Code was about to be published after being the subject of much debate. When this came to hand, the Sub-Committee considered all the information to hand and after debating the merits of all documents decided to revise the New Zealand Code on the Lines of the British CP3, Chapter 5. This decision was not taken lightly as it was realised even at that stage this could mean an increase in loadings.

Mr C.W. Newberry, a member of the Committee on CP3, Chapter 5, points out that investigation of wind damage has shown that wind forces are frequently greater than has been assumed in the past and it appears that many buildings have survived severe storms only because they have an in-built strength that is greater than was called for in their design. The extra strength and stiffness contributed by members that were considered to be non-load bearing and by cladding has helped provide a margin of safety beyond what was apparent and it is this hidden reserve which has in some cases masked a deficiency in the designed provision for wind.

With more sophisticated design procedures now available and coming into use, there is a danger that the hidden reserves of the past may be eliminated in current and future construction. He emphasizes that it is imperative that a new and realistic assessment of the probable imposed loads should be undertaken without delay.

3.0 N.Z.S. CODE OF PRACTICE NZS4203/303

3.1 Comments

The draft document received wide circulation but less than twenty letters commenting on the revision were received. Some of these were brief comments relating to format, whilst others dealt in depth with certain aspects. It is interesting to note that three of these came from Australia. By far the most detailed comment came from the Standards Association of Australia, which provided some very critical comment for the Committee to consider. This task has now been accomplished and the final draft is now ready for final approval by the Committee.

3.2 Format

It is proposed that the format adopted for other sections of the Loading Code will be followed for the wind section. Initially the draft was published in slightly different form but this will be rectified at the time of editing.

3.3 Introduction

An important part of any Code of Practice is the scope outlining the limits of application. The draft clearly defines this point and draws the designer's attention to the need for a more sophisticated approach in certain cases. Reference is made to the testing facilities available at the Universities and some Government Departments. If wind tunnel tests are carried out for special areas it is important that these be done by a recognised testing authority aware of the problems and sources of error in this form of testing.

As the draft is in the form of a Code of Pratice the Sub-Committee considered it essential to bring to the designers' attention the need for providing an acceptable environment for the people inside the building as well as those in the vicinity of the building. This aspect is not covered by CP3 at present. It is now accepted that this is part of the design and more attention is being paid to it now than in the past. Reference is given to publication on the subject.

3.4 Calculation of Wind Loads

This section outlines the procedure to be used in calculating the wind loads. It follows closely the British Code in many respects with the exception that the statistical factor S_3 has been omitted. In CP3 this factor is taken as unity except in the case of temporary structures, where a longer or shorter period of exposure is required, or where a greater than normal safety is required. Although the factor is not explicitly included in the draft, provision can be made if required by taking other basic wind speeds for other return periods than the standard 50 years. Rules for estimating winds with return periods of 5, 25 and 100 years are given. This is done by choosing the velocity for the varied return periods listed. This approach is also used by the Australians in their new specifications.

The Topography factor, S1, used in CP3, varies from 0.9 to 1.1 and unless there are any special conditions the factor is taken as unity. In the draft this factor is retained but its value is set between 1 and 1.2 It was considered that the 1.1 maximum of the British Code was not adequate for some valleys and gorges shaped to produce funnelling of wind and abnormal sites. It is unlikely that the maximum figure will be used extensively but it is included to bring to the designer's notice the need for a cautious approach in very exposed sites. The increased value is considered justified in this country whose topography varies from that in the United Kingdom. The Meteorological Service offers advice on this item.

3.5 Design Wind Speed

One of the most far reaching decisions in adopting the CP3, Chapter 5 was acceptance of the 3 second gust velocity in determining the wind forces. It was immediately recognised that the design wind loading would be greater under the proposed system than it is under the present Bylaw. Recent work at the Building Research Station has indicated that Gust loadings over intervals as short as only seconds, may be significant on major buildings. For example, on a building 60m high with a frontage of 45m, for a gust of 3 seconds, the total wind load measured showed a 60% increase over the load averaged for one minute. The new Australian Specification also used the three second gust as the design velocity.

The New Zealand Meteorological Service has 25 stations with continuous wind records of 15 - 32 years, 5 stations with 10 - 15 years record and about 64 stations no longer operating or whose length of record is less than 10 years. The maximum daily gust (about 3 second gust) and the ten minute mean speed at each hour are now taken from the wind records on a routine basis.

The direct recording of short period gusts is of importance in that this is the basic wind speed used in the code. Unfortunately it is not possible to distinguish durations of the wind speed for periods of less than about one minute from the normal anemograms except that the highest speed spikes are normally taken to be '3 sec.' gusts.

It is appreciated that there may be concern expressed by some designers that the Exposure A of the present Bylaw which gives the basic one minute mean velocity of 81 m.p.h. or 36m/s, has been increased in the windy areas to 50m/s and that the lowest isopleth on Figure 1 is 35m/sec. Although these increases are at first sight very considerable, other factors such as the terrain and building size will have a bearing on the final pressure calculated for the structure.

There is a trend for modern codes to provide a map of the country with isopleths plotted. The Italian, English and Australian publications have this. The N.Z. Meteorological Service produced the map in Figure 1 which gives isopleths at 5m/s intervals. The winds shown on the 3 second gusts likely to be exceeded on the average once in 50 years at a height of 10m. above level ground in an open position.

Because of the preferred paths of some types of storms and the effect of large scale topographic features on the broad airflow over the country, there are systematic regional differences in "windiness" in New Zealand.

The east coast can receive high winds from depressions sometimes of tropical origin moving in SE direction. Cook Strait and Foveaux Strait experience strong winds because of the funnelling effects. On the Canterbury Plains also, high winds due to the effects of the Southern Alps on the prevailing north western flow are found.

There is therefore some justification for the zoning when basic design winds are being chosen. However, the amount of wind data from which detailed zoning maps may be constructed is not large considering the wind variations caused by the broken topography of the country.

It is considered that Figure 1 gives the overall picture of wind variation correctly but it will certainly need to be amended in detail as more data becomes available. The map should not be used to derive design winds for the central mountain chain of New Zealand. The Meteorological Service offers advice on request for such areas.

As a supplement to Figure 1, Table 2 sets out the basic wind speed for some cities and towns. This table follows the Australian format including the basic wind speed for return periods of five and twenty-five years as well as fifty years.

3.6 Height Building Size Ground Roughness

The draft code follows closely the CP3, Chapter 5 format providing four classes of terrain and three of building factors although there was thought among some Committee members that these should each be reduced by one. The final draft now provides for three classes of terrain. In the definition of ground terrain more appropriate terms have to be used for New Zealand conditions.

The class of building is related to the response of the building to gusts. As cladding, glazing and roofing respond to severe gusts the three second gust velocity is used. For small buildings not exceeding 50m. in any direct a five second gust factor is also used. Large buildings, that is with a dimension exceeding 50m., do not respond to the smaller gust over the whole surface area within the gust period so a reduced factor is used equivalent to about a 15 second gust. Recent British findings to hand may mean an amendment to the above figures and it is hoped that this will be resolved by the Committee before the Code is published.

The height of building above ground level is also covered by Table 3. It has been found that a power law velocity profile is adequate under strong wind conditions with flow over flat terrain ranging from mud flats to city centres. Experimental work on these profiles have not been measured here to see if they fit the conditions here, so the values set out in CP3, Chapter 5 have been adopted.

A method of determining the height if the structure is on or near a cliff or excarpment is set out in CP3, Chapter 3. This approach has been included in the draft with modifications based on the work of Prof. de Bray of Auckland University, and as adopted in the Australian Code.

3.7 Shielding and Wind Direction

The draft code follows most overseas codes in that there is no variation of design wind speed according to the direction of wind. In other words, the maximum wind is assumed to blow from any horizontal direction.

Some overseas codes provide for some reduction in forces due to wind where there is shielding. The draft makes no allowance for shielding other than that normally taken into consideration in determining the terrain category.

3.8 Assessment of Loads on Structures

The preceding sections of the draft enable the designer to arrive at the dynamic pressure. The total force in the building is then calculated from the data supplied for the various shapes of building, or from experimental work. This gives the over-turning moments and shear on the total structure. Parts of the building such as external walls are then designed separately for the loading conditions set out in the code for those specified areas. The values of Cp and Cf have been based on experiments on models for a number of building shapes and wind directions. It is realised that pressure on a surface varies considerably but this detailed approach is not convenient for design purposes so a simplified mean pressure co-efficient over the whole surface is preferred and contained in the tables and figures set out in the code. This is drawn to designers attention by pointing out that the accuracy of such simplified data should be taken as plus or minus 15%.

Transient loads may cause a dynamic overshoot with the maximum deflection and accompanying stresses exceeding those caused by a steady load of the same amplitude. When the gust duration and the natural period of oscillation of the building are approximately equal this magnification is substantial. If the natural period of oscillation of the structure or structure element is 2 - 6 seconds dynamic overshoot is required by the Code to be allowed for by multiplying the design wind load for the structure or structure element by 1.7 and proportioning the relevant members to resist the magnified steady load.

3.9 Dynamic Effects and Vortex Shedding

In addition to the reference to dynamic loading in Clause 9, the Code has a specific section on flexible structures such as chimneys, lamp standards etc. that are subject to wind induced oscillations. Notes are given for guidance and determining preliminary calculations. It is emphasised that wind tunnel tests are necessary when refined estimates are required.

4.0 SUMMARY

(1) The draft code has adopted a basic wind speed based on the 3 sec. gust as used in the British and Australian Codes.

(2) The basic wind speed is modified by factors including allowance for topography of the surface, roughness of the environment, gust duration, height of building and building life.

(3) The draft code recognises higher energy and inherent loading in the shorter gusts and recorded evidence on existing structures confirms the correctness of this approach.

(4) Loads arising from the effect of wind on structures are assessed as realistically as possible from the best available evidence.