Wind Load Revisions in 2010 National Building Code of Canada and Future Research-Based Submissions

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ABSTRACT: Extreme wind events account for a significant number of casualties and damages all across the globe. Wind standards and building codes of practice aim to reduce the impact of such events on structures. Revisions and updates on major wind provisions take place continuously. By the end of 2010 the National Research Council of Canada will release the new edition of National Building of Canada, which will include minor revisions related to wind load recommendations. These changes are discussed along with some recent wind engineering research conducted at Concordia University which is also related to future code improvement.

KEYWORDS: Extreme winds, wind provisions, wind tunnel, wind load, patio cover.

1 INTRODUCTION

The severity and increased frequency of wind-related events over the last two decades has shifted the attention of structural and wind engineers towards better understanding of such disastrous events and, consequently, towards the improvement of national and international wind standards and building codes. The connection between extreme wind events and windinduced structural response has been examined thoroughly from various perspectives. Intensive research has been conducted including field studies, simulated experimental work and detailed numerical analysis. In most cases these research efforts produced valuable outcomes which formed the basis for development and subsequently improvement of several wind standards and codes of practice.

The North American region has a special interest in wind related research partly due to the several extreme wind phenomena, which occurred in the Eastern and Central USA, as well as Canada (e.g. hurricanes, tornadoes etc - see Figs 1 and 2). The wind engineering community has been highly active over the last four decades and, as a result, the Canadian and US wind standards are considered among the most advanced and elaborate across the world. The American Society of Civil Engineers published recently the 2010 version of the ASCE/SEI 7-10 Standard "Minimum Design Loads for Buildings and Other Structures" and the National Research Council of Canada will soon release the 2010 version of the National Building Code of Canada. This paper, discusses some of the changes that will be incorporated in NBCC 2010, as far as wind is concerned. In addition, there will be a presentation of up to date research conducted at the Building Aerodynamics Laboratory of Concordia University related to wind loads on patio covers. Such structures are currently absent from both Canadian and American provisions but may be considered for inclusion in the 2015 versions.

2 NATIONAL BUILDING CODE OF CANADA 2010

In the upcoming version of the National Building Code of Canada (NBCC) there are only minor changes, as far as the wind load provisions are concerned. The most critical change that will be introduced in NBCC 2010 is related to the update of the reference velocity pressures. The tabulated values are provided for each location and correspond to a return period of 50 years. The new values are based on recent statistical analysis performed by Environ-

ment Canada using this time available weather data up to 2008. As a minimum reference velocity pressure the NBCC 2010 will use the value of 0.30 kPa.



Figure 1. North-American map of tropical cyclones (Munich Re Group, 2009).



Figure 2. North-American map of tornadoes (Munich Re Group, 2009).

Further changes are related to the upstream exposure. Following the changes of the 2005 version, NBCC 2010 will reduce the number of different exposure categories by eliminating Exposure C. It should be noted that Exposures A, B and C were applicable only under the dynamic (detailed) method whereas the terms open and rough were used for the static (simplified) method. In addition, Exposure C was in use for cases where the terrain was very rough such as large cities with several and dense high-rise buildings. Another section that will be revised in the 2010 version is the one describing the minimum required length of the upstream terrain fetch. In the current version of NBCC (2005) the requirement for using Exposures B or C was that the applicable terrain roughness (i.e. Exposure B or C) persists in the upwind direction for at least 1.0 km or 10 times the building height, whichever is larger. In NBCC 2010 this requirement will be increased to 20 times the building height.

Finally, the definition of dynamically sensitive buildings will be revised including this time specific frequency criteria. In the 2005 version, buildings suspected to have vibration issues were defined either by their total height (i.e. greater than 120m) or by height to width ratio (i.e. height is four times the minimum effective width). A rather generic statement was provided in which lightweight buildings with low natural frequency and low damping properties were also included in the above category. In NBCC 2010 the frequency of 1 Hz has been adopted as the reference for defining the dynamically sensitive buildings. For cases where the

natural frequency is expected to be lower than 0.25 Hz the wind tunnel procedure will be required.

3 RESEARCH ACTIVITY FOR FURTHER POSSIBLE CODE PROVISIONS

Concordia University has been highly involved in the development of major wind standards and building codes of practice. Some of the recent areas of code-related research conducted in the Building Aerodynamics Laboratory are related to upstream exposure issues, pressures on roofs of various geometries, wind load paths on low-rise buildings and their effect on structural attenuation, wind-induced loads on parapets, free-standing canopy roofs, attached patio covers and torsional effects due to wind. A short description of the most recently conducted study, i.e. wind-induced loads on attached patio covers, will be discussed in the following sections and some up to date findings that are to be considered for inclusion in the succeeding version of NBCC and other wind standards will be presented. The discussion is based on a recently published paper (Zisis & Stathopoulos, 2010), in which more details can be found.

4 WIND LOADS ON ATTACHED PATIO COVERS

4.1 General description

Patio covers are relatively simple structures accommodating the same number of people or even more - as those of the building. Very few technical sources exist about patio cover wind design, therefore it is of great importance to treat these structures with the appropriate attention for both safety and economic reasons.

Patio covers are often treated as a subsection of canopies, i.e. extensions of roof, or as free (open) roofs. In most cases though, patio covers are a completely independent group of structures, which cannot fall under any of these categories. Canopies are used as covers and usually are not surrounded by walls. The specifications, use and geometry of canopy roofs, differs significantly from those of patio covers. Moreover, patio covers are often at a lower level than building's roof, thus they cannot be treated as roof extensions or overhangs.

4.2 Patio covers and wind standards

Wind standards and building codes of practice (with some notable exceptions) do not include any pressure coefficient provisions for the design of patio covers. The only codes that explicitly refer to patio covers are the International Building Code (IBC 2006) and the International Residential Code (IRC 2006) but their provisions do not seem to arise from any detailed study on these structures. The Australian Standard (AS/NZS 1170.2, 2002) also refers to attached canopies, awnings and carports, which can be considered similar to patio cover structures. The rest of the various national building codes refer rather implicitly to canopy roofs or to open buildings.

4.3 Wind tunnel study

A wind tunnel model of a patio cover attached to a gabled-roof building at a 1:100 geometric scale was constructed. The model has external dimensions of 15 cm by 10 cm (length – width) and a total height of 9 cm (ridge height). The gabled roof has a slope of 4:12. In order to consider different building configurations, the patio cover was attached to two different building heights. Three configurations were examined (Fig. 3); single storey house with patio cover at the roof height, two-storey house with patio cover at the roof height and two-storey

house with patio cover at the first floor level. The patio cover model was equipped with 30 pressure taps (Fig. 4), 15 on the top surface and another 15 on the bottom surface. It should be noted that the odd numbers are used for the top surface pressure taps (1, 3, 5 etc.) and even for the bottom surface (2, 4, 6 etc.). The tests were conducted in open terrain simulation characteristics. The value of the power law exponent alpha (α) was 0.14 and the corresponding turbulence intensity at the roof height was approximately 17.5% for the one-storey model and 14.0% for the two-storey model. In total, 28 wind directions were tested (Fig. 4).



Figure 3. Wind tunnel building and patio model dimensions.



Figure 4. Pressure tap location and notation on the patio cover model and nsidered wind directions.

4.4 Experimental findings

As already mentioned, the wind tunnel patio cover model was equipped with pressure taps both on top and bottom surfaces. This allows the real-time monitoring of wind pressure/suction on each side and most importantly the calculation of the net force component. The contour plots of the top, bottom and net mean (Fig. 5) and peak (Fig. 6) pressure coefficients are presented for Configuration III and the particular case of 30° wind direction. Both top and bottom surfaces experience pressures that reach the values of +0.50 (mean) and +1.20 (peak) in their dimensionless form (Cp). On the contrary, the net mean pressure coefficient, or in other words the total wind effect on the patio cover, is lower with critical values close to +0.40 (mean) and -0.90 (peak). Configurations I and II showed similar –relaxing– results when considering the simultaneous effect of both upper and lower surface wind flow.



Figure 5. Top, bottom and net mean pressure coefficient contour plots for 30 degrees wind direction (Configuration III).



Figure 6. Top, bottom and net peak pressure coefficient contour plots for 30 degrees wind direction (Configuration III).

The combined effect of top and bottom surface pressure contributions is also demonstrated through correlation analysis of the upper and lower pressure traces. Peak values are not likely to occur simultaneously for both surfaces, therefore the applied net pressure is in some cases significantly lower compared to the difference of the individually observed top and bottom critical pressures. As an example, the case of 60 degrees wind direction for configuration III and for pressure taps 3 (top surface) and 4 (bottom surface) was considered. In Figure 7 the signals for all top, bottom and net pressure coefficient are presented. Each signal includes the instantaneous, mean, maximum and minimum peaks for the total duration of 36 seconds. A summary of these values is presented in Table 1 as well. It should be noted that the above peak values are based on the most critical (maximum or minimum) instantaneous values. The correlation coefficient for the top and bottom signals, for this specific case, was found to be - 0.56.



Figure 7. Top, bottom and net pressure coefficient signal for 60 degrees wind direction, configuration III (pressure taps 3 and 4).

Table 1. Summary of the top,	bottom and net	t pressure coefficien	t values (60	degrees wind	direction,	configura-
tion III - pressure tap 3 and 4).		-		-		

	Pressure Coefficient (Cp)						
	Mean	Maximum	Minimum				
Top Surface	-0.18	0.47	-0.95				
Bottom Surface	0.11	0.64	-1.01				
Net	-0.29	0.61	-0.92				

The results of the wind tunnel tests were compared with the suggested by the American (roof overhangs – see ASCE/SEI 7-05, Figs. 6-11 B–D) and Australian (attached canopies, awnings, and carports) code values. Using single or multiple sets of pressure taps the variations of the maximum and minimum peak net pressure coefficient were derived with respect to the corresponding effective surface area. The resulting polylines were superimposed as shown in Figure 8 (configurations I, II and III). The notation of the corner, edge and interior region is also shown in Figure 8. Note that the ASCE 7-05 proposed values refer to 3-sec gust values therefore appropriate transformation was made to the wind tunnel values (divided by 1.53^2 – figure C6-4, ASCE/SEI 7-05). The results clearly show that the ASCE 7 values overestimate net wind suctions (uplift force) but conform to the net wind pressures. For the negative net pressure coefficients (force upwards) all configurations tested show significantly lower values than those in ASCE 7-05 for eaves.

The comparison of wind tunnel values with the Australian Standards (net pressure coefficients) is presented in Table 2 (0/90/270 degrees wind direction). Similarly to the ASCE

standard, the AS/NZS proposed values refer to 3-sec gust values therefore appropriate transformation was made to the wind tunnel values (divided by 1.53^2). The agreement between the results of the current study for the specific wind directions mentioned in the Australian standard is in most cases quite good, with some discrepancies observed mainly for Configuration III and wind direction parallel to the attached wall. However, it should be mentioned that for these specific wind directions (90/270 degrees) the AS/NZS considers the patio cover as a free-standing roof.



Figure 8. Variation of the peak net pressure coefficient with the area - Configuration I, II and III.

Wind Direction		0°	90°/270°										
					-								3.65
Configuration													
Region		-	A B		C			15.00			` →		
AS/NZS 1170.2:2002	0.46	-0.20	0.40	-0.30	0.00	-0.40	0.20	-0.20				$\hat{1}_{0^{\circ}}$	
Current Study	0.45	-0.19	0.52	-0.66	0.40	-0.42	0.32	-0.19					7
									90°⊏>	Α	B	С	<270℃
Configuration		Ш							3 50	3 50	8.00		
Region		-	A B					← → ← → ← 0.00			→		
AS/NZS 1170.2:2002	0.35	-0.75	0.40	-0.30	0.00	-0.40			90°⊏∕>		Δ	В	270
Current Study	0.29	-1.03	0.47	-0.80	0.32	-0.11			~				
										<u>د ب</u>	0.00	▶ € 9.00	→
Configuration	III												
Region		-		A	В		C		90℃	A	B	С	270
AS/NZS 1170.2:2002	0.43	-0.58	0.40	-0.30	0.00	-0.40	0.00	-0.20		3.00	3.00	9.00	 _ >
Current Study	0.25	-0.59	0.20	-0.59	0.33	-0.18	0.33	-0.14					•

Table 2. Comparison of the AS/NZS suggested net pressure coefficients with the wind tunnel results, for 0 and 90/270 degrees wind directions.

Figure 9 shows proposed design net pressure coefficients GCp for patio covers recommended for possible inclusion in ASCE 7. Measured values have been enveloped to reflect the most critical configuration and wind direction by following the same procedure as with the rest of codified pressure coefficients for roof surfaces of low-rise buildings. In addition a summary of all AS/NZS suggested values, presented in Table 2, have been included in the same chart. These values have been considered as local pressures (smaller tributary area) and have been grouped into positive and negative sets. The comparison indicates that all of the AS/NZS values are located between the recommended by the current study envelope based design values. The recommended design net pressure coefficients have been deliberately maintained at a higher level to cover for the limited geometries and configurations examined in the wind tunnel study. For simplicity purposes, no edge / corner zones have been determined on the patio cover.



Figure 9. Proposed net pressure coefficients for design of patio covers

5 CONCLUSIONS

The paper discusses the changes that will be introduced in the upcoming version of the National Building Code of Canada. These changes are mainly related to the exposure categories, the updated reference velocity pressure maps and the definition of dynamically sensitive buildings.

The research conducted at Concordia's University Buildings Aerodynamics Laboratory towards the development and update of current wind provisions is also discussed. A recent experimental study examines the wind-induced loads on attached patio covers. Mean and peak local pressure coefficients were evaluated for three building configurations. The findings are also compared with provisions from two building codes.

The significant differences found create an uncertainty for the accuracy of the different codes. With the exception of Australian code, there is no specific guideline for patio cover wind load calculations, which allows many questions to rise. The current study indicates the need to update the available wind standards and include sufficient information for adequate design of patio covers attached to low-rise buildings.

6 ACKNOWLEDGEMENT

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