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Field monitoring of wind loads on "in-service" buildings: experimental methodology and data analysis

M. Chavez [1], A. Baskaran[2], M. Aldoum[3], T. Stathopoulos[4], T.N. Geleta[5], G.T. Bitsuamlak[6]

[1]*National Research Council of Canada, Canada, mauricio.chavez@nrc-cnrc.gc.ca*
[2]*National Research Council of Canada, Canada, Bas.Baskaran@nrc-cnrc.gc.ca*
[3] *Concordia University, Canada, muradaldoum@gmail.com*
[4] *Concordia University, Canada, statho@bcee.concordia.ca*
[5] *Western University, Canada, tgeleta@uwo.ca*
[6] *Western University, Canada, gbitsuam@uwo.ca*

SUMMARY:
The majority of wind load provisions in the National Building Code of Canada (NBC) were developed in the 70s. Since then, the Canadian provisions have remained practically unchanged. The National Research Council of Canada (NRC) is conducting an extensive wind load investigation to verify whether NBC provisions need to be updated or not. The investigation is being carried out using field measurements complemented with wind tunnel experiments. This paper focuses on the field component of the project only. The challenges to identify, instrument and gather data from an "in-service" building are presented. The paper provides details of the experimental methodology including the data post-processing and analysis for code comparison. The data post-processing and screening procedures include strong wind cut-off to avoid atmospheric instability and stationarity tests of the wind speed and pressure data. The intention is to share the lessons learn and document the approach used to make field data appropriate for code verification.
Keywords: wind load, field measurements, roof cladding, codification

1. INTRODUCTION

The National Building Code of Canada, (NBC, 2020), provides the wind load provision for structural components and roof claddings on six roof shapes specified in the NBC as Figures 4.1.7.6-C, D, E, F, G and H. Considering the significant progress in modelling wind loads since their last update, these provisions may require revision. A research collaboration between the National Research Council of Canada (NRC), Concordia University, and Western University was established to verify the current wind load provisions in NBC. The project goal is to contribute to the discussions in the preparation for the forthcoming NBC revision cycle. To this end, a recent publication (Chavez et al. 2022) by the authors provided recommendations to update Figure 4.1.7.6-C in NBC-2020. The current specific objective is to present in detail the field instrumentation, data collection, and data processing procedures. The techniques and procedures in this work were based on the lessons learned from the prominent field studies (Levitan et al. 1991; Richards et al. 2001) and particular solutions to the challenges of instrumenting "in-service" buildings.

2. SITE AND INSTRUMENTATION

Full-scale measurement is per se a challenging domain; but if the purpose is to compare to code provisions, additional constraints need to be considered. Those constraints start with the site

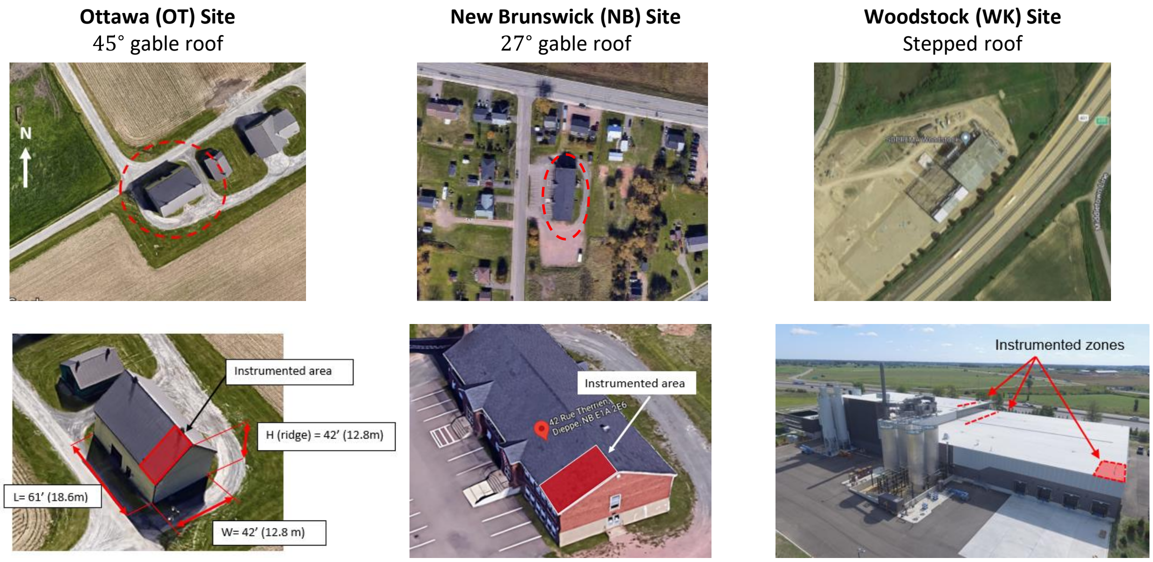

Figure 1. Building used so far to verify current wind load provisions in NBC-2020.

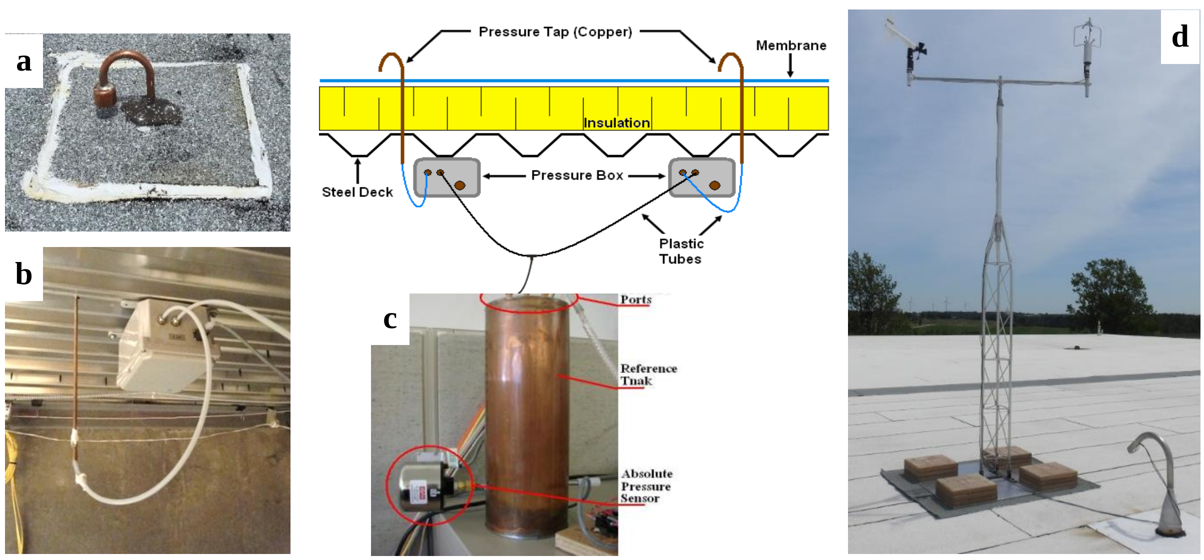

Figure 2. (a) Pressure tap, (b) transducer box, (c) reference pressure, (d) wind tower on the roof

selection and the practicability to instrument the building. The selected building should be a fair representation of the code specifications (shape, and surroundings). Fig. 1 presents 3 examples of buildings that are being monitored to date. In general, the buildings should be in a fairly open exposure condition, with minimum surrounding buildings. Typically, the external wind load is measured by 15 pressure taps (PT) strategically installed on the roof to cover all the roof zones. Each sensor is composed of a ¼-inch diameter and approximately 12-inch-long copper tube which is inserted through the entire roof assembly (Fig. 2a). The external end of the tap is bent to prevent water intrusion, while the internal end is connected to dedicated differential pressure transducer (Fig. 2b). The reference pressure (P_r) that is connected to every transducer is measured inside a copper tank of 12" height and 4" diameter vented to the building interior for practical reasons. It is in a closed room with minimal temperature changes. It is connected to all transducers via a long plastic tube. The wind data is measured by a propeller and an ultrasonic anemometer, both installed on top of a 16ft pole as shown in Fig. 2d. The field data is continuously collected at a rate of 100 Hz and low pass filtered at 10 Hz in the post-processing stage.

3. FIELD DATA ANALYSIS

The data collected from the field is processed meticulously to extract segments of time history that can be used for wind load computations. The high-level procedure of segments extraction is illustrated in Fig. 3. The most important step of the procedure is the segment scrutiny, which involves a screening process to avoid unstable atmospheric conditions, obstructed wind directions, and non-stationary data in any of the collected time histories. The reverse arrangement and run tests, the two commonly used methods in field data analysis (Levitan et al. 1991). All these criteria are crucial for the extracted data to be considered as a synoptic wind data. Fig. 4 shows a sample 24 hr long raw data with the four segments extracted from it. The segment duration is 10 min.

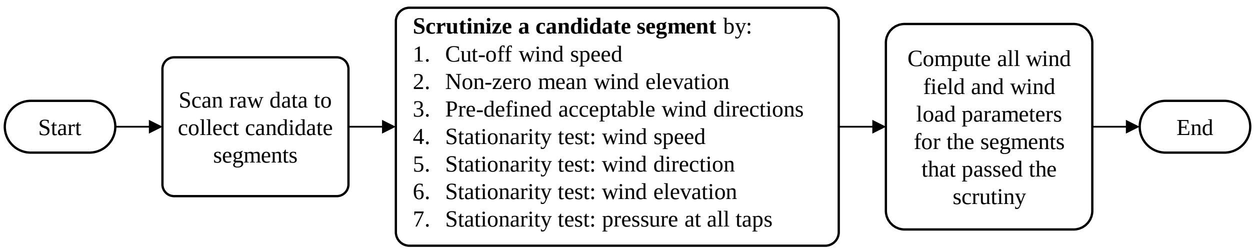

Figure 3. Overview of field data processing procedure including segment extraction.

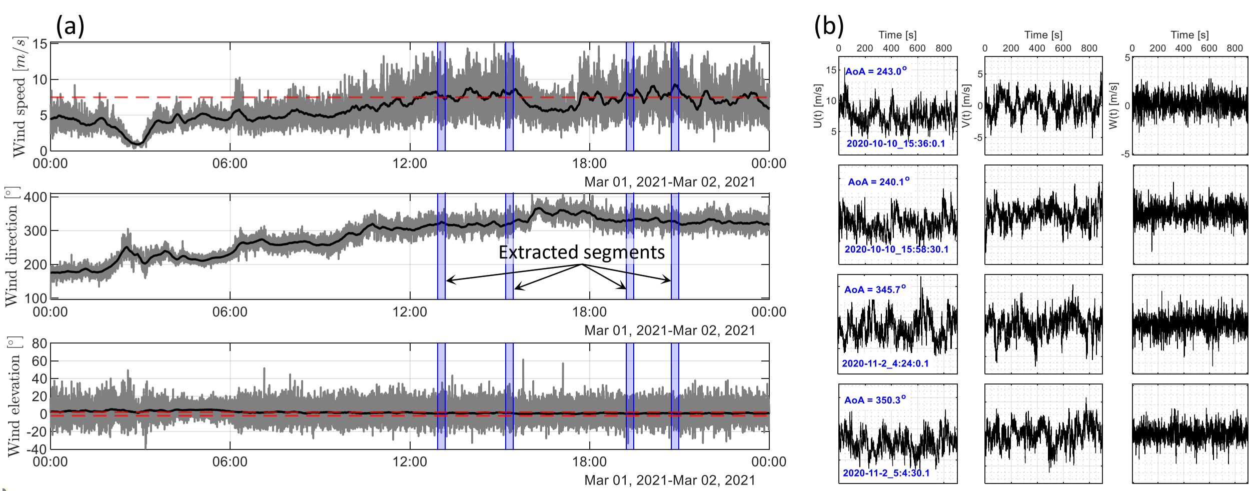

Figure 4. Sample data from the Ottawa site showing (a) 24 hr long raw wind speed, wind direction, and wind elevation time histories and (b) time histories of $U(t)$, $V(t)$, and $W(t)$ for four sample segments.

4. RESULTS

Data collected from the Woodstock (WK), Ottawa (OT), and New Brunswick (NB) sites spanning for several months is processed using the procedure described previously. Some results (segments) from WK, OT, and NB sites, are presented in Fig. 5. The figure shows the mean wind speed magnitude, turbulence intensities, and integral length scale of all extracted segments. In general, the OT site shows less turbulent conditions while WK site shows the most turbulent wind conditions. Sample local surface pressure load results at select taps are shown in Fig. 6. The mean and peak C_p data shows a large scatter that reflects the scatter observed in the wind field statistics. The overall pattern of load observed in the mean C_p is as expected from general building aerodynamics.

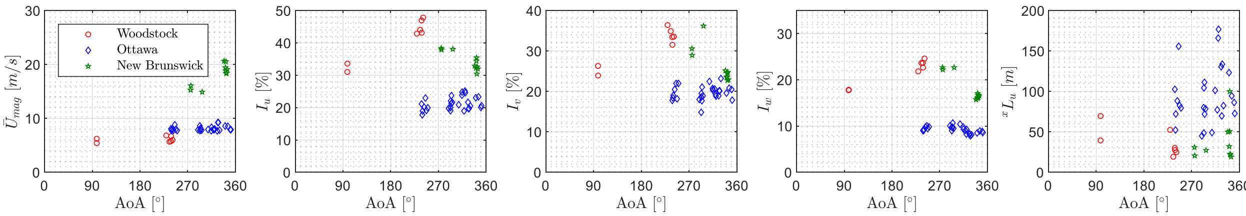

Figure 5. Wind statistics of extracted segments from the Woodstock, Ottawa, and New Brunswick sites.

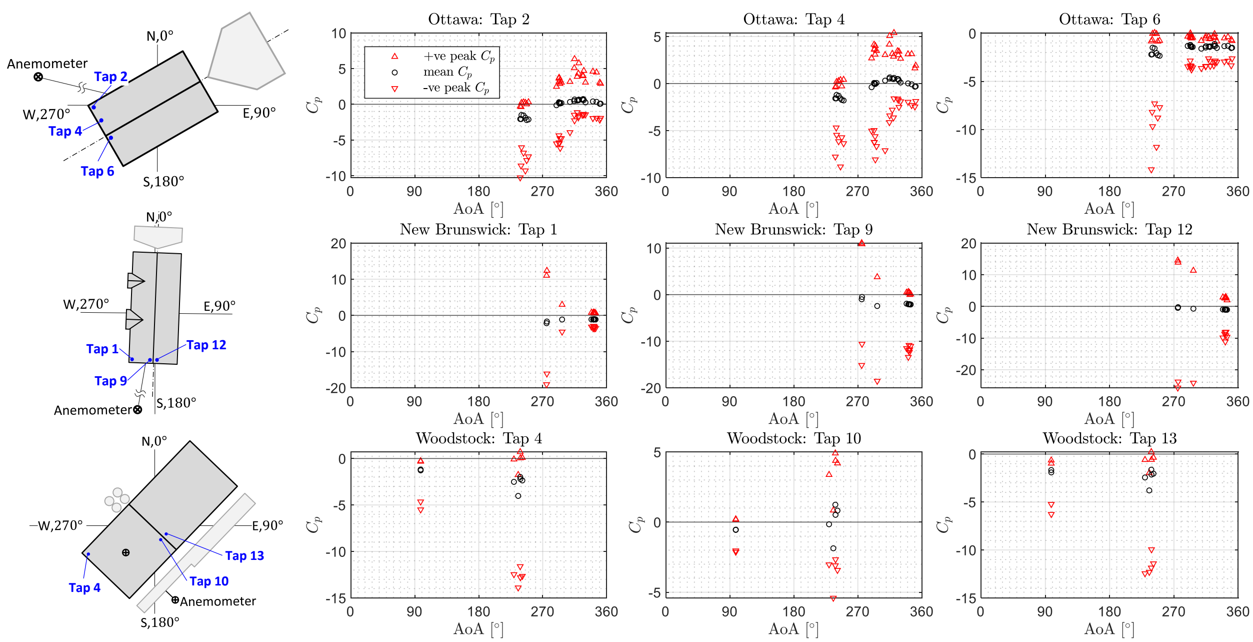

Figure 6. Wind statistics of extracted segments from the Woodstock, Ottawa, and New Brunswick sites.

5. CONCLUSIONS

The field instrumentation, data collection, and data processing procedures were described. The field data collected from three sites is were presented. The data screening procedure resulted in a range of values reasonably comparable to previous field studies.

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