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In situ measurements of wind pressures on low slope membrane roofs

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ABSTRACT

Pressure distributions created by wind flow on low slope roofs is an issue addressed by many wind tunnel studies and selective field experimental studies. Building codes and standards specify pressure coefficient data to determine the wind loads for commercial roofing claddings. Field measurements can provide valuable data to validate the current code provisions for wind loads, as well provide supporting data for existing wind uplift test methods for roof claddings. Thus the Special Interest Group on Dynamic Evaluation of Roofing Systems (SIGDERS) selected four locations (Ottawa, Vancouver, Mt. Pleasant and Rialto) across North America and collected wind speed, wind direction and wind pressure data for extended time periods to understand the wind interaction with low slope membrane roofs. This paper presents the data collected from November 2012 to November 2013 from the Ottawa, Ontario site.

Based on the National Building Code of Canada's (NBCC) zoning procedure, pressure taps were installed to obtain data for the corner, edge and field roof zones. Occurrences of wind speed exceeding 16 m s^{-1} were considered for various wind directions. Peak and mean pressure coefficients were calculated and compared with NBCC (2010)'s specifications. When instantaneous peak pressure coefficients were compared with the NBCC (2010), the measured data exceeded NBCC (2010)'s specifications for some wind directions. Nevertheless, when the pressure coefficients were compared by paring with their respective tributary area, the data concluded that the current NBCC (2010)'s specifications for the roof cladding and components are equally adequate for the wind load design of low slope membrane roofs.

1. Introduction

Evaluation of wind suctions on low slope roofs has remained a long-lasting industry challenge. Generally, as wind flows around a building, the windward areas of the low slope roof experience higher negative upward pressures due to flow separation. The magnitude of the wind effect depends primarily on wind speed, wind direction and building geometry. The National Building Code of Canada (NBCC, 2010) presents a detailed calculation methodology for the design of roof claddings. Design specifications are provided by segmenting the roof area into three zones of varying pressure levels, namely the corner zone with highest suction value, edge zone with moderate suction value and field zone with low wind stresses.

Functional roofs protect buildings against all weather conditions. To fulfill the required functions, commercial roof usually consist of multiple components such as a structured roof deck to transfer wind, snow and other loads, thermal insulation to control undesired heat losses or gains, and a waterproof membrane to prevent any form of water from intruding into the building interior. Attachment of the roof components can be done by adhesives, ballast or mechanical fasteners. The outermost layer absorbs the highest stresses and is typically made of flexible or rigid materials (EPDM, PVC or modified bitumen). However, the flexibility of the membrane complicates the matter of pressure suction and distribution. Under windy conditions, such membranes tend to deform significantly, creating balloon-like shapes (Fig. 1). This fluttering membrane dynamic can modify the conventional notion of flow separation from the leading edge. Tanaka et al. (1999) and Baskaran and Smith (2008) studied the effect of membrane flexibility of the mechanically attached roof systems on the pressure distribution.

Despite extensive industry research and investigation, insurance industries reports that roofing material failures are one of the main sources of all claims after major wind events (FM, 1985). Roof failures still occur nowadays due to the increasing rate and power of storms and tornadoes (NCA, 2014), leading to a large number of insurance claims, as documented by RICOWI (2006, 2007a, 2007b).

Building codes and standards specify the pressure coefficient data to determine wind loads for commercial roofing systems. These specifications are mostly derived from wind tunnel studies and therefore have limited validation with field measured data from membrane roof assemblies. The roofing community of North America has undergone much change over the last 25 years, along with advances in material science, computer-aided design and engineering applications. As a result, the wind tunnel data which

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was developed over three decades ago can be said to be less appropriate to quantify wind induced loads of current flexible roof claddings. Moreover, to avoid unreasonably costly aero-elastic modeling, current wind tunnel models are simplified in shape and made from rigid (Plexiglas) materials. This prevents the wind tunnel studies' ability to satisfactorily model the behavior of flexible roof coverings while maintaining the Reynold number requirements for flow simulations. This suggests that full scale studies are important in order to support current codes of practice.

The number of full scale studies carried out on membrane roof assemblies is significantly low. Of the few studies, the Texas Tech experiments have made a major contribution to the wind engineering field (Levitan et al., 1990, 1991, 1992). Using the Texas Tech database, several bench mark exercises with wind tunnel simulations were performed. Fig. 2 shows one such example by Surry (1991), confirming that due to the roof results of an oblique wind approach, significant differences exist between the full scale and wind tunnel data. More specifically, on the building/model windward side, the average value of the peak pressure coefficient Cp is equal to −4.8 for the full scale test, and reaches as high as −6.0. These values are compared to Cp of −3.2 for the wind tunnel simulation. Peterka et al. (1997) determined the pressure distribution and wind effects on steep slope roofs with asphalt shingles. Stathopoulos et al. (1990, 1999) investigated the pressure

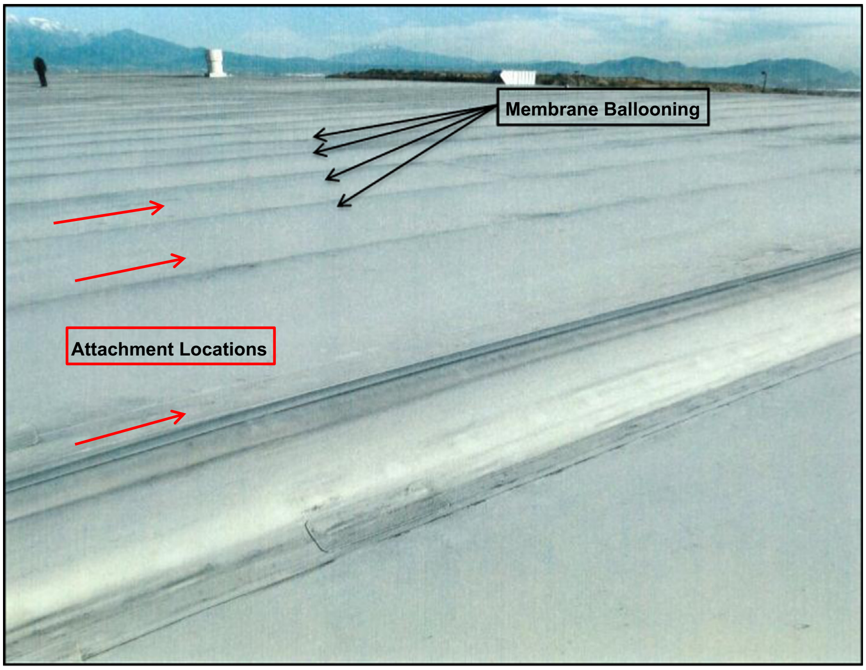

Fig. 1. Typical ballooning performance of low slope membrane roofs to wind effects.

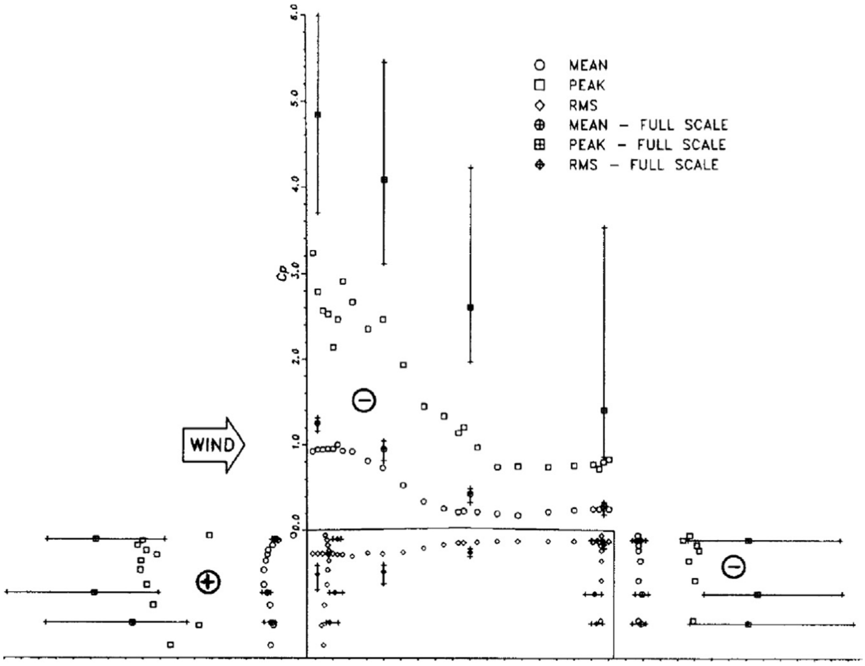

Fig. 2. Comparison of full scale measurements vs. wind tunnel results by Surry (1991).