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Application of statistical models to predict roof edge suctions based on wind speed

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ABSTRACT

This work compares and predicts the response of roof edge components to wind load. The edge components consist of three different parapet coping configurations on the edge of a commercial building's roof system. Full-scale highly non-Gaussian data acquired on a low-rise building is used for analysis. The comparison shows that strong suction is observed on the front flashing of all configurations, contrarily to what is specified in building codes. The prediction of the edge component response to wind load is accomplished with both a Gumbel distribution model and a translation method recently proposed in the literature, which estimate the extreme value distribution of the pressure coefficient. A Gumbel model is commonly used to represent the distribution of the peak pressure coefficient. The model parameters are determined from observed peaks, defining the Gumbel method. Recent work has proposed an alternative, the translation method, using the pressure coefficient entire time history instead, modeled as a translation from a Gaussian random process. Major gains include accurate and stable performance for strongly non-Gaussian data. The present results show that the translation method produces a more realistic estimate of the peak pressure coefficient distribution than the Gumbel method.

1. Introduction

Commercial roofs exist in several geometries and configurations. Components such as bitumen, metal and membranes, are used to protect the building's interior from exterior weather elements. As part of the roof's perimeter, the roof edge acts as an effective termination and transition between the roof and the wall (Fig. 1).

In most instances of commercial roofs, it constitutes of a parapet which is covered by metal components. The parapet can be constructed with various types of substrate including wood, gypsum and steel. Normally, the metal components cover the parapet by means of an inner layer, namely cleat (nailed to the substrate), and an outer layer, namely coping (mechanically engaged to the cleat). As wind separates from the roof edge, it breaks down into vortices which create high pressure differences at the roof's perimeter. In fact, the wind flow mechanism is complex, and features such as roof slope and parapet shape and height can add to its complexity. In simple terms, one can assume that three different forces are exerted on roof edges due to wind flow separation (Fig. 1):

- F_1: horizontal force, which oscillates between the in- and outward directions, on the front face of the roof edge;
- F_2: uplift force, which is acting on the top face of the roof edge;
- F_3: pull-off force, due to membrane tension acting on the back face of the roof edge.

At present, there is no existing code specification for wind load design of roof edges. Investigation of recent hurricanes (Charley, Katrina and Ike) identified major roof failures due to failure of edge systems (Baskaran et al., 2007). Fig. 2 shows hurricane-induced roof failures.

The figure illustrates individual failures in some components, or composite failures, in which the failures happened simultaneously in different components, or happened in some components as a consequence of the failure in other components. For instance, a failure in the cleat can cause coping failure; billowing of the membrane can induce failure of any roof edge component.

ASCE 7-10 provides design specifications for wind pressures. The design wind pressure for components and cladding elements of parapets are specified in Chapter 30 – see Fig. 30.7–1 of ASCE 7-10 (2013), reproduced here as Fig. 3.

As indicated in Fig. 3, the windward parapet ("Load Case A") is characterized by p_1 and p_2, whereas "Load Case B" is characterized by p_3 and p_4. Note that p_1 and p_3 are positive values, similarly to

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the wall pressure p_5, whereas p_2 and p_4 are suctions, similarly to the roof pressures.

Bedair (2009) conducted full-scale testing on a low-rise building in order to examine the wind-induced net pressure acting on the surface of the parapet. The author compared the wind pressures measured on the parapets with the existing National Building Code of Canada NBCC (2005) specifications, as shown in Table 1. Roof corner and wall values of C_pC_g were used for comparison purposes. As there is no specification in the NBCC regarding C_pC_g for the parapet, equivalent NBCC values of C_F for the parapet are included in Table 1. Based on the Table, the design force coefficient is higher than the measured force coefficients making the design more conservative.

Wang et al. (1995) reported wind pressure coefficients for roof edges tested at the Texas Tech Wind Engineering Research Field

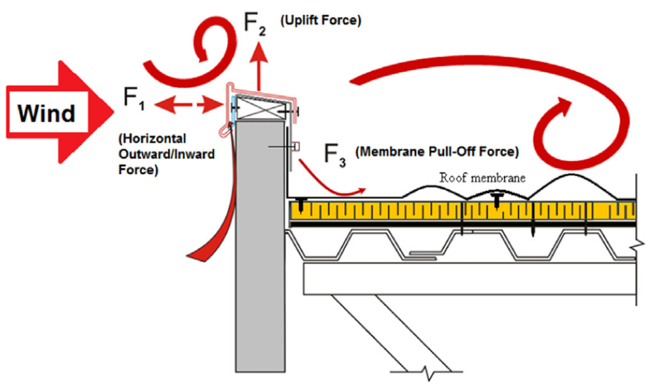

Fig. 1. Wind-induced forces on a roof edge.

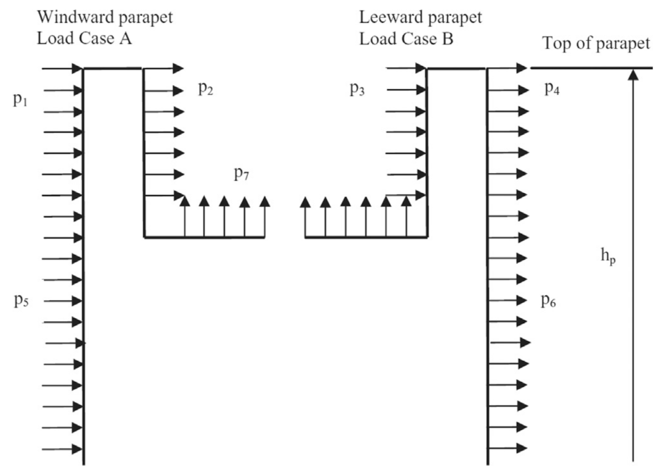

Fig. 3. Existing Code Specification for parapet design (ASCE 7-10, Fig. 30.7–1).

Table 1
Net NBCC-roof specifications and measured data on parapets by Bedair (2009).

Study		Corner	Mid-span
$(C_pC_g)_{wall}$ (NBCC, 2005)		1.8	1.8
$(C_pC_g)_{roof}$ (NBCC, 2005)		−5.4	−2.5
$(C_F)_{parapet}$ (NBCC, 2005)		7.2	4.3
$(C_F)_{parapet}$ (Bedair, 2009)	Full-scale	3.72	2.88
	Wind tunnel	3.68	3.36

Notes: 1. These values represent the largest peak values from all wind directions. 2. The design force coefficient (C_F) for a particular region (corner or edge) of a parapet is given by: $(C_F)_{parapet} = (C_pC_g)_{wall} - (C_pC_g)_{roof}$, where C_pC_g is the design pressure coefficient.

Fig. 2. Typical roof edge failures during high-wind conditions: (a) complete failure, (b) partial failure, (c) cleat failure and (d) coping failure.