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Full-scale wind loads on flashing

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SUMMARY:
Flashing on low-slope commercial roofs is often one of the first components to fail during high wind events and can begin the cascade of damage to a building's roof system and internal contents. Previous studies investigating wind loads and performance of low-slope roof flashing were conducted without the ability to change the directionality of the wind and the ability to change the wind speed velocity. As well, wind loads prescribed by the American Society of Civil Engineers Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE 7-16) are based on model scale buildings where components like flashing cannot be scaled down without changing the mechanical properties and cannot accurately capture the wind load over small spatial areas. The purpose of the current investigation is to use a full-scale building tested in the Insurance Institute for Business and Home Safety (IBHS) wind tunnel to better understand the full-scale pressures flashing experiences.

Keywords: flashing, wind loads, low-rise buildings

1. INTORDUCTION

Edge metal systems serve as the termination of roof and wall covers for single ply roofing systems and help maintain the roofing system's weatherproofing. As such, edge metal systems serve as the first line of defense against severe weather and is also the first component to fail during high wind events. The failure can then lead to a cascade of damage to the building's roof system and internal contents. Edge metal consist of two primary sections: an inner layer called the cleat which is mechanically fastened to the header of the wall and the exterior portion called the flashing which holds onto the cleat by friction. On a single ply roofing system, the edge metal is classified into two different types: flashing and coping. Flashing is used to terminate the roofing system when the wall and the roof system come together, and coping is used to terminate the roofing system when the building has a parapet wall. This study aims to discuss the full-scale pressure loads on flashing.

Following Hurricanes Charley and Ivan, the Roofing Industry Committee on Weather Issues (RICOWI) began investigating the performance of flashing and modes of damage that occurred during severe weather by launching post disaster investigations. After Katrina and Ike, RICOWI launched two more post disaster investigations that found similar damages occurring to edge metal systems (RICOWI 2007).

When flashing fails it exposes small gaps in the construction of the building which can allow air and water infiltration into the interior of the building. Additionally, that failure then also allows the single ply membrane to act as a sail in the wind and begin to peel back exposing additional areas of the roof that water can then infiltrate. Figure 1 shows the damage caused to a gymnasium floor after Hurricane Ike removed the flashing system but did not peel back the membrane. In this instance the flashing system came disengaged with the cleat due to corroded fasteners. Despite the relatively small, exposed area, water was still able to penetrate through the header of the building and cause extensive damage to the interior of the building (RICOWI 2007).

Figure 1 RICOWI, Inc. 2007. "Hurricane Ike Wind Investigation Report." Roofing Industry Committee on Weather Issues Inc., Powder Springs, Georgia. The flashing system became disengaged from the cleat, the fully adhered EPDM membrane did not peel back, but still allowed enough water to come through the header of the wall.

The American Society of Civil Engineers gives recommendation for the pressures loads that should be accounted for when designing low slope buildings (ASCE 2016). However, the loads are based on model scale wind tunnel data where pressures are measured further from the edge and analyzed over tributary areas larger than typical flashing. Given the extremely high-pressure gradients close to the edges of the roof it is not clear if the wind loads for roof Components & Cladding are sufficient for flashing elements, Moreover, flashing elements can allow for air infiltration underneath which is not accounted for in current design provisions. McDonald et al. (1997) studied the pressures on full scale edge metal systems but did not have the ability to control the wind speed or direction. These factors limited the studies scope to typical weather events, not severe weather conditions where scaling windspeeds might cause higher induced loads. The current investigation examines the wind loads on several different flashing systems of full-scale buildings and compares both the external pressures to those from model scale wind tunnel results and design standards.

2. EXPERIMENTAL SETUP

2.1. Test specimen

To gain a better understanding of the forces acting on flashing, IBHS constructed a 1200 sq. ft. building with a roof slope of slope ≤ 9.5°. The building had plan dimensions of 40 ft. x 30 ft. x 11 ft. Throughout construction, pressure sensors were installed to measure the wind pressure acting on the cleat, flashing, wall, and roof top in 36 locations along the building. At each of these 36 locations, a pressure sensor located on the wall approximately 1 ft. down from the leading edge and a pressure sensor located on the roof approximately 3 ft. away from the leading edge were installed to compare the loads on the flashing to the loads experienced by the wall and roof as well as historical data. To gain an understanding of how different edge metal systems' geometry might play a role in the loads experienced, three profiles of flashing systems were chosen.

2.4. Analysis

To compare to ASCE7-16 wind loads, (ASCE 2016) all pressures were converted to GCp coefficients. When reporting peak GCp values, the peak GCp coefficient are statistical peaks of time histories. The time history is divided into 4 sections and a Gumbel distribution is fitted to the peak value from each section using a Liebline BLUE formulation (Liebline, 1974). The reported peak GCp is the median value from the 4 sections. GCp values were calculated using Eq (1) where ρ is the density of air, V is the wind speed velocity at the height of the building, and ΔP is the change in pressure.

$$GCp = \frac{\Delta P}{0.5\rho V^2} \tag{1}$$

3. RESULTS

3.1 Comparison to ASCE 7-16 and critical wind angle

ASCE 7-16 gives guidance for what pressure loads should be used when designing a building. GCp values given by ASCE 7-16 are based on model scale wind tunnel testing where the pressures experienced by small components like flashing cannot be scaled down without changing the material properties. Figure 2 shows the detail of one of the flashing systems used in this study. Figure 3 shows the GCp values of the wind loads experienced by the vertical (fascia) and horizontal (flange) segments of the flashing as well as their respective ASCE 7-16 values. The GCp values presented in Figure 3 are from the flashing sensor location F2, across all wind angles. While the mean external loads fall within the ASCE 7-16 values, the minimum loads exceed their respective ASCE 7-16 values on both the flange and fascia section of the flashing. The highest suctions occur on the flange between wind angles 250° - 290°. However, for both the flange and fascia the GCp values from ASCE 7-16 for their respective sections were exceeded. GCp on the fascia and flange also exceeded their respective ASCE 7-16 values between wind angles 0°/360°-30° and wind angles 150°-180°.

Figure 2 Flashing systems are composed of two layers: the interior cleat (maroon in the picture) and the exterior portion (white) which is broken up into three parts. The hem section connects to the cleat by tensions, the fascia section extends vertically down the wall of the building, and the flange section runs horizontally along the roof and is held down by fasteners.

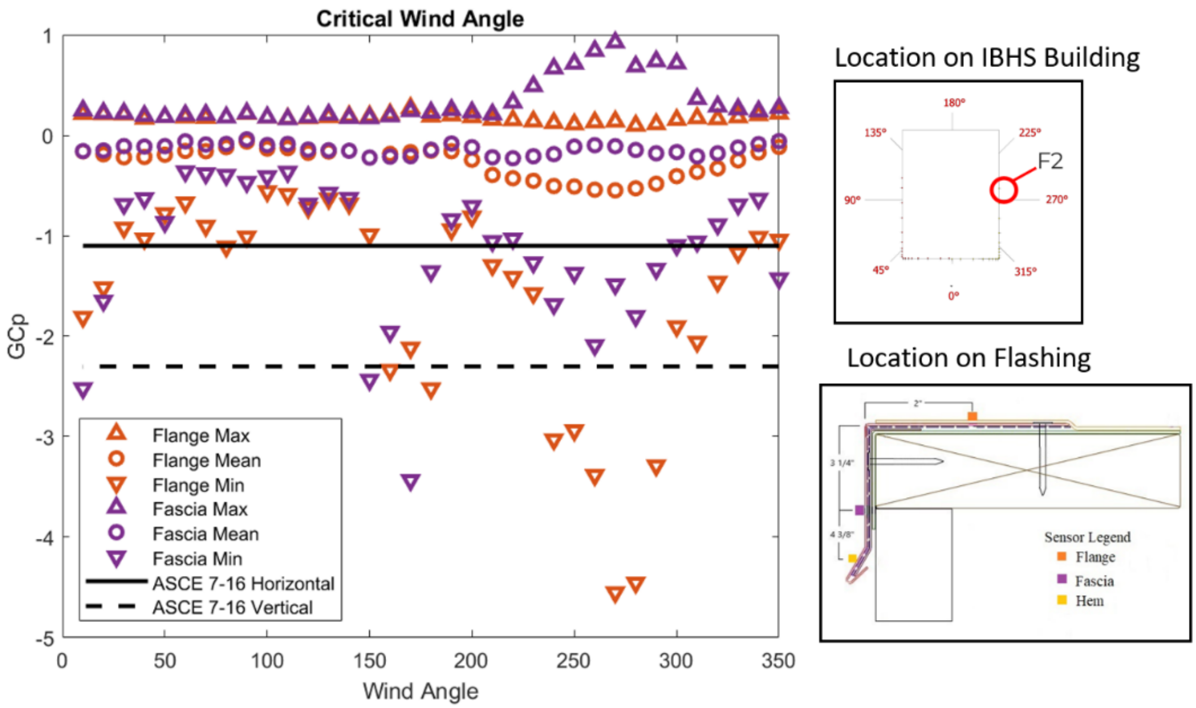

Figure 3 Critical wind angle for the flange (horizontal) and fascia (vertical) sections of the flashing system over 36 wind angles.

3. CONCLUSIONS

The full manuscript will present the observed wind loads from the 3 flashing systems present and provide a detailed comparison to both ASCE 7 and model scale wind tunnel data. As well as more detailed comparison of the wind pressures at different tributary areas for design.

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