ICWE 16
August 27-31, 2023
FLORENCE - ITALY
16th International
Conference on
Wind Engineering

An empirical model for wall-soffit pressure coefficients on a low-rise building

Karim Mostafa [1], Ioannis Zisis [2], Ted Stathopoulos [3]

1 PhD, CEE, Florida International University, Miami, FL, USA, kmost002@fiu.edu
2 Associate Professor, CEE, Florida International University, Miami, FL, USA, izisis@fiu.edu
3 Professor, BCEE, Concordia University, Quebec, Montreal, Canada, statho@bcee.concordia.ca

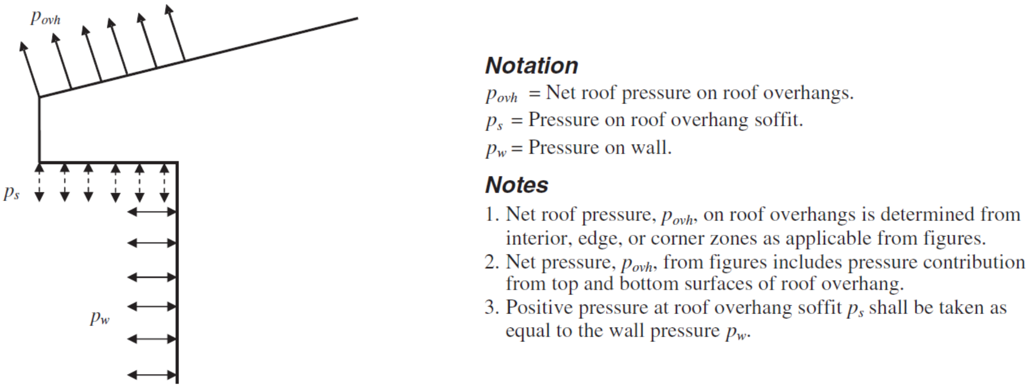
SUMMARY

Roof overhangs are designed to withstand wind loads at both the upper and bottom surfaces (soffits). Design guidelines for roof overhangs in North American Wind standards state that the positive pressure coefficient on soffits is the same as the adjacent walls. No information is provided about the maximum overhang widths where this assumption shall be applied. In addition, this assumption does not specify the soffit-wall relation for negative pressure coefficients. Thus, the validity of this assumption needs to be examined for different overhang widths, and various wind directions. A large-scale experimental study was carried out at the Wall of Wind (WOW) Experimental Facility for six models with different overhang widths. The experimental results confirmed that the positive pressure coefficients on soffits, may be taken the same as the pressure coefficients on the adjacent walls, regardless of the soffit widths, while this is not the case for negative pressure coefficients. Therefore, an empirical equation has been developed to describe the relation between wall-soffit negative pressure coefficients for different overhang widths.

Keywords: Roof overhangs, Roof soffits, Wind tunnel, Wind standards and code of practice, Empirical model

1. INTRODUCTION

Low-rise buildings are greatly affected by extreme wind events. The risk of wind-induced failure is particularly increased on roofs and roof overhangs. The latter are commonly used in residential and industrial buildings for weather protection against wind, snow, rain, and sun. Roof overhangs are prone to damage because they are subjected to wind from both the upper and bottom surfaces (soffit) (Mostafa et al. 2022). ASCE 7-16 (2016) and 7-22 (2022) provide methods for analysis of the loads on overhangs, both for main wind force resisting systems (MWFRS) and component and cladding (C&C) loads, but the commentary does not provide any information as to the maximum width of overhang for which this analysis is valid. In section 30.9, it is stated that the pressure on the bottom covering of the roof overhang is the external pressure coefficient on the adjacent wall surface as implemented by Vickery (2008) and shown in Fig.1. Therefore, to study the validity of this assumption for different overhang widths and to investigate the soffit-wall relation of negative pressure coefficient, a large-scale experimental campaign was conducted at the Wall of Wind (WOW) Experimental Facility at Florida International University (FIU) (Gan Chowdhury et al. 2017).



Notation

p_{ovh} = Net roof pressure on roof overhangs.
p_s = Pressure on roof overhang soffit.
p_w = Pressure on wall.

Notes

1. Net roof pressure, p_{ovh}, on roof overhangs is determined from interior, edge, or corner zones as applicable from figures.
2. Net pressure, p_{ovh}, from figures includes pressure contribution from top and bottom surfaces of roof overhang.
3. Positive pressure at roof overhang soffit p_s shall be taken as equal to the wall pressure p_w.

Figure 1. ASCE 7-16 - Fig. 30.9-1 Components and Cladding (All Building Heights)

2. METHODOLOGY

A hip-roof building layout was selected with full-scale dimension of eave height of 7.5 m and horizontal dimensions of 12.2 m by 15.24 m. All models were built at 1:10 scale. Two roof slopes (4:12 and 6:12), and three overhang widths (0.6 m, 1.2 m and 1.6 m), were selected in this study as shown in Table 1. Pressure taps were installed on walls, soffits, and roof overhangs, and all models were tested for 40 wind directions with a sampling time of 60 seconds.

Table 1. Prototype and model dimensions

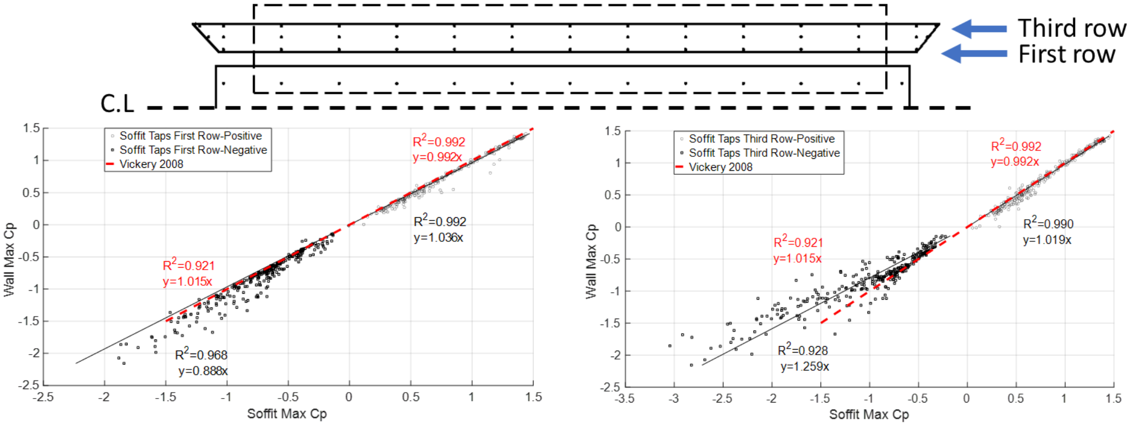
Model	Roof Slope	Building Dimensions		Model Dimensions		No of pressure taps
		L x W x h	Overhang	L x W x h	Overhang	
		(m)	(m)	(m)	(cm)	
A	4:12	15.2 x 12.2 x 7.3	0.6	1.52 x 1.22 x 0.73	6	344
B	4:12		1.2		12	304
C	4:12		1.8		18	362
D	6:12		0.6		6	278
E	6:12		1.2		12	304
F	6:12		1.8		18	352

3. EMPIRICAL MODEL

Regression Analysis was carried out on the wall upper taps and adjacent soffit taps for all models using Pearson's correlation (R factor), as shown in Eq. (1).

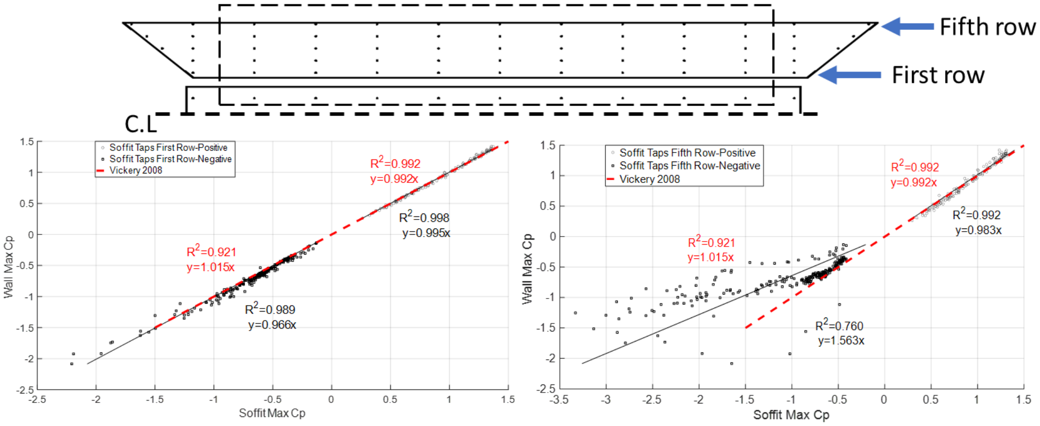
$$R = \frac{\Sigma(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\Sigma(x_i - \bar{x})^2 \Sigma(y_i - \bar{y})^2}} \tag{1}$$

For models of 0.6 m overhang width, the first row is the one next to the wall and the third row is the outer edge row; similarly for the models of overhang width of 1.8 m, the first row is the row adjacent to the walls and the fifth row is the edge rows. It was found from the regression plots that the positive peak pressures were well correlated (i.e., R-squared values near to 1) and the slope for the near and far rows for all the models is close to 1, confirming the assumption adopted by ASCE 7-16 and 7-22. However, for the negative peak pressures, the R-squared values significantly decrease for the taps located far from the wall, especially for wider soffits, and likewise, the slope is not close to 1 due to the divergence of peak negative pressure coefficients for the soffit and wall soffit especially for wider overhangs. To validate the current findings, the results were compared to previous literature (Vickery, 2008). Sample figures from the regression analysis used in developing the empirical model are shown in Fig.2 and Fig.3.



(a) (b)

Figure 2. Linear Regression Relation between Upper Taps in South Wall and (a) first row of taps (b) third row of taps in soffit for roof slope 4:12 with overhang width 0.6 m



(a) (b)

Figure 3. Linear Regression Relation between Upper Taps in South Wall and (a) first row of taps (b) third row of taps in soffit for roof slope 4:12 with overhang width 1.8 m

Different parameters have been considered while developing the empirical model for wall-soffit pressure coefficients, such as the soffit width, roof slope and wall peak surface pressure coefficient. For positive pressure coefficient, the empirical equation that governs the wall and soffit pressure coefficient is the same as the assumption in ASCE 7-16 and ASCE 7-22, regardless of overhang widths, as shown in Eq. (2).

$$Cp_{Soffit} = Cp_{Wall} \tag{2}$$

The empirical model for negative pressure coefficient is more challenging in terms of developing a linear relation between the soffit and the wall pressure coefficients. This is due to the turbulence occurring underneath the soffit which affects the suction among the soffit and among the walls independently for different wind directions. However, a relation has been developed for predicting the soffit pressure coefficient from the wall pressure coefficient that is a function of the overhang width. The roof slope did not seem to have a recognizable effect on changing the wall and soffit pressure coefficients, therefore, the empirical equation is governed only by wall pressure coefficient and the soffit width. The empirical equation for negative pressure coefficients as shown in Eq. (3) can be used for preliminary estimating the peak critical soffit pressure coefficient by knowing the peak corresponding wall pressure coefficient, and the soffit width (W) which used in Eq. (3) in m.

$$Cp_{Soffit} = 3.50 * Cp_{Wall} - 0.68 * W + 5 \tag{3}$$

These coefficients might be utilized in future codification attempts to assist designers to represent better design pressure coefficients on roof overhangs.

ACKNOWLEDGEMENTS

The authors are grateful to the support provided by Florida Building Commission Order B83FC1 for funding this research and to the staff at the WOW at FIU for their support in performing the experimental work.

REFERENCES

ASCE. (2016). “Minimum design loads for building and other structures.” American Society of Civil Engineers, ASCE/SEI 7-16, Reston, VA.

ASCE. (2022). “Minimum design loads for building and other structures.” American Society of Civil Engineers, ASCE/SEI 7-22, Reston, VA.

Gan Chowdhury, A., Zisis, I., Irwin, P., Bitsuamlak, G., Pinelli, J.-P., Hajra, B., and Moravej, M. (2017). “Large-scale experimentation using the 12-fan wall of wind to assess and mitigate hurricane wind and rain impacts on buildings and infrastructure systems.” *Journal of Structural Engineering*, American Society of Civil Engineers, 143(7), 4017053.

Mostafa, K., Zisis, I., and Stathopoulos, T. (2022). “Large-Scale Wind Testing on Roof Overhangs for a Low-Rise Building.” *Journal of Structural Engineering*, 148(11), 1–21.

Vickery, P. J. (2008). “Component and Cladding Wind Loads for Soffits.” *Journal of Structural Engineering*, 134(5), 846–853.