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# Wind Loads on Sunshade Elements: Horizontal and Vertical Sunshades

Antonios Rofail and Nicholas Truong

Windtech Consultants, Bexley, NSW, 2207, Australia

reception@windtechglobal.com

## ABSTRACT

*The addition of sunshades and other small attachments to building facades is prevalent and the wind loading they experience is an important part of their design. The current Australian and New Zealand wind loading standard does not provide a method to estimate these wind loads although methods are included within the AWES Wind Loading Handbook. In this paper sunshade net pressure coefficients were derived from wind tunnel pressure studies conducted by Windtech Consultants on commercial projects as well as from a simplified large scale wind tunnel model. Recommendations for pressure coefficients that are suitable for inclusion within a future Australian and New Zealand wind loading standard have been made. Further wind tunnel testing and analysis will conducted on additional sunshade designs.*

## INTRODUCTION

Modern building facades have multiple complex elements including sunshades. These sunshades are exposed to wind loads and need to be adequately designed. The current Australian and New Zealand Standard, Structural Design Actions Part 2: Wind actions (AS/NZS 1170.2:2021) does not provide specific guidance for the estimation of wind loads on these sunshade elements. It is recognized that it is difficult to predict loads on sunshades without wind tunnel testing as the geometry and location of the sunshades have a substantial effect.

AWES (2022) provides guidance in estimating these sunshade wind loads as a factor applied to the local external façade pressures (not accounting for local area factors) that range from 0.6 to 1.5 depending on the type, orientation and location of the sunshades. Lau and Rofail (2023) discussed these current provisions and provided example coefficients for the five sunshade types. This paper presents the findings from an investigation of sunshade wind loads from 21 wind tunnel studies and an isolated large scale building model. The naming convention in Figure 1 has been used in this paper.

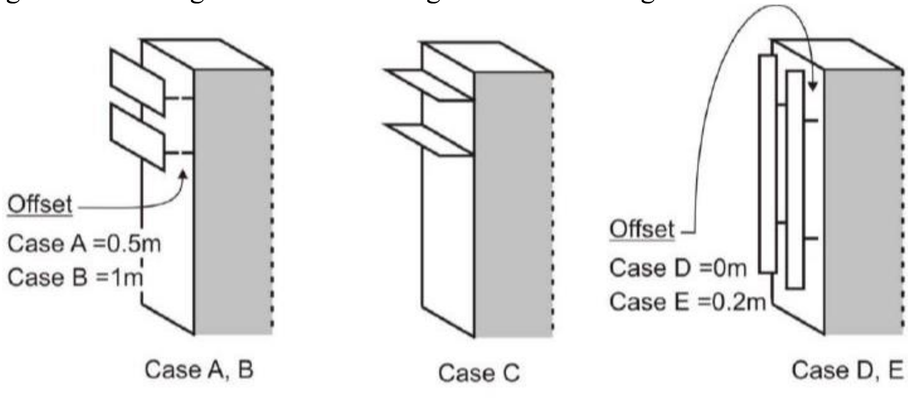


**Figure 1. Common Sunshade Types from AWES (2022)**

## METHODOLOGY

### Coefficients

The differential pressures acting on either side of the sunshades were measured by directly instrumenting both sides of the element. The peak net pressure coefficient presented in this paper were calculated using the upcrossing method. These net pressure coefficients were then expressed as 0.2s gust coefficients using the turbulence intensity of the tested profile and a gust factor of 3.8 (Holmes, 2015). The coefficients presented are equivalent to aerodynamic shape factors ($C_{shp}$) and include $K_l$.

### Case Studies

Twenty-one recent façade cladding wind tunnel pressure studies where the net pressures acting on the sunshade elements were directly measured have been analyzed and classified. These studies are summarised in the Table 2. Photos of two examples of previous wind tunnel studies are presented in Figure 2. In the current paper Types C, D and E have been analysed.

**Table 1. Previous wind tunnel studies with sunshades**

| Sunshade Type | Number of studies |
|---|---|
| A | 5 |
| B | 1 |
| C | 8 |
| D | 13 |
| E | 3 |

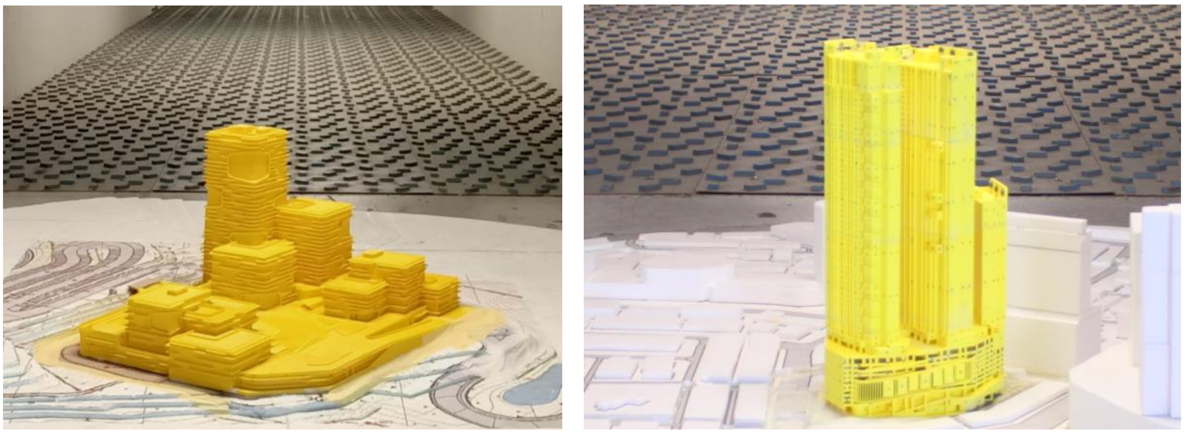

**Figure 2. Representative Type C and Type D Case Study**

### Isolated Prismatic Building Model

Wind tunnel testing was also conducted on an isolated large scale prismatic building. The building was tested with horizontal and vertical sunshade configurations representing a building that is 45m in height, having a building aspect ratio (h/b) of 3 and a side ratio (d/b) of 2. The vertical and horizontal sunshades had depths of 1m (full-scale) and spacings of 3 and 3.5m respectively. This wind tunnel model study was carried out with a geometric scale of 1:100. Additional testing was conducted using a 1:50 scale model and with sunshades located on the shorter face. Figure 3 presents an example of the tested building and sunshades.

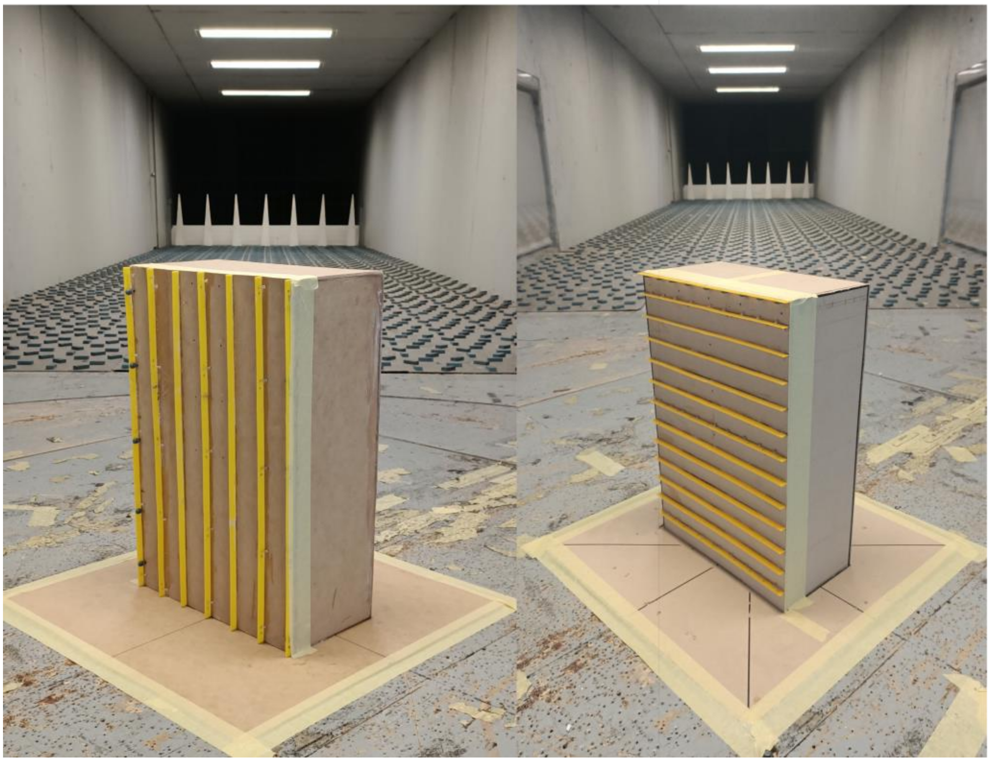

**Figure 3. Isolated Prismatic Building Model with sunshades: vertical (left), horizontal (right).**

## RESULTS

Result of the wind tunnel testing have been presented for three sunshade configurations. For all configurations, the results from both the isolated prismatic model testing and the case studies have been used to determine the recommended pressure coefficients. These pressure coefficients have been presented graphically, plotted against normalised height or normalised width. The very close agreement between the results from the 1:100 scale and 1:50 scale models demonstrates the absence of Reynolds Number effects.

### Horizontal Type C

Figure 4 and Figure 5 present the results for the horizontal sunshade case. Figure 4 shows that there is a relationship between normalized height and pressure coefficient. Figure 5 shows that for sunshades located in the top 20% of the building there is also a relationship between normalised width and pressure coefficient.

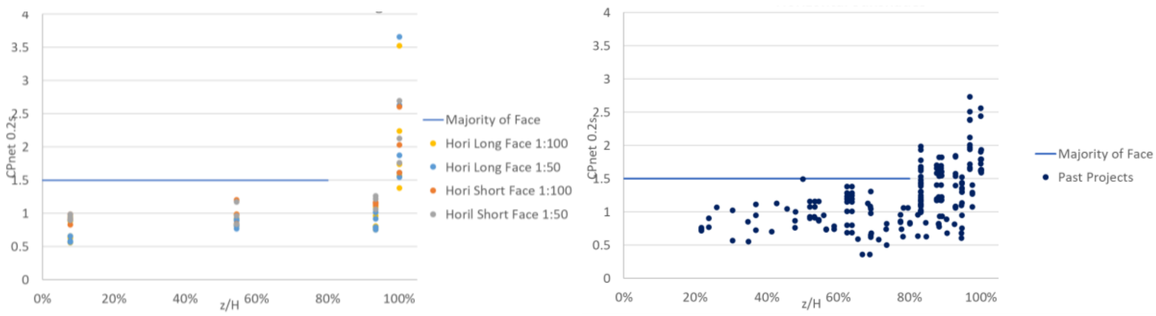


**Figure 4. Horizontal Sunshade $Cp_{net}$ versus z/H for all x/b**

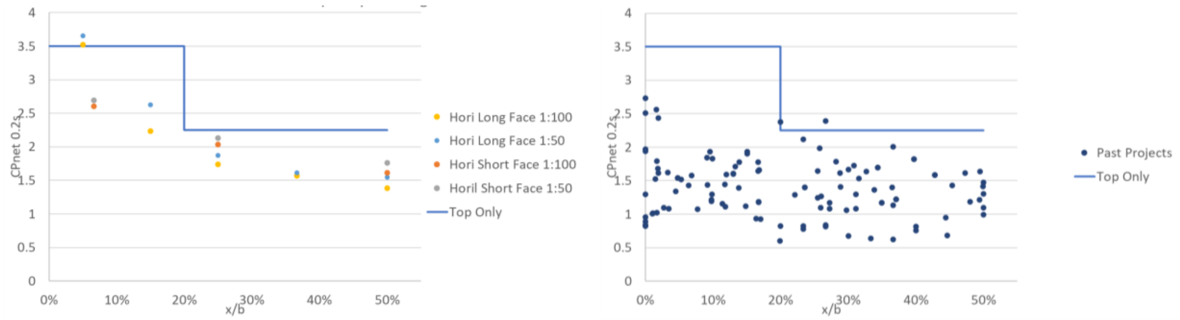


**Figure 5. Horizontal Sunshade $Cp_{net}$ versus x/b for z/H > 80%**

Based on the data presented in Figure 4 and Figure 5 the following net pressure coefficients have been proposed for elements located:

- <80% of the height of the building: **±1.5**
- >80% of the height of the building and > 20% of the width from the vertical edge: **±2.25**
- >80% of the height of the building and within 20% of the width from the vertical edge: **±3.5**

### Vertical Type D

Figure 6 and Figure 7 present the results for the attached vertical sunshade case. Figure 6 shows that there is no clear relationship between normalised height and pressure coefficient. Figure 7 shows there is a relationship between normalised width and pressure coefficient.

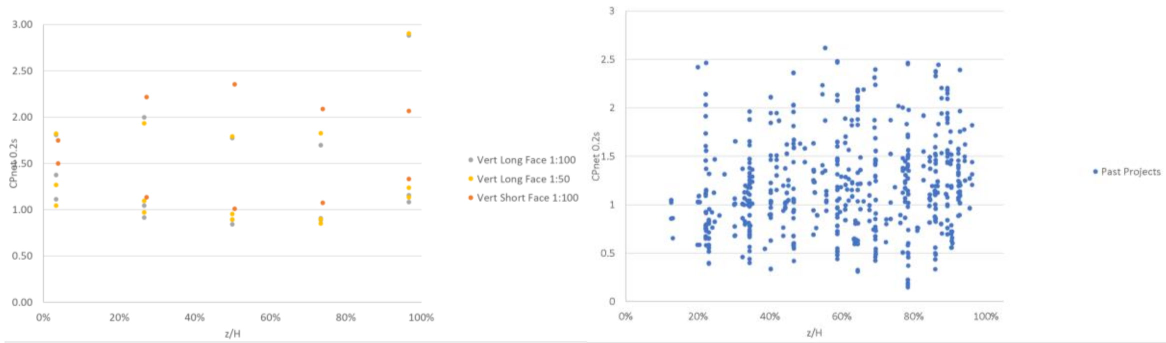


**Figure 6. Vertical Sunshade $Cp_{net}$ versus z/H for all x/b**

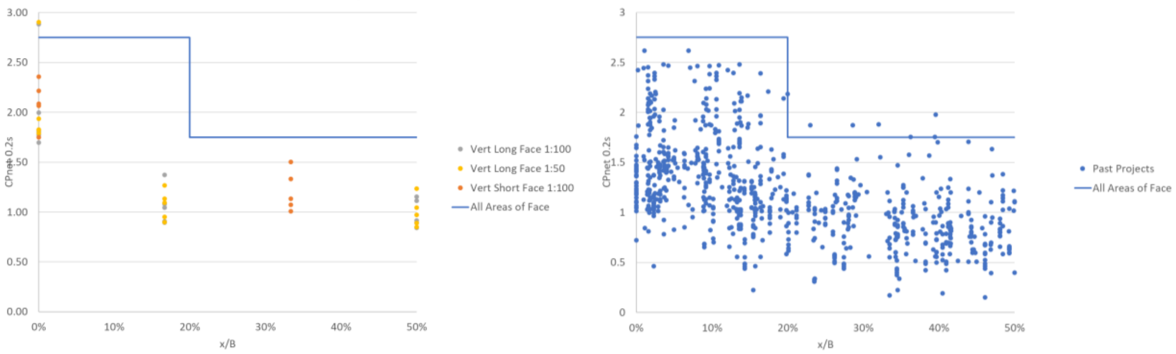


**Figure 7. Vertical Sunshade $Cp_{net}$ versus x/b for all z/H**

Based on the data presented in Figure 7 the following net pressure coefficients have been proposed for elements located:

- All heights and further than 20% of the width from the vertical edge: **±1.75**
- All heights and within 20% of the width from the vertical edge: **±2.75**

**Vertical Offset Type E**

Figure 8 and Figure 9 present the results for the attached vertical sunshade case. Figure 8 shows that there is no clear relationship between normalised height and pressure coefficient. Figure 9 shows there is a relationship between normalised width and pressure coefficient.

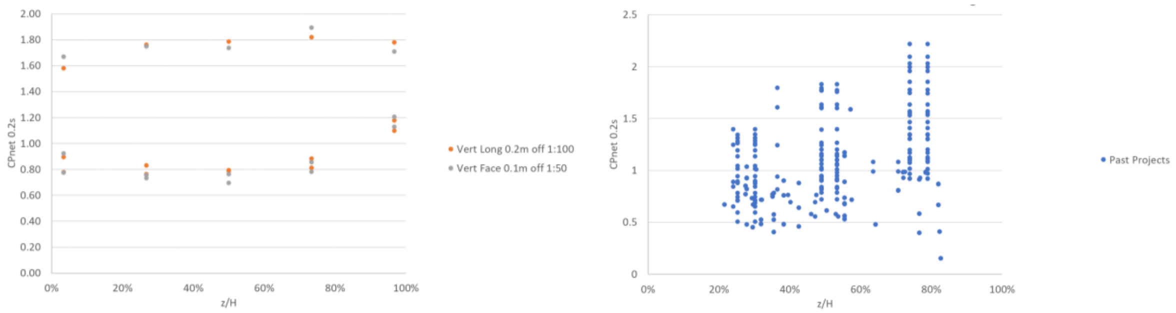


**Figure 8. Vertical Offset Sunshade $Cp_{net}$ versus z/H for all x/b**

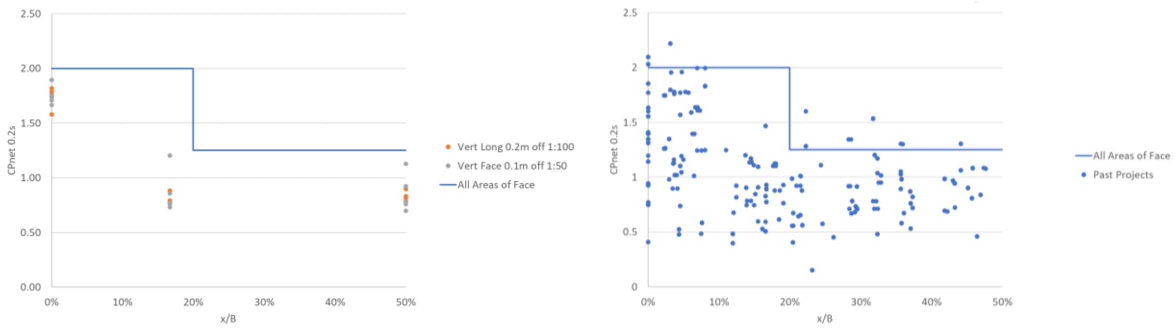


**Figure 9. Vertical Offset Sunshade $Cp_{net}$ versus x/b for all z/H**

Based on the data presented in Figure 9 the following net pressure coefficients have been proposed for elements located:

- All heights and further than 20% of the width from the vertical edge: **±1.25**
- All heights and within 20% of the width from the vertical edge: **±2.0**

**Comparison with simplified Australian/ New Zealand Standard (AS1170.2) approach**

The pressure coefficients presented above can be compared to simplified estimate from the Australian/New Zealand Standard (AS1170.2:2021) for sunshade elements nearby to the wall and roof edges. For horizontal sunshades located close to the top of the building, the wind loads can be estimated assuming they were small elements similar to eaves. For this case the pressure coefficients would range from 4.2 in the corners ($K_l$ region RC1 and WA1) to 3.8 in the center ($K_l$ region RA2 and WA1). The proposed pressure coefficients represent a 17% to 40% decrease on these estimates. For vertical sunshades near the edge these can be estimated using the difference between the side wall pressures and the windward wall pressures. For this case the pressure coefficients would be 3.2 ($K_l$ region SA5 and WA1). The proposed pressure coefficients represent a 13% decrease on these estimates.

## DISCUSSION AND CONCLUSION

The pressure coefficients equivalent to aerodynamic shape factors ($C_{shp}$) for three sunshade geometries have been presented. These coefficients are suitable for inclusion within the current Australian and New Zealand Standard, Structural Design Actions Part 2: Wind actions (AS/NZS 1170.2:2021), which currently does not provide specific guidance for the estimation of wind loads on sunshade elements. Further testing is planned for Type A and B sunshade elements.

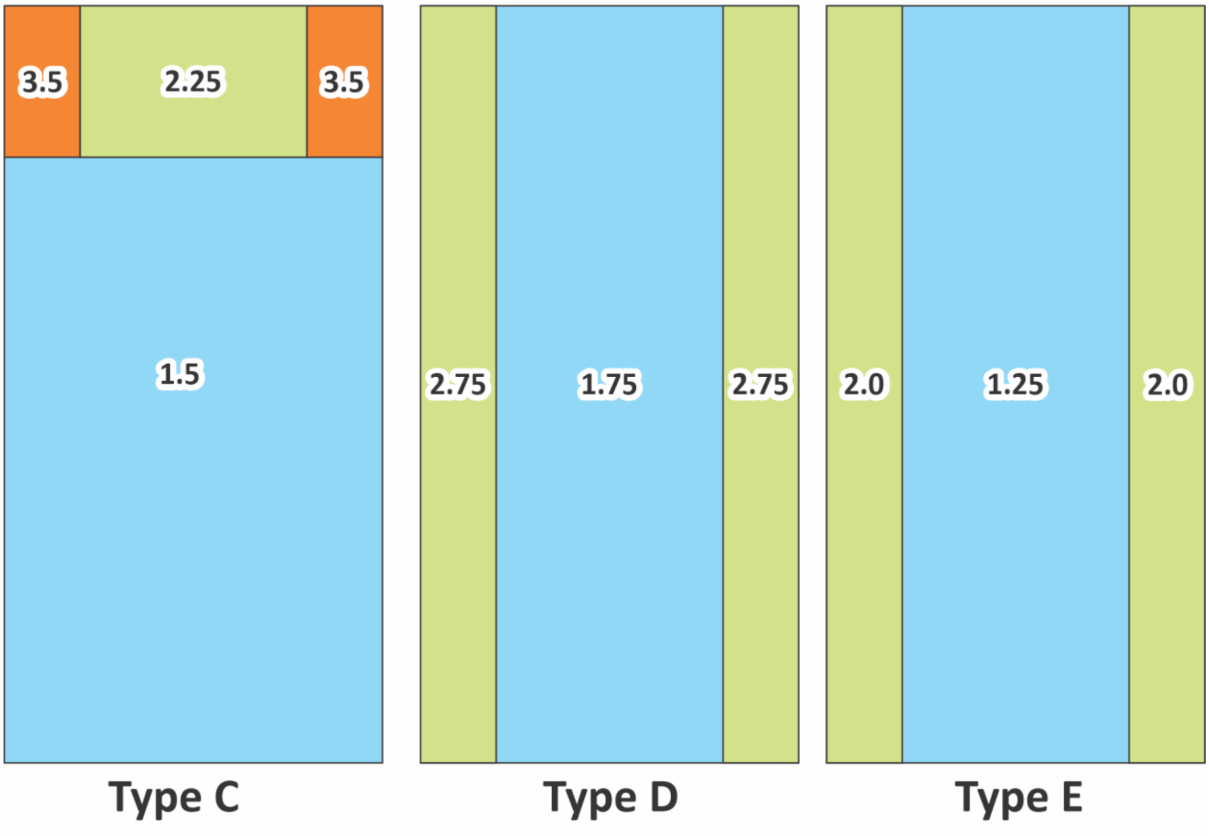


**Figure 10. Scale diagram showing proposed pressure coefficients ($C_{shp}$)**

**Reference List**

Australasian Wind Engineering Society, *Wind Loading Handbook for Australia and New Zealand, Background to AS/NZS1170.2 Wind Actions*. 2022

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Holmes, J.D., *Wind loading of structures*, 3rd Edition, CRC Press Boca Raton, Florida, USA, 2015

Lau, R. and Rofail, A., "Wind Loads on Sunshade Elements: Horizontal Sunshades", 21st Australasian Wind Engineering Society Workshop, Sydney 2-3 February, 2023