Wind Loads on Sunshade Elements: Horizontal Sunshades

Raymond Lau, Antonios Rofail [1]
[1] *Windtech Consultants, Bexley, NSW, 2207, Australia*

ABSTRACT

The addition of sunshades and other small attachments to building facades is common and these elements can experience wind loads significantly higher than the adjacent façade. There is currently no guidance provided in AS/NZS1170.2 (2021) for the estimation of wind loads on these sunshade elements however the AWES Wind Loading Handbook (2022) provides factors to determine sunshade pressures. Sunshade net pressure coefficients were obtained from past façade cladding wind tunnel pressure studies conducted by Windtech Consultants and also from a prototype wind tunnel model study and compared against the current guidance in AWES (2022). The analysis of these studies shows general agreement with AWES (2022) estimates. It is recommended to continue the analysis presented in this paper to develop appropriate prediction models for the net pressure coefficient for various sunshade Types.

1. Introduction

There is increasingly more complexity on building facades in recent times and the addition of sunshades to building facades is now commonplace. These sunshades can experience significantly higher wind loads than the building façade and it is recognized that it is difficult to predict these without wind tunnel testing as neighbouring buildings, the geometry and location of the sunshades have a substantial effect.

AWES (2022) provides guidance in estimating these sunshade wind loads by providing factors ranging from 0.6 to 1.5 depending on the Type and location of the sunshades to be used with the nearby façade external pressure coefficient (Table 1 and Figure 1). This paper presents the preliminary findings from investigation of sunshade wind loads from recent wind tunnel studies conducted by Windtech Consultants and prototype wind tunnel model testing.

2. Methodology

2.1 Current Practice

Sunshade net pressures are typically obtained from façade cladding wind tunnel pressure studies by instrumenting the sunshade element directly as conducted by Windtech Consultants. The pressures acting on the exposed sides of the sunshades of past projects were obtained in terms of peak pressure coefficients using a scaled hourly mean wind speed. The pressure coefficient is defined in (1) and (2) below.

$$C_{p,max} = \frac{p_{max} - p_0}{\frac{1}{2}\rho \bar{V}_h^{\,2}} \quad (1)$$

$$C_{p,min} = \frac{p_{min} - p_0}{\frac{1}{2}\rho \bar{V}_h^{\,2}} \quad (2)$$

Where:

- P_{max} , P_{min} = peak pressures
- P_0 = atmospheric pressure
- $\frac{1}{2}\rho\bar{V}_h^{\,2}$ = dynamic pressure at building height *h*

The net pressure coefficient, $C_{p,n}$, was formed by using the differential pressures acting on either side of the free surface. These net pressure coefficients were then expressed as gust coefficients using the turbulence intensity of the tested profile and a gust factor of 3.8 (Holmes, 2015).

Where instrumenting the sunshades is not feasible due to scale or other limitations, sunshade factors provided in AWES (2022), Figure 1, can be used with the nearby façade external pressure coefficients to provide the net sunshade pressure coefficient. Where wind tunnel testing has not been carried out the external pressure coefficients on building façade can be derived from AS/NZ1170.2 (2021) as shown in Tables 2-4.

Table 1. Sunshade Factors for Various Sunshade Types (AWES 2022)

Case	**Sunshade Factor, K_s**	
	Edges	**Central Areas**
A	0.8	0.6
B	1.2	1.1
C	1.3	1.4
D	1.5	0.7
E	1.3	0.7

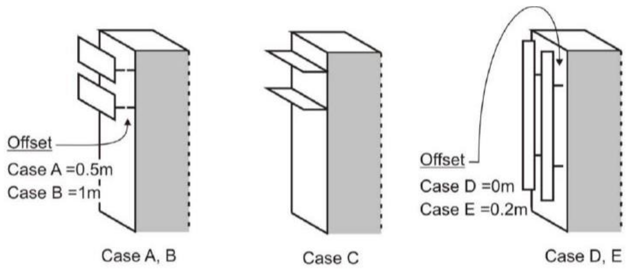

Figure 1. Common Sunshade Types and Ks Factors from AWES (2022)

Table 2. AS/NZS1170.2 (2021) External Pressure Coefficient Estimates for Façade Pressure Coefficients. $K_l\ C_{p,e}$

Location to façade edge	**Negative (Side Walls)**	**Positive (Windward)**
0.5a	-1.95	1.2
a	-1.3	1.2
>a	-0.975	1.2

*a is the minimum of 0.2b, 0.2d, h

Table 3. AWES (2022) Net Pressure Coefficient Estimates for Type C Sunshades. $K_s\ K_l\ C_{p,e}$

Location to façade edge	**Negative**	**Positive**
0.5a	-2.535	1.56
a	-1.69	1.56
>a	-1.365	1.68

*Edge K_s Factors used for locations within 0.5a and a to façade edge and Central Area K_s Factors elsewhere

Table 4. AWES (2022) Net Pressure Coefficient Estimates for Type D Sunshades. $K_s\ K_l\ C_{p,e}$

Location to façade edge	**Negative**	**Positive**
0.5a	-2.925	1.8

a	-1.95	1.8
>a	-0.6825	0.84

*Edge K_s Factors used for locations within 0.5a and a to façade edge and Central Area K_s Factors elsewhere

2.2 Case Studies

A review of the recent façade cladding wind tunnel pressure studies conducted by Windtech Consultants where the net pressures acting on the sunshade elements were directly measured has yielded a total of 21 studies. These studies were classified into several sunshade Types, as provided in Figure 1 from AWES (2022), and summarised in Table 5 below.

Table 5. Previous wind tunnel studies with sunshades

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

Table 5 shows the most common sunshade Types were horizontal and vertical projections attached to the building façade with no offset, Types C and D (refer to Figure 1). As these were the most common Types of sunshades, the net pressures acting on studies with these sunshade types were chosen for the initial investigation with preliminary findings on sunshade Type C shown in this paper. The net pressure coefficients of Type C sunshades are plotted against their height ratio (height of sunshade as a ratio of building height) and compared to the AWES (2022) estimates of the sunshade net pressure coefficients as outlined in Table 3 of Section 2.1. A representative wind tunnel study project was also selected from the previous studies (shown in Figure 2), to be further investigated.

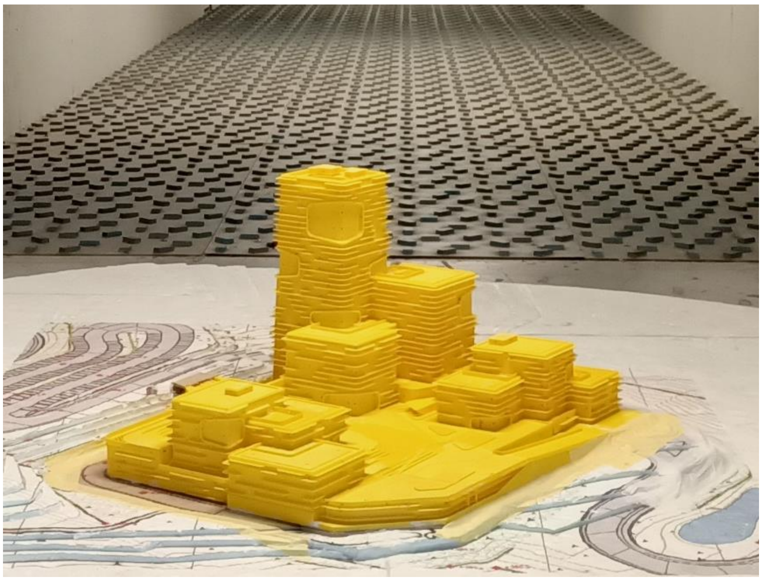

Figure 2. Representative Type C Case Study

2.3 Prototype Wind Tunnel Model Study

To verify the net sunshade pressure coefficients obtained from the various case studies outlined in Section 2.2 a basic prototype wind tunnel model 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 5m and 3.5m respectively. This wind tunnel model study was carried out with a geometric scale of 1:100. Figure 1 shows the models tested.

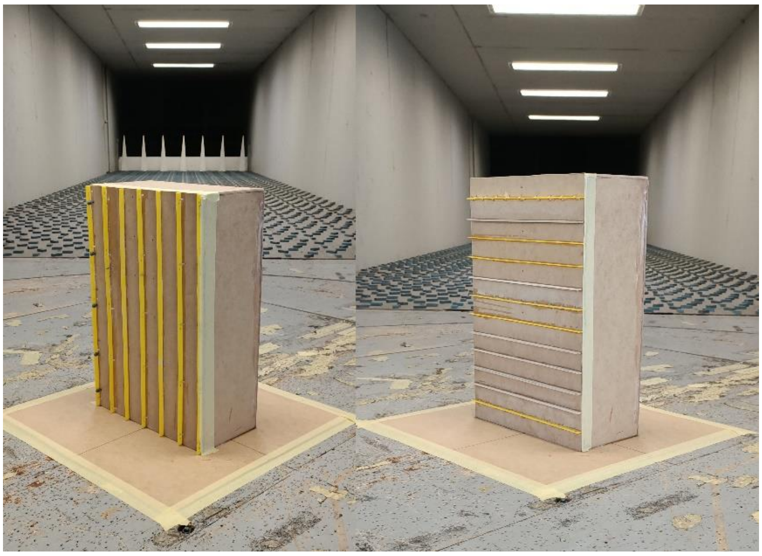

Figure 3. Photos of tested model configurations: vertical sunshades (left), horizontal sunshades (right).

The net sunshade pressure coefficients obtained from the horizontal sunshade model configuration is plotted against height as well as horizontal distance to the nearest façade edge. These are compared to the net sunshade coefficients derived from the code estimates and historical wind tunnel study data from Sections 2.1 and 2.2.

3. Results Analysis

Figure 4 shows the plot of net sunshade pressure coefficients for Type C sunshades against height for: AWES estimates (2022), past wind tunnel studies (8 in total) and the prototype wind tunnel study model. The net sunshade pressure coefficients varied across the previous wind tunnel studies however were generally within the maximums calculated using the AWES (2022) Ks factors. The results from the current study model also agreed well with the previous wind tunnel studies. Further testing of this model will be undertaken to include the case of a horizontal fin located at $z=h$. The pattern in the scatter of pressure coefficients shows a general increase with height of the horizontal sunshades. Variation within fixed height ratios show that sunshade pressures also vary with their proximity to façade edges.

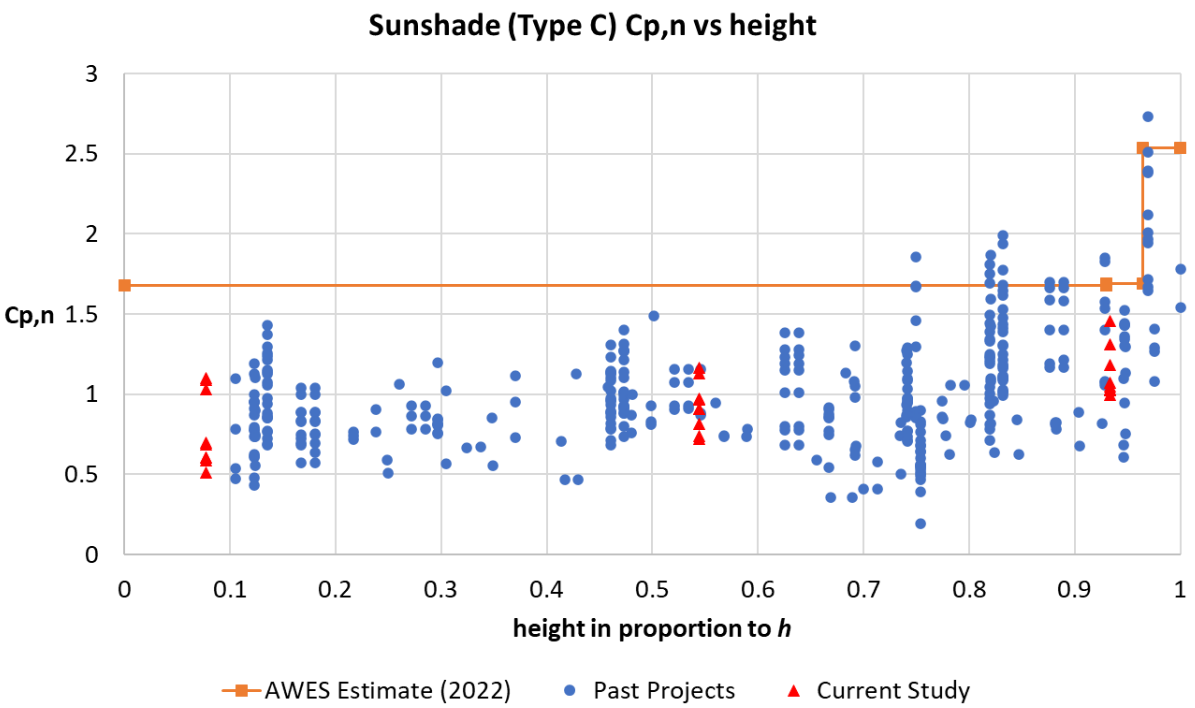

Figure 4. Chart of net pressure coefficients for C Type sunshades from AWES estimates (2022), 8 previous projects and the current study against height

Further investigation of a representative project (Figure 2) which included a large number of C Type sunshades was conducted and the variations of the sunshade pressures against height and proximity to the nearest façade edge are shown in Figures 5 and 6.

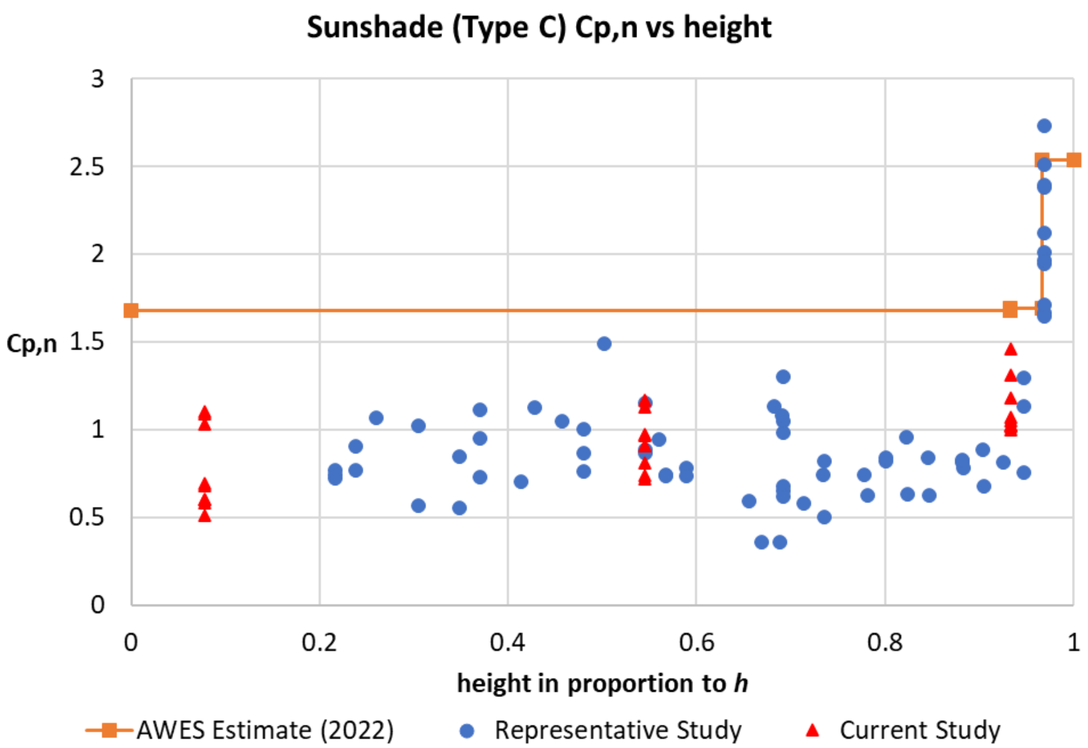

Figure 5. Chart of net pressure coefficients for C Type sunshades from AWES estimates (2022), the representative project (Figure 2) and the current study against height

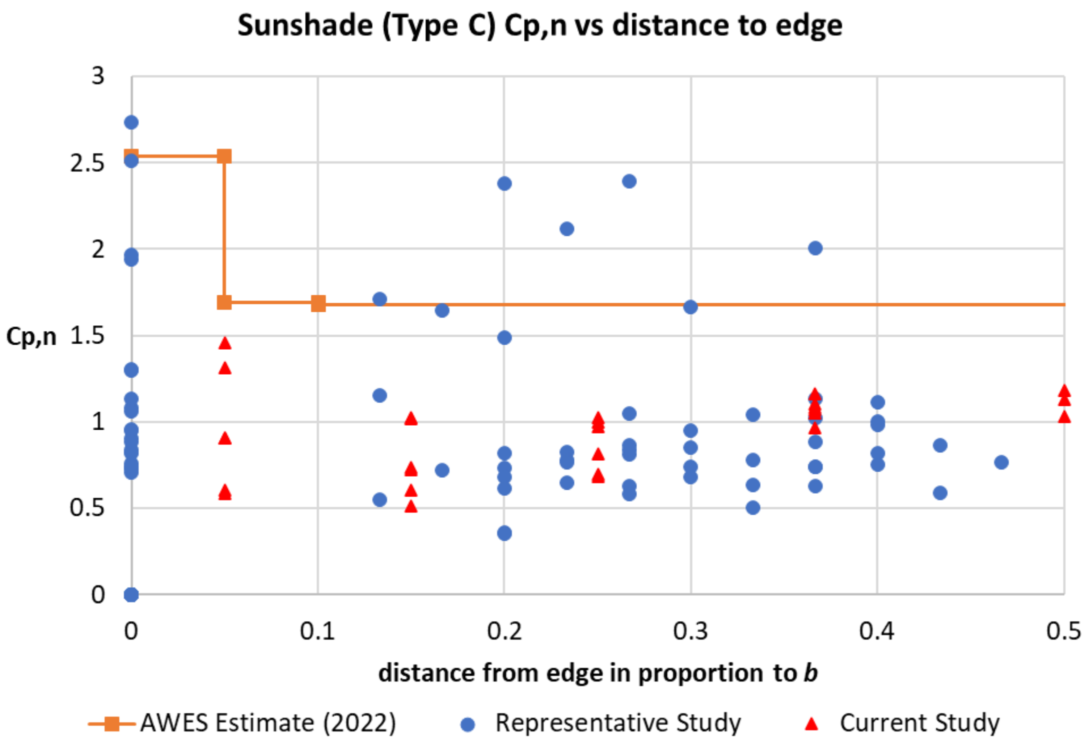

Figure 6. Chart of net pressure coefficients for C Type sunshades from AWES estimates (2022), the representative project (Figure 2) and the current study against distance to edge

While the sunshade pressures for regions near façade edges are well predicted with the current guidance in AWES (2022) the pressures along the central areas seem over estimated compared to the current study. The points in the representative project where the $C_{p,n}$ is higher than the current guidance are all at z=h. The current wind tunnel study is yet to incorporate the cases of z=h and x=b.

4. Conclusions

Net pressures coefficients for one of the most common sunshade Types, horizontal projection sunshades (Type C), were estimated using AWES (2022) guidance and compared to previous wind tunnel studies conducted by Windtech Consultants and a prototype model study. The analysis of these studies shows general agreement between AWES (2022) estimates of sunshade net pressure coefficients, prototype wind tunnel model study and previous wind tunnel study results from representative cases. These studies show variation of net pressures to be highly dependent on sunshade location.

The ultimate aim of the study on sunshade pressures, of which the preliminary findings are presented here, is to develop a codified approach to the prediction of wind loads on the sunshade Types A, B, C, D and E. Further testing using the prototype models as well as reference to representative cases will be employed to develop appropriate prediction models for the net pressure coefficient for these sunshade Types.

References

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

Standards Australia, (2021), "Structural design actions. Part 2 Wind actions", Australian/New Zealand Standard, AS/NZS 1170.2:2021.

Holmes, J.D., (2015), “Wind loading of structures”, 3rd Edition, CRC Press Boca Raton, Florida, USA