Nineteenth Australasian Wind Engineering Society Workshop, April 4-6, 2018, Torquay, Victoria

Wind Load Calculation Using AS/NZS 1170.2 and Shielding Parameter

Seifu Bekele

Global Wind Technology Services (GWTS), Melbourne, Australia

ABSTRACT

Wind load calculations using the Australian/ New Zealand Standard, AS/NZS 1170.2 are used for low, medium, and high-rise buildings. The predicted wind loads are mostly used as the final design value and are also used as the initial design input before the wind tunnel predicted value is available.

The Australian/ New Zealand Standard provides very good predictions in the case of simple geometry and surroundings. Researchers have presented several comparisons of the Standard against other standards and wind tunnel tests, finding that in most cases there is a reasonable agreement with wind tunnel values. However, most of the comparisons undertaken for simple geometry and surroundings in the case of complex geometry and in-built environment found that the predicted values differed widely from both the wind tunnel results as well as general experience-based expectations.

This paper presents wind load calculations based on the Australian/ New Zealand Standard and the effect of shielding parameters. This is illustrated with wind load predictions for different configurations where the shielding parameters plays varying roles. Comparison with other sources as well as the need for improvement in using this parameter will be presented.

1. Introduction

There is a large body of existing research regarding the understanding of wind load on buildings (Davenport, A.G., 1977, Melbourne, W.H., 1980, Holmes, J.D., 1981, Stathopoulos, T. et. al. 1994, , Ho. T.E.C., et al 1992). Based on such research, many countries have implemented building codes and standards to guide and control the design of structures. Such codes and standards include the Australian/New Zealand Standard (AS/NZS 1170.2), British standard (BS6399:Part 2), Eurocode (EN1991), Japanese Standard (AIJ), American standard (ASCE 7-05) and international standard (ISO 4354). The challenge for these standards include serving a growing built environment, complex shape and the increase in height combined with changes in construction material over time. Some standards have responded to these challenge by incorporating new findings, and have been able to serve both low-rise structures and high-rise buildings through their adaptations.

The Australian/ New Zealand Standard (AS/NZS 1170.2) is a well-developed document which aims to provide guidance in the design of structures by considering various characteristics of wind structure interaction. One of the parameter utilized by the Standard to consider wind load is a shielding parameter. This parameter is used to reduce a wind load when there is a significant number of buildings upstream of the subject structure. This is the only standard known to provide a shielding reduction for all structures. However, the standard warns that tall buildings with a certain combination may lead to local and overall increases in wind actions.

Shielding effect is a complex fluid structure problem; the shielding effect may increase or decrease the wind actions depending on the separation distance, locations of the shielding structures and the density of the shielding. Significant research has been presented under shielding or interference effects (Holms and Best, 1979, English E.C. 1990, Kim, C.Y., et. al. 2015). An early study on the influence of neighboring buildings by Harris, C.L. 1934 studied the influence of the neighboring buildings on the Empire State Building. He reported that the pressure on certain faces of the building was somewhat increased by the presence of the neighboring structures, resulting in pressure on the windward face and suction on the leeward face was decreased.

The presence of another building, or a group of buildings, has a greater impact, either beneficial or adverse, according to the relative position, width, and gap between it and the structure. This impact leads to complex flow. The interference effect on high rise buildings leads to building collapse, with such collapse occurring due to the impact of the interference effect on the curtain wall (Sparks et al, 1994, Yu X. F., 2015). An Increase of a negative pressure up to 1.8 times of isolated building on an 11-storey building were reported by Jozwiak et al. (1995) based on wind tunnel testing. Effects of neighboring buildings on wind load studies using wind tunnel testing on tall buildings reported an increase in alongwind wind loads of up to 10%-20%, crosswind wind loads of up to 30% and torsional moment increase up of up to 40% (Cho, K. et. al., 2004).

2. Australian/ New Zealand Standard (AS/NZS 1170.2:2011)

The Australian/ New Zealand Standard AS/NZS 1170.2:2011 is the only standard which has detailed parameters for taking the advantage of the shield effect. Throughout the updating of the standard over the years, the shielding parameter has not been altered significantly in the 1989 Australian Standard. The shielding parameter in AS/NZS 1170.2:2011 is described as follows:

"*Shielding multiplier (Ms) that is appropriate to a particular direction shall be as given in Table 4.3(in the Standard and as Table 1 in here). The shielding multiplier shall be 1.0 where the average upwind ground gradient is greater than 0.2 or where the effects of shielding are not applicable for a particular wind direction or are ignored.*

Attention shall be given to possible combinations of tall buildings which are placed together, and the overall increase in wind actions which can be caused by such buildings providing shielding

Table 1. Shielding Multiplier

TABLE 4.3	
SHIELDING MULTIPLIER (Ms)	
Shielding parameter	Shielding multiplier
(s)	(Ms)
≤ 1.5	0.7
3.0	0.8
6.0	0.9
≥12.0	1

Buildings within a 45^o sector of radius 20h (symmetrically positioned about the directions being considered) and whose height is greater than or equal to z shall be deemed to provide shielding.

Shielding parameter (s)

The shielding parameter (S) in Table 4.3 shall be determined as follows:

$$s = \frac{l_s}{\sqrt{h_s b_s}} \qquad (1)$$

Where

l_s *= average spacing of shielding buildings, given by:*

$= h\left(\frac{10}{n_s} + 5\right)$

h_s *= average roof height of shielding buildings*

b_s *= average breadth of shielding buildings, normal to the wind stream*

h = average roof height, above ground, of the structure being shielded

n_s *= number of upwind shielding buildings within a 45° sector of radius 20h and with* $h_s \geq z$

The 45° sector shielding area illustrated in 1989 Australian Standard AS/1170.2 is shown in Figure 1.

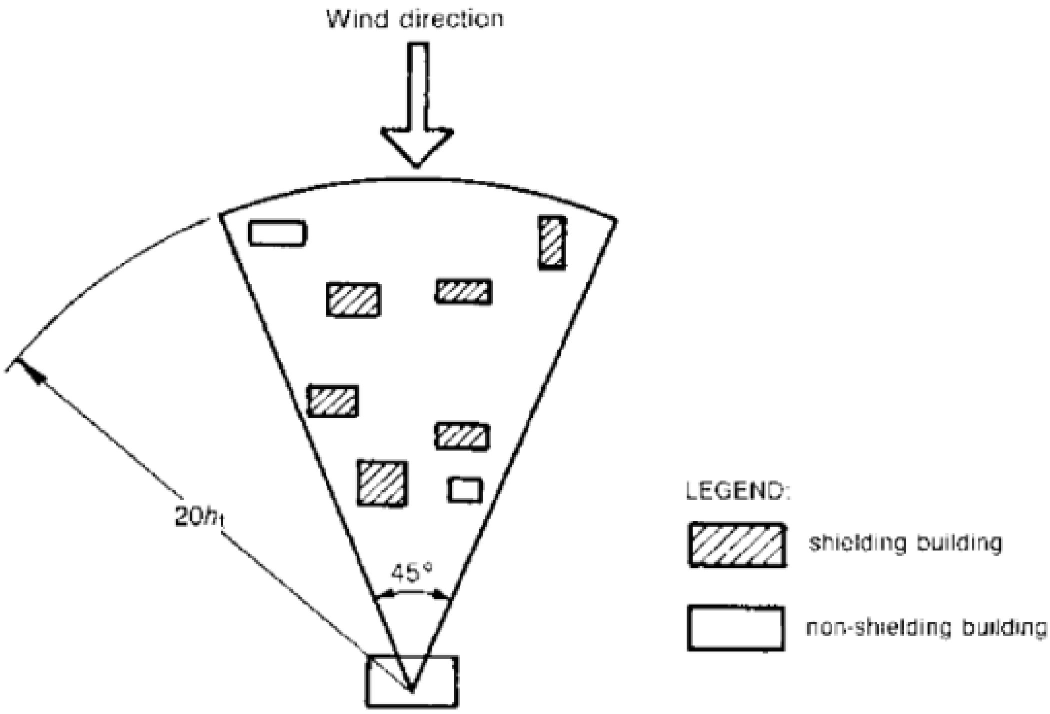

Fig. 1. The Shielding area sector (AS 1170.2 ,1989)

The shielding factor calculated by the above relations is multiplied with other parameters to define the site wind speed as shown in Equation 2. Since the shielding factor is connected with the site wind speed, the reduction due shielding has a square effect on wind loads. Thus, the maximum reduction set by the standard is 51% in wind loads.

$$V_{sit,\beta} = V_R \, M_d \, (M_{z,cat} \, M_s \, M_t) \qquad (2)$$

Where M_s is shielding Multiplier

3. Shielding Calculation using AS/NZS 1170.2

The shielding parameter as presented above considers the building height of the subject building, the number of buildings in 45° sector and the average height and width of the shielding buildings. The covered distance is defined by 20h, where h is the building height of the subject building. However, where the shielding buildings are located (within the sector - i.e. the actual distance from the subject building is not considered directly). Many researchers have pointed to the distance and the location of the shielding buildings in reduction or amplification of the wind response by the subject building. In this paper two types of configurations- low rise-buildings and high-rise buildings are investigated using CFD simulations.

The CFD simulation uses Reynold Stress turbulent model, mean inflow boundary of Category 3 profile with turbulent kinetic energy and dissipation rate profile as the boundary condition. Steady state simulation is used to investigate the relative difference between different configurations and to form a basis for further study.

The subject building and the shielding buildings have the same length and width, 10m by 15m. In Type A simulation, the subject building is 10m height and the shielding buildings are 20m height. There are five configurations in Type A simulation. The first configuration is an isolated building whilst the other configurations are single-row shielding at 10m, 50m, 100m and 200m away. All the buildings are inside the 45° requirement stipulated by the Standard AS/NZS 1170.2. The maximum distance of 200 is selected to correspond to 20h, the furthest point to be considered for shielding calculation. The in-between locations which are selected will provide the same shielding parameter, but are expected to have different wind effects on the subject buildings. The layout of different configurations is shown in Figure 2. The different Configurations in Type A is shown in Table 2.

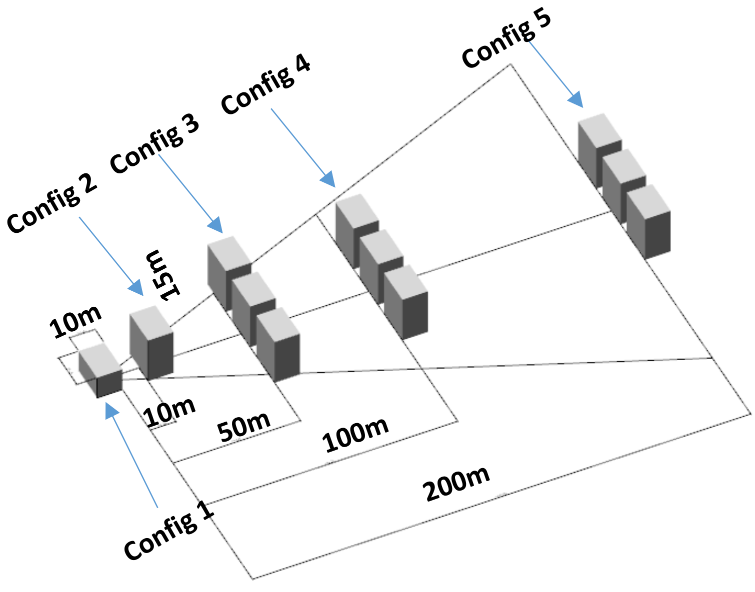

Fig. 2. CFD simulated configurations

Table 2. CFD simulated cases

Type	Configuration	Separation Distance	Main Building (W x D x H)	Shielding Building (W x D x H)
A	1	Isolated	15 x 10 x10	15 x 10 x20
	2	10m		
	3	50m		
	4	100m		
	5	200m		

The shielding parameter according AS/NZS 1170.2 for Type A arrangements are as follows:

h = 10, ns = 3, bs = 15, hs = 20

$l_s = h\left(\frac{10}{n_s} + 5\right) = 10\left(\frac{10}{3} + 5\right) = 83.3$ for Configuration 3,4 and 5

for Configuration 2, ns = 1, thus $l_s = 150$

$s = \frac{l_s}{\sqrt{h_s b_s}} = \frac{83.3}{\sqrt{20x15}} = 4.8$ for Configuration 3,4 and 5. For Configuration 2, s = 8.7

Using the above values, we will find the Shielding Parameter for AS/NZS 1170.2

M_s = 0.86 for Configuration 3,4 and 5. M_s = 0.95 for Configuration 2. Even though configuration 3,4 and 5 location form the subject building vary considerably, they have the same shielding parameter.

The CFD simulations for all cases evaluated are based on the Centerline of the front, top and back faces of the subject building. Figure 3 shows the pressure coefficients on the centerline. The pressure coefficients are formed based on the roof height wind speed of the subject building. From the figure we can see that the effect of the shielding buildings in Configuration 2 to 4 on the subject building is to change the windward wall from positive pressure to negative pressures while Configuration 5 shows a reduction in positive pressure at the front face. Kim, Y.C. et. al. 2015 has reported similar values pressure coefficients based on wind tunnel study on the of effect of the shielding buildings. These values are different form the standard shielding multiplier values. For Configuration 2, The Standard provide a Shielding Multiplier of 0.95, while you can observe the biggest effect on Configuration 2. Thus, the Standard need to address these cases resulted due to the upwind location of the shielding buildings with respect to the subject building.

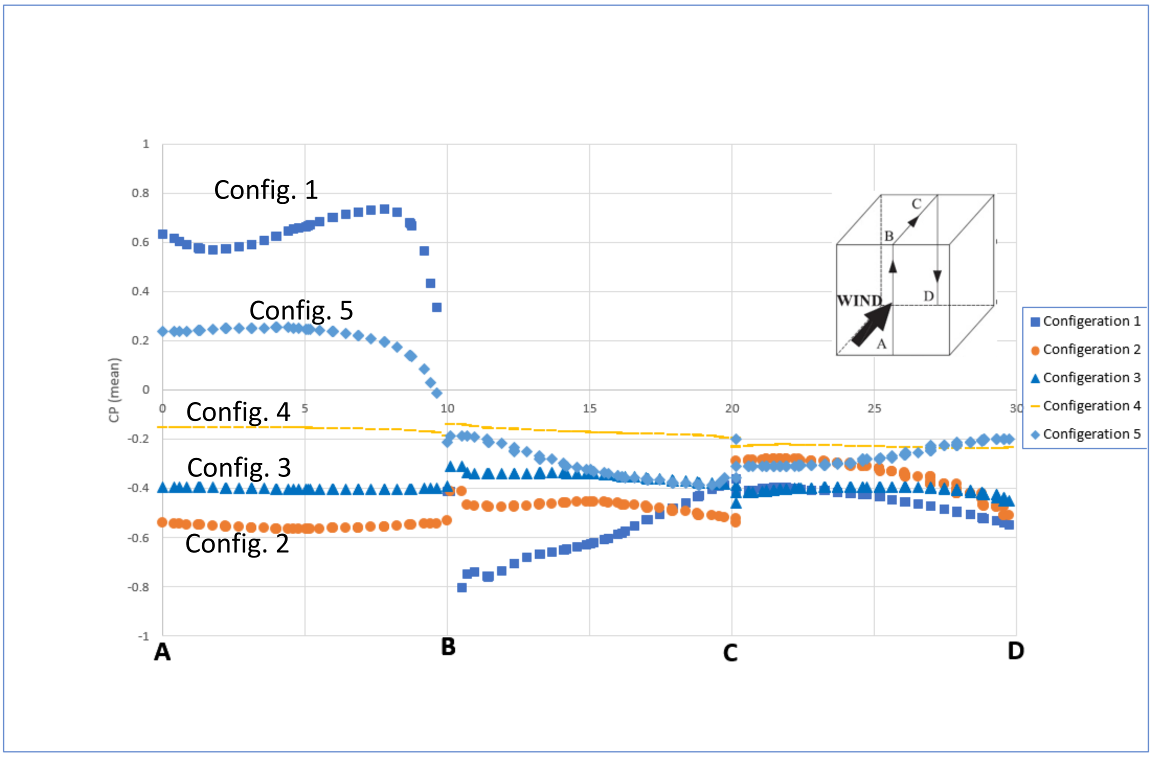

Fig. 3. Type A Cp Values Comparison

4. Conclusions

The shielding effect is the result of complex fluid structure interaction. Wind action may increase or decrease as per the density, separation distance, the height and location of the upstream buildings, with such finding having been shown by many researchers. AS/NZS 1170.2 is the only standard which considered the shielding factor to reduce the wind action. However, the parameter formulation doesn't include all factors contributing to shielding and interference effect. As a result it may lead to an underestimation of the wind loads.

In this paper CFD simulations were used to show the variation produced by the shielding structure as per their distance from the main building. Based on the literature review and the simulation presented here the author suggests a revision of the shielding parameter in As/NZS 1170.2. The following suggestions for changes are presented herewith:

1. Limit the shielding parameter applicability to low-rise buildings, buildings below 40m or their fundamental frequency are well above one.
2. Change the shielding parameter to relate to pressure coefficients rather than site wind speed.
3. Integrate the location of the building and separation distance in the Shielding Multiplier.
4. Revise the 20h distance based on the latest available wind shielding studies.
5. Include interference effect, particularly for high rise buildings sensitive to dynamic loads and their responses amplified by the buildings upstream. The risk of amplification is much higher than the benefit they get from reduction. Those interested in reducing the loads can use wind tunnel tests.

References

Anderson W., Meneveau C., (2010), "A large-eddy simulation model for boundary-layer flow with horizontally resolved but vertically unresolved roughness elements.", *Boundary-Layer Met.* 137:397–415

Cho, K., Hong, S., Hwang, K., (2004)," Effects of Neighboring Building on Wind Loads", CTBUH October 10-13, Seoul, Korea.

Davenport, A.G., (1977), "The Prediction of Risk under Wind Loading. Proceedings, 2nd. International Conference on Structural Safety and Reliability", Munich, 511-538

English, C.E., (1990), "Shielding Factors from Wind-tunnel Studies of Prismatic Structures.", J. Wind Eng. Ind. Aerodyn. 36, 611-619

Harris, C.L., (1934), "Influence of Neighboring Structure on the Wind Pressure on Tall buildings.", U.S. Department of Commerce Bureau of Standards, Research paper RP637, Part of Bureau of Standards Journal of Research, Vol. 12.

Ho, T.C.E., Surry D., Davenport A.G., (1992), "Low Building Wind Load Variability with Application to Codes.", J. Wind Eng. Ind. Aerodyn. 41-44, 1787-1798

Holmes, J.D., Best, R.J., (1979), "A Wind Tunnel Study of Wind Pressures on Grouped Tropical Houses.", James Cook University of North Queensland, Wind Engineering Report 5/79.

Holmes, J.D., Best, R.J., (1981), "Reduction Factors for Wind Directions for use in Codes and Standards.", Colloque, 'Construire avec le Vent', Nantes, France, 15-19 June 1981.

Holmes, J.D., (1983), "Wind Loads on Low Rise Buildings -A Review.", CSIRO, Division of Building Research, Report

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

Jozwiak, R. Kacprzyk. J., Zuranski, J.A., (1995)," Wind tunnel investigations of interference effects on pressure distribution on a building.", J. Wind Eng. Ind. Aerodyn. 57, 150-166.

Kim,Y.K., Tamura, Y., Yoon, S., (2015)," Proximity effect on low-rise building surrounded by similar-sized buildings." J. Wind Eng. Ind. Aerodyn. 146, 150-162

Melbourne W.H., (1980), "Comparison of Measurements on the CAARC Standard Tall Building Model in Simulated Model Wind Flows.", J. Wind Eng. Ind. Aerodyn. 6, 73-88

Sparks, P.R., Schiff, S.D., Reinhold, T.A. (1994), "Wind Damage to envelopes of houses and consequent insurance losses.", J. Wind Eng. Ind. Aerodyn. 53, 145-155.

Standards Australia, (2011), "Structural design actions. Part 2 Wind actions", Australian/New Zealand Standard, AS/NZS 1170.2:2011.

Stathopolos, T., Wu, H., (1994)," Knowledge-based Wind loading for envelope design: beyond building codes", J. Wind Eng. Ind. Aerodyn. 53, 177-188.

Yu, X.F., Xie, Z.N., Zhu, J.B., Gu, M., (2015), "Interference effects on wind pressure distribution between two high-rise buildings.", J. Wind Eng. Ind. Aerodyn. 142, 188-197