Wind loads

Structural provisions and loading

TOOLBOX

GREENHOUSE CONSTRUCTION AND SAFE OPERATION

Overview

Wind loads can prove particularly challenging for greenhouses in Australian conditions. It's important to note what the following terms mean:

- **Windward is toward the wind; toward the surface or point from which the wind blows**
- **Leeward is the side, surface or point to which the wind blows.**

Wind loads are covered by the AS/NZS 1170.2:2011 Structural Design Actions – Wind Actions. The objective of this Standard is to provide wind actions for use in the design of structures subject to wind action.

This fact sheet provides an overview of the best practice considerations, as well as an overview of the AS/NZS 1170.2:2011, before outlining specialist wind loading of porous canopy structures.

Best practice considerations

These best practice considerations mainly relate to low and medium technology greenhouses and grow structures rather than high technology. For further information on the technology levels please refer to the *Getting the basics right* toolbox fact sheet in this series.

Durability

Important considerations include, but are not limited to:

- All components of the structure should be chosen by taking into account the design working life of the structure and the environment where they will be in service. Ease and costs related to access to the components, should they need to be replaced, also needs to be considered
- Galvanized steel structures are quite durable, however other steel components, such as square hollow section (SHS) columns, should be provided with an appropriate paint system, for example specified with a 'Duragal' finish or alternatively galvanized.

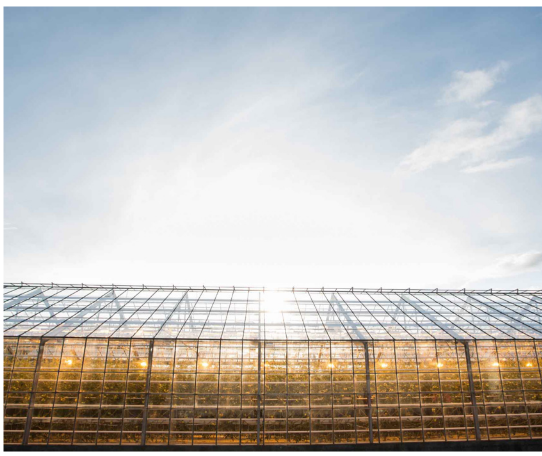
Foundations

Some points to consider include, but are not limited to:

- Each type of footing for a particular structure should be purpose designed (do not copy footing sizes from other areas where factors such as the design loads and soil type are likely to be different)
- Generally, footings in sand will usually be wider than those in clay due to the reduced bearing capacity
- Generally, footings in highly or extremely reactive soil will have additional depth and steel reinforcement to control soil heave movements
- The sides of footings should be close to vertical, wherever feasible

KEY MESSAGES

- Wind loads are covered by the AS/NZS 1170.2:2011 Structural Design Actions – Wind Actions, which outlines the design procedure, calculation of wind loads, regional wind speeds, and site exposure multipliers
- It's important to consider wind loads on durability, foundations, cable-guyed structures, cantilever post structures, hoop structures and igloo structures
- Recent research has provided significant breakthroughs in the effectiveness and design security of porous canopy structures



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- Extend the tops of footings at least 75 mm above finished ground level and provide a slope to the top surface.

Cable-guyed structures

Always check:

- Connections between cables: horizontal steel cables should be connected to each other to improve the overall stiffness of the cable grid system
- Connections to top of exterior columns: the tensile force in the inclined cable (assuming it is sloped at 45°) will typically be about 1.4 times larger than in the horizontal cable and so good practice is to ensure that the inclined cable is also at least 1.4 times stronger
- Connections to top of interior columns: horizontal cables are best run continuously from one exterior column to the other exterior column at the other end of the complete cable length. However, these cables need to be restrained to the tops of the interior columns
- Exterior footings for inclined cables: should be designed to resist the combined effects of the horizontal and uplift loads that will be applied by the inclined cable. In order to prevent:
  – Water pooling on the footer, the top of the footing should also be finished with a slight bevel/slope
  – Corrosion of the perimeter cable, the footing should be extended high enough off the ground so it's raised.

Cantilever post structures

It's important that:

- Horizontal top rails are a sufficient diameter so they will not buckle if subjected to compression loads. As a guide, ensure the ratio of the top rail length (i.e. distance between their supporting posts) to their diameter is not more than 100 and the pipe wall thickness is not less than 3 mm
- Galvanized bolts are considered in the top rails to prevent them becoming loose or applying tension elsewhere in the structure.

Hoop structures

It is recommended that pipe clamp joints use an extra 10 mm bolt installed through the clamp and the end wall mullion. This will add a higher degree of structural strength to wind loads.

Igloo structures

It is recommended that three sets of crossed tension roof bracing and three ties between the end and first internal frames should be used at both ends. This ensures the top of the end wall mullions are supported by struts/ties to transfer the wind loads from the end walls via the roof bracing to the wall bracing member.

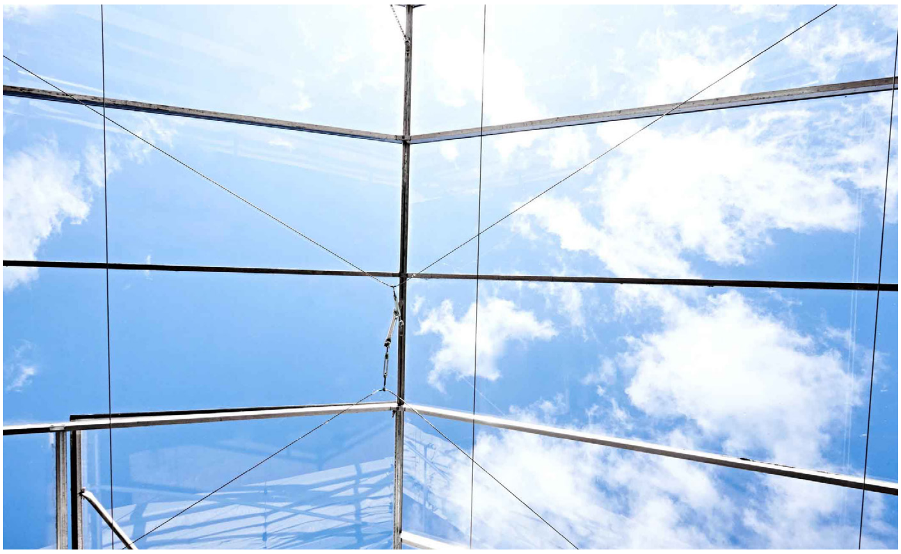
Design procedure

Design wind loads for greenhouses need to consider the:

- Basic wind speed (**V**)
- Velocity pressure ($\mathbf{q}_z$) where z is the height, which is calculated taking into consideration the exposure category, the surrounding terrain, the wind direction, and the occupancy of the structure
- Design wind pressure (**p**) which is calculated taking into consideration the direction of the wind, the exposure category, the height of the building or element, and the porousness and openness of the structure.

Calculation of wind loads

In order to determine the wind action (**W**) on greenhouse structures engineers need to:



- Determine site wind speeds ($\mathbf{V}_{sit,\ \beta}$): defined for the 8 cardinal directions (β) at the reference height (**z**) above ground
- Determine design wind speed from the site wind speeds ($\mathbf{V}_{des,\theta}$): which is taken as the maximum cardinal direction site wind speed ($\mathbf{V}_{sit,\beta}$) linearly interpolated between cardinal points within a sector ±45 degrees to the orthogonal (right angle) direction being considered
- Determine design wind pressures (Pa in Pascals) and distributed forces (drag force per unit area f in pascals)
- Calculate wind actions based on:
  – Directions to be considered
  – Forces on surfaces or structural elements (e.g. wind pressure, frictional drag, force coefficients)
  – Forces and moments on complete structures
  – Performance of fatigue-sensitive elements
  – Serviceability of wind-sensitive structures.

The structure types and associated importance levels are outlined in Table 1 below.

Table 1: Classification of greenhouses for importance levels as per AS/NZS 1170.0:2002

CONSEQUENCES OF FAILURE	DESCRIPTION	IMPORTANCE LEVEL	COMMENT
Low	Low consequence for loss of human life, or small or moderate economic, social or environmental consequences	1	Minor structures (failure not likely to endanger human life)
Ordinary	Medium consequence for loss of human life, or considerable economic, social or environmental consequences	2	Normal structures and structures not falling into other levels
High	High consequence for loss of human life, or very great economic, social or environmental consequences	3	Major structures (affecting crowds)
		4	Post-disaster structures (post disaster functions or dangerous activities)
Exceptional	Circumstances where reliability must be set on a case by case basis	5	Exceptional structures

TOOLBOX
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Regional wind speeds

Regional wind speeds (V_R) for all directions based on three second gust wind data are outlined in the table and figure below.

Table 2: Regional wind speeds[1]

REGIONAL WIND SPEED (M/S)	REGION				
	NON-CYCLONIC			CYCLONIC	
	A (1 to 7) Southern and inland Australia	W	B Inland northern Australian coast	C Northern Australian coastline	D West coast north of Perth
V_5	32	39	28	F_C 33	F_D 35
V_{10}	34	41	33	F_C 39	F_D 43
V_{20}	37	43	38	F_C 45	F_D 51
V_{25}	37	43	39	F_C 47	F_D 53
V_{50}	39	45	44	F_C 52	F_D 60
V_{100}	41	47	48	F_C 56	F_D 66
V_{200}	43	49	52	F_C 61	F_D 72
V_{500}	45	51	57	F_C 66	F_D 80
V_{1000}	46	53	60	F_C 70	F_D 85
V_{2000}	48	54	63	F_C 73	F_D 90
V_R	$67 - 41R^{-0.1}$	$104 - 70R^{-0.045}$	$106 - 92R^{-0.1}$	F_C x $(122 - 1\text{-}4R^{-0.1})$	F_D x $(156 - 142R^{-0.1})$

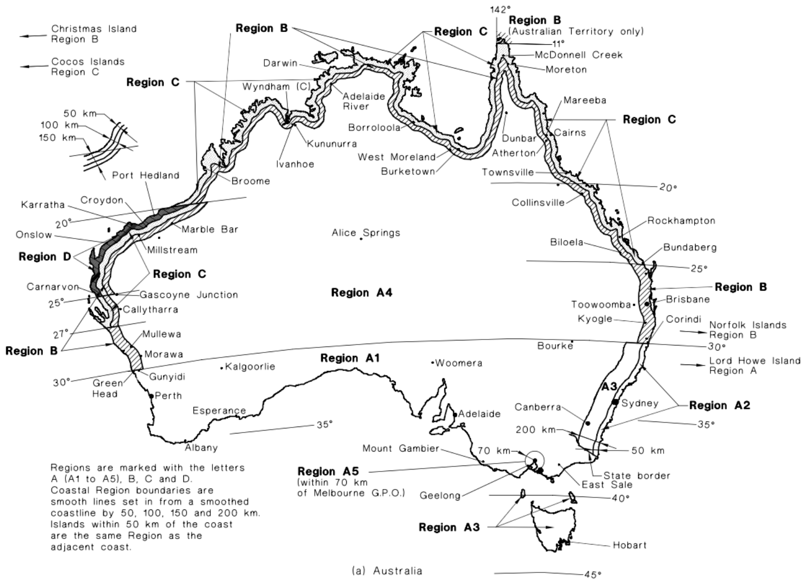

Figure 1: Wind regions in Australia in accordance with AS/NZS 1170.2:2011

Regional wind speeds also need to consider the:

- Wind direction multiplier (**M_d**)
- Wind speed factors in cyclonic zones (regions C and D), which are:
  – For ultimate limit states wind speeds, **F_D** = 1.1.
  – For ultimate limit states wind speeds, **F_C** = 1.05.
  – For serviceability limit states wind speeds, FC and **F_D** = 1.0.

[1] Where R (average recurrence interval) is the inverse of the annual probability of exceedance of the wind speed (i.e., P for ultimate or serviceability limit states).

Site exposure multipliers

Engineers may also need to calculate the exposure multipliers relating to site conditions related to:

- Terrain/height ($M_{z,cat}$) over which the approach wind flows towards a structure, which includes:
  – Category 1: exposed open terrain with few or no obstructions
  – Category 2: water surfaces, open terrain with scattered obstructions (1.5-10m high)
  – Category 3: terrain with a number of closely spaced small obstructions (3-5m high)
  – Category 4: terrain with a number of closely spaced large obstructions (10-30m high)
- Shielding (M_s) is 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
- Topography (M_t).

The design must take account of known future changes to terrain roughness when assessing terrain category as well as protected cropping structures providing shielding.

Specialist wind loading of porous canopy structures

Porous canopies are those structures covered by woven net and the resilient, lightweight, tensile systems provide great structural efficiency. However, they are not appropriately covered by the standard AS/NZS 1170.2:2011 Structural Design Actions – Wind Actions. Recent research has provided significant breakthroughs in the effectiveness and design security of these structures.

The key findings of the recent research undertaken by Osborn (2016) are:

- Reduction in the magnitude of the wind action on the roof from increasing the porosity of the canopy compared to a non-porous canopy
- Redistribution of wind action on the walls from increasing the porosity due to the flow of wind in and out of the canopy interior, rather than a reduction
- Less separation or disturbance of the wind at the wall to roof intersection than would occur on a non-porous structure.

This has provided a strong basis for the structural design of large flat roofed porous canopies for normal wind actions in Australia, which will assist engineers to design safer protected cropping structures.

IMPORTANT QUESTIONS TO ASK

- What is the basic wind speed in my region?
- Does the designer have experience with assessment of wind loads under the local conditions?
- Has the designer or manufacturer of my new greenhouse considered AS/NZS 1170.2:2011 Structural Design Actions – Wind Actions?
- Is the new structure certified to AS/NZS 1170.2:2011 standards?
- What are the main areas of my structure that are subject to wind loads? Are durability, foundations, cable-guyed structures, cantilever post structures, hoop structures and igloo structures all relevant?

REFERENCES AND FURTHER READING

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