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TECHNICAL REPORT

Research and Revisions in AS/NZS 1170.2 - 2021

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ABSTRACT – This paper summarises activities in the area of Wind-Structural Engineering in Australia between 2012 and 2021, including the work, carried out for Standards Australia and research at Universities in Australia. The main changes are; the redefinition of wind regions and the recalculation of wind direction multipliers in Section 3, refinement of terrain height, shielding and topographic multipliers in Section 4, inclusion of an open area volume factor for internal pressure and changes to the local pressure factor and area reduction factors in Section 5, new data for along-wind and cross-wind response of slender structures in Section 6, and revised data for curved roofs and new data for open conical roofs and ground mounted solar panel arrays in the Appendices. These revision are based on research carried out in this period.

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ACTIVITIES OF THE STANDARDS AUSTRALIA COMMITTEE BD 6/2 FOR AS/NZS1170.2

The Standards Australia committee for the wind loading standard AS/NZS1170.2 (Chaired by Prof John Holmes) reviewed and published AS/NZS1170.2:2021 [1]. This revision was carried out over period of more than 3 years preceding its publication in August 2021. Extensive public consultation was carried out followed by a cost benefit assessment by the Australian Building Codes Board and the ratification by each State prior to publication. Table 1 shows this process Chaired by John Holmes with Secretarial support from Standards Australia was carried out by Working Groups (WGS) that were responsible for Sections in AS/NZS1170.2:

Table 1. Working Groups.

Working Group (WG)	Convener
WG Section 1 and 2	Mark Edwards
WG Section 3	Bruce Harper
WG Section 4	John Holmes
WG Section 4.3	Matthew Mason
WG Section 4.4	Richard Flay
WG Section 5	John Ginger
WG- Section 6	Tony Rofail
WG Appendix A and B	Phil Blundy
WG Appendix C	Graeme Wood
WG Appendix D	John Ginger
WG Appendix E	John Holmes

This Section describes the work carried out by Working Groups (WGs) dealing with the main Sections and the Appendices of the previous version of AS/NZS1170.2:2011 [2]. The changes have mainly resulted from recent research work from Australasia and other parts of the world, in addition to changes in format and notations. These changes are also posted at: https://youtu.be/DfJx830H9JA.

Changes to Layout and Format

The layout and format of AS/NZS1170.2:2011 [1] has changed from the previous version. The 'Definitions' and 'Notations' have moved from the Appendices A and B to the front end of the document. The Aerodynamic Shape factor, C_{fig} has changed to C_{shp} throughout the document. Appendices C, D and E become Appendices A, B and C.

Changes to SECTION 2

Clause 2.5.5 (Stress exceedances): Clarification of the application of this clause for fatigue assessment.

Clause 2.5.8 (Windborne debris): Changes to missile test speeds when the impacted surface is not vertical.

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Changes to SECTION 3

Clause 3.1 (Regional wind speed according to Figure 1): 'Uncertainty' factors, 'F_C' and 'F_D', for cyclone regions removed. New regions A0, B1 and B2 are defined with some boundary changes. Region A0 (inland Australia), Region B split to form B1 – SE Queensland (thunderstorm dominated and extended west to 200km) and B2 - tropical cyclones. Interpolation of regional wind speed across Cyclone Regions C and D, according to the distance from the smoothed coastline. For Cyclone Regions C and D only Maximum values of V_R listed in Table 1. Lower values can be used depending on the distance from coastline.

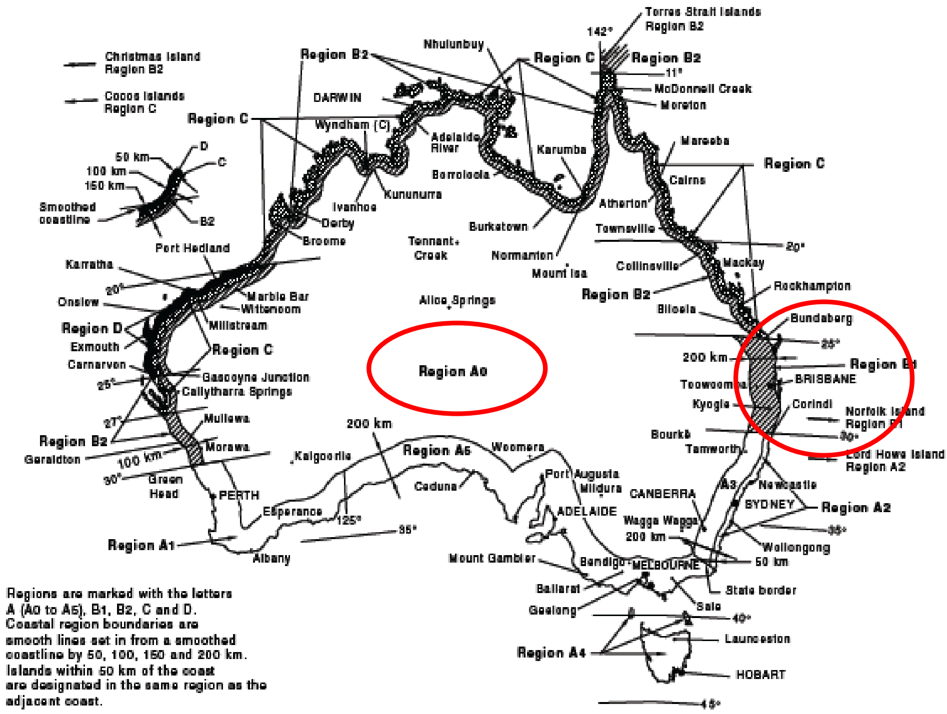

Figure 1. Wind Regions – Australia.

Clause 3.3 (Wind direction multiplier M_d): Values have been re-calculated for all regions. Value of 1.0 specified for chimneys, tanks and poles and for cladding in Regions B2, C and D.

Clause 3.4 (Climate change multiplier, M_c): New multiplier, M_c = 1.05 introduced for Cyclonic regions B2, C and D.

Changes to SECTION 4

Clause 4.2 (Terrain-height multiplier, $M_{z,cat}$): Terrain Category 1.5 removed from descriptions. All over-water surfaces defined as Terrain Category 1. $M_{z,cat}$ values for Terrain Category 2.5 included in Table 4.1. In Region A0 (Central Australia) only Terrain Category 2 can be used.

Clause 4.3 (Shielding multiplier, M_s): M_s = 1.0 for buildings with heights > 25m. Restricted definitions of shielding buildings on steep hills.

Clause 4.4 (Topographic multiplier, M_t): Reduced values of M_t for structures in Region A0 (Central Australia).

Changes to SECTION 5

Clause 5.3 (Internal pressures): $C_{p,e}$ in Table 5.1(B) replaced by $C_{p,e}$. K_a. K_l. New Clause 5.3.4 added to define open area volume factor, K_v.

Clause 5.4.2 (Area reduction factor, K_a): K_a < 1.0 added for windward and leeward walls.

Clause 5.4.4 (Local pressure factor, K_l): Additional case– RC2 added at ridge-downwind corner of pitched gable roofs. Definition of '*a*' changed for very large roofs.

Changes to SECTION 6

Clause 6.2 (Along-wind response): New Clause 6.2.3 added for towers, poles & masts. New Clause 6.2.4 added for horizontal slender structures.

Clause 6.3 (Cross-wind response): New Clause 6.3.2.3 defines changes to C_{fs} for three cross sections (tall buildings). New Clause 6.3.3 describes more advanced method for obtaining loads on chimneys, masts and poles.

Changes to APPENDICES

Appendix A, Table A3 (formerly C3): Revised shape factors provided for curved roofs.

Appendix B, New Section B3.3: Shape factors provided for conical free roofs.
Appendix B, New Section B6.2: Shape factors provided for inclined solar panel arrays on ground ('solar farms').

Appendix C, Section C2.3 (formerly E2.3): Advice on wind loads for 'porous' industrial complexes provided.

MAJOR RESEARCH STUDIES

This Section describes research projects carried out on Wind-Structural Engineering at Universities in Australia. PhD thesis resulting from these projects are also listed.

James Cook University, Cyclone Testing Station.
The Cyclone Testing Station at James Cook University in Townsville has carried out a number of large research projects dealing with wind loading and structural response and damage/vulnerability.

CSIRO Flagship project: Engineering and vulnerability modelling of structures to extreme winds in collaboration with Uni Newcastle, UNSW, Swinburne and UWA. Investigators: John Ginger, David Henderson, Mark Stewart:

This project obtained wind loads from wind tunnel model tests and applied simulated loads on typical full-scale timber framed contemporary house structures and determined the load distribution and transfer within the structural system. The data is used for assessing the performance of these house types under increasing wind loads.

PhD: Satheeskumar, Navaratnam (2016) *Wind load sharing and vertical load transfer from roof to wall in a timber-framed house.*

BNHZ-CRC project: Improving the resilience of existing housing to severe wind events, in collaboration with GeoScience Australia. Investigators: John Ginger, David Henderson, Martin Wehner, Mark Edwards:

This project obtained wind loads from wind tunnel model tests and developed a software package called Vulnerability and Adaptation to Wind Simulation (VAWS) that uses data from full scale structural testing to determine load distribution and progressive failure of a range of typical at risk house types and determines the damage index. The project also provides a range of practical retrofit options and calculates the benefit-costs of carrying out these measures.

PhD: Parackal, Korah Ipeson (2018) *The structural response and progressive failure of batten to rafter connections under wind loads.*

ARC Linkage project: Optimization of internal pressure for designing industrial buildings in collaboration with Australian Steel Institute (ASI). Investigators: John Ginger, David Henderson, John Holmes, Scott Woolcock:

This project studied the internal pressures in typical steel frame steel clad sheds with a range of wall openings in full scale. In addition, the correlation of external internal and resulting net pressures on various parts of a building was studied at model scale.

PhD: Humphreys, Mitchell (2020) *Characteristics of wind-induced internal pressures in industrial buildings with wall openings*.

PhD: Bodhinayake Geeth (2021) *Correlation of internal and external pressure fluctuations in industrial buildings*.

University of Western Sydney and University of Sydney
ARC Discovery Project: Bushfire-enhanced wind and its effects on buildings. Investigators: Professor Kenny Kwok, Dr Yaping He:

This research project aimed to identify the mechanisms governing bushfire-wind interaction and determine the wind load effects on buildings due to bushfire-enhanced wind. Using a fire-induced force and acceleration analysis, numerical simulation and a fire-wind tunnel test facility, we showed that wind-fire interaction caused significant increases in the wind velocity and changes to the wind velocity profile at near ground downstream of a fire source. We also identified the effects of wind velocity, fire intensity, fire-source configuration, and terrain slope on the fire-induced wind enhancement. We have developed a customised and benchmarked computational platform adapted to study the wind loads on buildings due to bushfire-enhanced wind.

PhD: Esmaeel Eftekharian: (2020) *Investigation of Buoyant Plume Wind Enhancement*.

Project: An Uncoupled Fluid-Structure Interaction Numerical Framework to Estimate Wind Induced Loads on Super-tall Structures Investigators: Dr. Damith Mohotti, Dr. Ali Amin, Dr. Kapil Chauhan:

This research studied and presented a novel numerical framework to determine structural responses of wind sensitive structures via an uncoupled Fluid Structure Interaction (FSI) technique. Experimental wind tunnel measurements of slender structures using multi-degree of freedom (MDOF) aeroelastic models subjected to turbulent wind was used for validation. The proposed numerical framework and technique was able to replicate similar outcomes to that measured experimentally. These outcomes were obtained at a low computational cost thus making it a viable tool to be used in practical engineering applications.

PhD: Kasun Wijesooriya: *An Uncoupled Fluid-Structure Interaction Numerical Framework to Estimate Wind Induced Loads on Super-tall Structures.*

POST WINDSTORM DAMAGE INVESTIGATIONS

Cyclone Yasi [3]

Tropical Cyclone Yasi (TC Yasi) made landfall on 3 February 2011 with the eye passing over the Mission Beach region. The maximum wind gusts were estimated at 140 to 225km/h across the area stretching from Townsville to Innisfail. The range of wind speeds across the impacted region was estimated at 55% to 90% of design wind speed 250 km/h. Buildings designed and constructed to the standards introduced in the 1980s performed well. Typically less than 3% of all Post-80s houses in the worst affected areas experienced significant roof damage, whilst more than 12% of the Pre-80s housing had significant roof damage. Recommendations are made for the upgrading of Pre-80s housing to improve the resilience of communities along with ongoing maintenance programs. The low incidence of damage to Post-80s houses indicates that the current building practices are able to deliver a satisfactory outcome for most of the building at these load levels. Water ingress through the building envelope is evident in these situations, and materials and fittings should be selected with a view to their resilience to wind-driven rain.

Brisbane Storm [4]

Two adjoining storm cells moving in a northerly direction subjected Brisbane and neighbouring suburbs to severe hail, damaging winds and localized flooding on the 27 November 2014. A maximum gust wind speed of 141km/h was measured at Archerfield Airport, with speeds estimated to be approximately 40 to 80km/h in other affected suburbs. Severe hail (40 mm diameter typical) accompanied the storm causing damage to windows and water ingress particularly in older housing, with older window glass performing poorly against the wind-driven hail. Another contributing factor was the significant horizontal component in the trajectory of the hail caused by the strong winds. Most of the observed damage was due to hail, fallen trees and downed power lines. Damage estimates by the state government were revised to over $1billion, with over 100,000 insurance claims submitted. Although winds were lower than design level, some cases of significant roof damage did occur, due to (i) building age with rot in timber roof members and/or corrosion of connections or (ii) installation of new roof cladding (in some cases replacing tile with metal cladding) without upgrading the tie down connections to contemporary building standards. Roof structure damage was typically associated with a breach in the windward wall generating a large increase in internal pressure and adding to the external suction loads on the roof.

Cyclone Debbie [5]

Tropical Cyclone Debbie crossed the Queensland coast north east of Airlie Beach on 28 March 2017. The Cyclone Testing Station deployed six mobile anemometers (SWIRLnet) in the area between Ayr and Proserpine. And investigated the performance of houses; larger residential structures such as apartments, strata properties and resort accommodation; commercial and public buildings; and sheds in the affected areas. A wind field developed using anemometer data showed that buildings within the study area experienced wind speeds lower than their relevant design wind speed. Inadequate tie-down details between battens and rafters or trusses, and between the roof structure and walls caused many of the structural failures in buildings constructed before the 1980s. Tie-down connections between roof structure and walls that had been inappropriately detailed also failed on some recently constructed buildings. This study reaffirmed the findings of previous damage investigations concerning the vulnerability of components. Newer buildings reported significant damage from wind-driven rain entering the building even though there was little structural damage.

Cyclone Seroja [6]

Tropical Cyclone Seroja crossed the Mid-West coast of Western Australia near Port Gregory on 11 April 2021. TC Seroja caused extensive damage to buildings in coastal and inland towns. The study focused on the performance of houses built since the late 1990s in Kalbarri, Northampton, and Port Gregory but included other buildings such as apartments, strata properties and commercial buildings. The report describes the impact of a tropical cyclone on communities in Wind Region B and highlights the need to review Australian codes, standards and building practices for this region. Analysis data indicated that the maximum wind speed over land was between 46 and 51 m/s (166 to 184 km/h) at Kalbarri, around 80 to 90% of the design wind speed. The wind speed over Morawa, the town along cyclone track in Wind Region A that experienced the highest wind speed was estimated to have been 37 m/s (134 km/h) which is between 80% and 90% of the design wind speed for houses. Around 10% of buildings in Kalbarri and Northampton had damage classified as 'severe'. The performance of roofs significantly influenced the level of overall damage to buildings. Some newer houses in Kalbarri had structural damage. The main cause of severe structural damage to houses in Kalbarri was the combination of large suction on the roof and an increase in internal pressure created by an opening in the building envelope (usually from wind-borne debris breaking a door or window in a windward wall). Houses in Wind Regions A and B that are designed using AS 4055 have N wind classifications that are based on low internal pressures. Because the tie-down connections in the roofs of many of the buildings were designed assuming low internal pressure, they were not strong enough to cope with the higher loads that were applied when a door or window broke. The report recommends that Wind Region B is classified as cyclonic in AS/NZS 1170.2 and AS 4055. The design wind speeds would remain the same, but designers would use higher internal pressures applicable for buildings with openings, enabling buildings to comply with the robustness requirements.

CONCLUSIONS

Activities in the Wind-Structural Engineering area in Australia, in the period of 2012 to 2021 is presented in this paper, including the main changes in AS/NZS 1170.2 (2021). A summary of these changes are:

the redefinition of wind regions and the recalculation of wind direction multipliers in Section 3, refinement of terrain height, shielding and topographic multipliers in Section 4, inclusion of an open area volume factor for internal pressure and changes to the local pressure factor and area reduction factors in Section 5, new data for along-wind and cross-wind response of slender structures in Section 6, and revised data for curved roofs and new data for open conical roofs and ground mounted solar panel arrays in the Appendices. These revision are based on research carried out in this period.

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