Technical Guidance Document

Assessment of buildings as a Place of Refuge for Cyclones

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James Cook University Australia
Cyclone Testing Station
Queensland Government

Contents

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1. Introduction

The Department of Energy and Public Works (DEPW) *Places of Refuge: Guidance on site selection* (2023) provides broad guidance on the identification of buildings that may be designated as places of refuge.

DEPW engaged the Cyclone Testing Station (CTS) to prepare a process for a third party to assess the likely performance of buildings to the criteria detailed in the *Places of Refuge: Guidance on site selection*. The objective of the resilience assessment is to inform local councils about risks associated with using a building as a place of refuge to accommodate people during an extreme wind event such as a tropical cyclone. The process uses analytical techniques and a series of questions to evaluate many factors that affect the resilience of buildings.

It is assumed that the local councils will have considered the information in the Guidance on Selection document to identify buildings with suitable siting requirements. Once those elements have been considered this document can be used to deliver a more focused assessment of the structural components of the building.

This Technical Guidance Document identifies key building issues that affect the resilience of buildings to severe wind events and includes an explanation of why particular elements in the building are vulnerable to wind damage. It highlights the importance of checking specific elements and details and their role in contributing to the resilience of the building. Most importantly, it is designed to be as simple as possible and to aid consistency of assessments between buildings. The assessment process does not include inspection of all aspects of the building's structural components. Experience of the user is required to evaluate the appropriateness of the building's components hidden within the clad or concrete structure.

Use of the Guidance on Selection document and this Resilience assessment guidance cannot eliminate the chance of the building suffering damage. The assessment guidance is intended to provide a mechanism to compare the suitability of an existing building as a place of refuge to the location a resident would otherwise be in (e.g. a house or caravan, etc.).

1.1 Scope

The assessment process covers buildings or parts of buildings in Queensland. It is applicable to:

- Multi-storey or single storey buildings
- Sheds, warehouses, and workshops
- Buildings with office-like activities
- Largely open buildings such as leisure centres
- Community centres and halls.

A separate assessment is completed for each building on the property. (Where a property contains several identical buildings, a representative assessment may be performed on one of these building.)

The hazards included are:

- Wind loads (including tropical cyclones); and
- Wind-driven rain.

The assessment of the suitability of the building against direct impacts of flood, storm surge or bushfire is outside the scope of this document.

- Buildings that are designated as places of refuge for tropical cyclones should be above the estimated maximum high-water mark for combined flash flooding, riverine flooding, and storm surge. (All three sources of inundation can occur simultaneously in tropical cyclones.) An assessment on the suitability of a particular building with respect to inundation risk is outside the scope of this document and should be undertaken by an appropriately qualified person.

- Places of refuge may also need to be located outside bushfire-prone areas or have features that make them bushfire resistant. An assessment on the suitability of a particular building with respect to bushfire risk is outside the scope of this document and if required, should be undertaken by an appropriately qualified person.

1.2 Use of the assessment

Buildings can be prioritised for an assessment based on age, location, size and function of the building. It may prove economical to perform assessments in conjunction with other condition assessments on the site.

The assessment involves undertaking:

- A wind load evaluation to AS/NZS 1170.2:2021 (Standards Australia, 2021) for the building.
- A comparison of wind loads with capacities of key cladding and structural elements in the building.
- Questions on the resilience and condition of other elements in the building.
- An assessment of the outcomes and answers to rank the building as to its likely performance as a place of refuge.

A local council could evaluate candidate buildings in a specific location and rank them using the performance criteria, and then select the most resilient buildings and undertake mitigation if required.

As many features of the building do not change over the life of the building, a future update assessment could involve checking that the building has not been altered since the initial assessment and answering only the condition questions.

The same process could be used to evaluate the resilience of buildings during the planning and design stage. This will indicate features or elements that may be less resilient. Designers can select alternative materials or elements and then check the resilience of the modified design.

2. Background Information

2.1 Tropical cyclones and places of refuge

Windstorms can be broadly classified as: tropical cyclones, thunderstorms, tornados, and gales. Tropical cyclones generally impact coastal regions in the tropics but have been recorded as far south as northern NSW. In 1954 a tropical cyclone crossed the coast at the Gold Coast. Tropical cyclones are large scale events:

- The damage footprint is large and can exceed the area of a single local authority.
- They are long-lived events. Typically, a 48-to-24-hour warning is issued for a coastal crossing. If a tropical cyclone was predicted to cross the coast at a significant population centre, there may be sufficient warning to evacuate people from the most vulnerable areas and activate places of refuge.

The warning time associated with other high wind events such as thunderstorms and gales is generally not long enough to activate places of refuge. Therefore, they will mainly be used when a tropical cyclone is forecast.

Tropical cyclones can produce very high rainfall, and storm surges (the ocean surface at the shoreline can be elevated by a few metres). The combination of these effects means that places of refuge must be located well above flood and storm surge levels and cope with both extreme wind speeds and wind-driven rain.

A consequence of extended periods of very strong winds in tropical cyclones is that debris can be carried by the wind and impact buildings. Therefore, places of refuge should satisfy the following performance requirements to offer a measure of safety to occupants during a tropical cyclone:

- Have an envelope that remains substantially intact.
- Have a structural system that survives the event.
- Minimise the chances of injury to those inside.

The safety risks to occupants include injuries from building damage or impact from wind-borne debris and injuries that can be attributed to water ingress (e.g., occupants slipping and falling, or a wet ceiling collapsing on occupants).

2.2 Wind actions on places of refuge

Structural designers evaluate wind actions using the Australian and New Zealand Standard AS/NZS1170.2:2021 (Standards Australia, 2021). The National Construction Code (NCC) (Australian Building Codes Board 2022) sets the design level that is a function of the importance of the building. The level of loading is linked to the ‘annual probability of exceedance’ and it is prescribed in Table B1.2b in Volume 1 of the NCC. The importance level of a building is linked to Table B1.2a. These tables are shown in Figure 1.

Few public buildings may be specifically designed to accommodate many people during a high wind event, but, by definition, every place of refuge is expected to accommodate a large number of people while the strong winds are affecting the building.

If the opportunity arises to design a building as a place of refuge, it is appropriate to specify it as least an importance level 3 building. However, in making use of an existing building it is recognised that it may not have been designed as an importance level 3 building.

Importance level	Annual probability of exceedance for non-cyclonic wind	Annual probability of exceedance for cyclonic wind	Annual probability of exceedance for snow	Annual probability of exceedance for earthquake
1	1:100	1:200	1:100	1:250
2	1:500	1:500	1:150	1:500
3	1:1000	1:1000	1:200	1:1000
4	1:2000	1:2000	1:250	1:1500

Importance level	Building types
1	Buildings or structures presenting a low degree of hazard to life and other property in the case of a failure.
2	Buildings or structures not included in Importance Level 1, 3 and 4.
3	Buildings or structures that are designed to contain a large number of people.
4	Buildings or structures that are essential to post-disaster recovery or associated with hazardous facilities.

Figure 1 – Excerpts from NCC 2022 Volume 1

Figure 2, below, shows wind regions as defined in AS/NZS 1170.2:2021 (Standards Australia, 2021). For example, the Sunshine Coast, Brisbane and Gold Coast are in wind region B1. Atherton is in B2 and Rockhampton, Townsville, Cairns and Karumba are in wind region C.

Both wind regions B1 and B2 would have design regional wind speed derived from severe thunderstorms and tropical cyclones. Wind region C design wind speed is derived from tropical cyclones.

AS/NZS 1170.2 (Standards Australia, 2021) has always had requirements for the use of high internal pressure coefficients in the design of buildings in wind region C and D, but they were not mandated for wind region B1 or B2. As a result, most buildings in wind region B1 and B2 are designed for lower internal pressures.

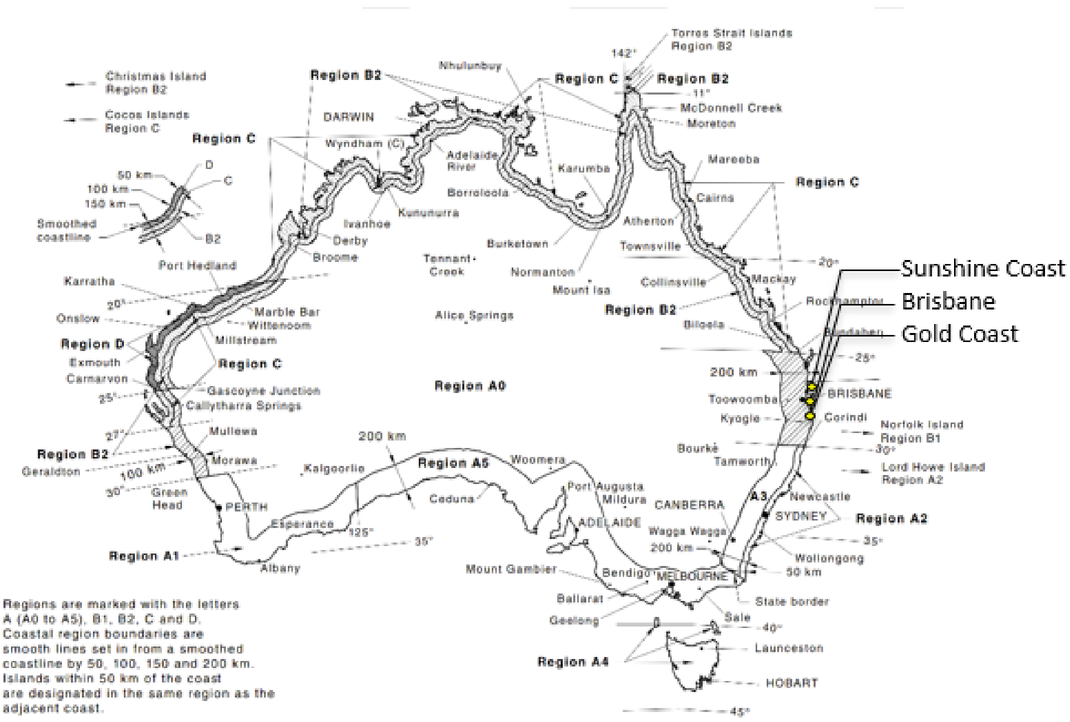

Figure 2 – Wind regions in Australia from Fig 3.1(A) in AS/NZS 1170.2:2021

2.3 Internal pressures in places of refuge

Structural designers should anticipate realistic scenarios of openings in the building envelope when calculating internal pressures.

The external pressures on a building in a wind stream are represented in Figure 3, with arrows away from the surface showing suction. Suction on the roof applies upward forces that can lift the roof if it isn't tied down properly. The wind applies pressure towards the surface on only the windward walls, tending to push those walls into the building. Figure 3 shows a sealed building; there are no significant openings that would allow air into the internal spaces and the internal pressures in this scenario are generally low with positive internal pressure coefficients of around +0.2 to 0 and negative internal pressure coefficients of – 0.2 to – 0.3.

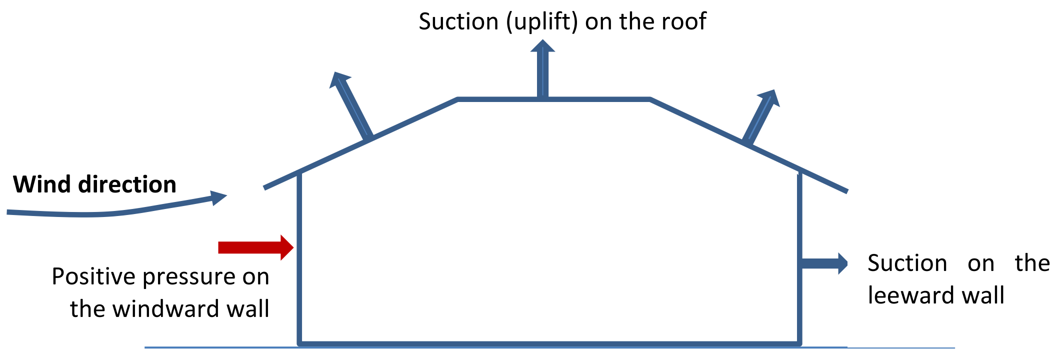

Figure 3 – Typical external pressures on a sealed building

If there is an opening in a windward wall (e.g., caused by a window or door left open or broken by wind-borne debris), the internal pressure increases. This situation is illustrated in Figure 4 and shows that the net pressure across the roof is the sum of upward pressure on the underside of the roof and upward suction on the upper side of the roof. The net pressure on the roof in Figure 4 is significantly higher than the net pressure in Figure 3. Therefore, openings in the windward wall can substantially affect the net pressures and therefore, the loads on all the building elements.

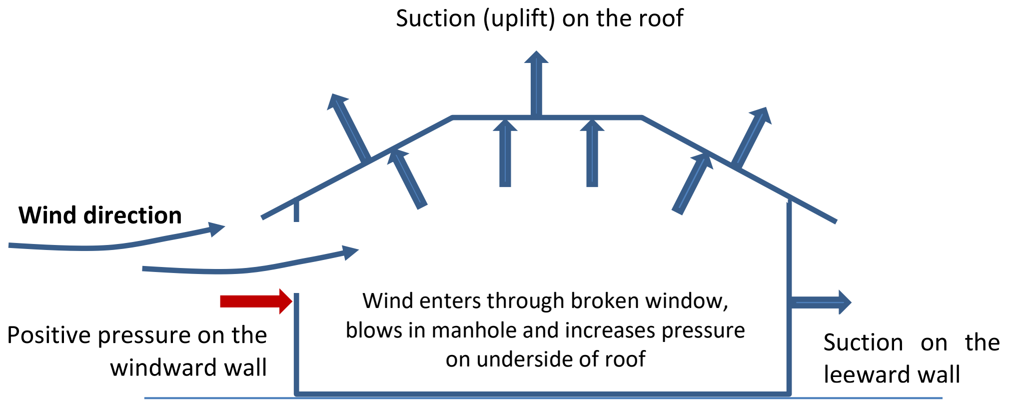

Figure 4 – Typical internal pressures on a building with an opening on a windward wall

The internal pressure coefficient for the scenario shown in Figure 4 is usually +0.7. If the wind direction changes so that the opening is on a side wall, then the internal pressure coefficient is –0.65.

CTS damage investigations have shown that openings can occur in any wind event in wind regions A, B, C and D. Different scenarios create openings that can lead to wind damage:

- Windows or doors can be left open to provide ventilation.
- Doors can be opened to provide access into the building just prior to a severe gust.

The following scenarios can create openings during tropical cyclones (which can and do happen in wind region B1 – e.g., the 1954 Gold Coast cyclone):

- Failure of door or window latches so that doors or windows blow in.
- Unrated windows and doors fail during winds before the peak gust.
- Doors or windows are struck by wind-borne debris.

Any of the five scenarios listed are possible in a place of refuge where people may be coming and going at any time, it is suggested that all places of refuge be checked for performance with internal pressure coefficients of +0.7 and –0.65.

2.4 Wind-borne debris in wind events

Wind-borne debris and the damage it causes has been observed in wind events across all wind regions. Debris is particularly damaging during tropical cyclones as the wind speeds are faster and last much longer than winds in thunderstorms. Wind-borne debris can cause damage to the cladding, windows and/or structural elements of buildings. Some building elements may be designed to resist impact from wind-borne debris, and windows and doors may be protected by debris screens.

Wind-borne debris may include:

- Vegetation – branches from trees or shrubs
- Loose, lightweight materials such as stored building materials, garden furniture, trampolines, tools or equipment
- Transportable items such as boats, trailers, and caravans
- Larger unanchored items such as shipping containers
- Small, inadequately anchored buildings such as garden-type sheds, gazebos, shade structures or
- Detached pieces from buildings that have been damaged. e.g., roof panels.

Some building elements are particularly vulnerable to impact from wind-borne debris. They are mainly fragile building elements including:

- Windows
- Doors
- Garage doors
- Asbestos or fibro cement sheets or
- Light external elements such as gutters and flashing.

Some cladding elements have been tested for impact resistance using the debris loading specified in AS/NZS 1170.2 (Standards Australia, 2021). This loading is only representative of debris loadings and real wind-borne debris may have more, or less, energy than the loading in the Standard. The test criteria for debris impact does not test for wind load resistance.

Mitigation against damage from debris includes replacement of fragile elements with those designed to resist impact from debris, or by installation of appropriately designed and rated screens.

While the use of an appropriate internal pressure coefficient means that wind-borne debris that creates an opening in the building envelope will not cause loss of the roof, it is still desirable to prevent debris entry into a place of refuge to keep people safe. It is therefore wise to protect any vulnerable elements with debris screens or shutters, or other mechanisms to resist impact from flying debris.

2.5 Wind forces on buildings

The design wind speed for a particular site must consider factors that can either increase or decrease the local wind speed (e.g., building height, terrain, topography, shielding from other structures, suburban terrain). As the pressure experienced on a structure is proportional to the wind speed squared, a small increase in wind speed gives a much larger increase in loads. Therefore, a building on a hill-top location, that has been designed without proper consideration for this increase in wind speed over the hill, is at an increased risk of failure.

Figures 3 and 4 illustrate the wind pressures acting on a building. They show the high suction pressures at the leading edge of the roof and general upward pressures across the whole roof surface. The windward wall surface is subjected to external pressure, with most other surfaces experiencing suctions. Rain landing on the windward wall will be driven towards the interior of the building.

Buildings resist the pressures applied to the envelope using the following chain of elements:

- The envelope elements (cladding, doors and windows) must have sufficient strength and resilience to carry the pressure differential across the element and transfer it to fasteners.
- Roof and wall cladding may be fastened to a frame using bolts or screws that transmit all the loads from the pressures applied to the cladding.
- Windows and doors transmit loads to frames using hinges, latches and other hardware. These elements must all have sufficient capacity to carry those loads.
- The building structure carries all of those loads to the ground using several different elements that may include connections, bracing, frames and footings.

Failure of any of these elements can endanger building occupants. The impact of the damage is generally larger for failures deeper into the chain of elements. Figure 5 shows significant roof damage. However, even relatively minor damage to flashings as shown in Figure 6 can allow significant volumes of water to enter the building. (See Section 2.6)

Figure 5 – Wind damage to roof structure and walls

Figure 6 – Wind damage to flashings

Damage investigations have shown that some elements such as automatic sliding doors and garage doors are particularly vulnerable to damage from strong winds as shown in Figure 7. Vulnerability in garage doors, installed in wind regions C and D, benefits from the revision to the garage door standard in AS/NZS 4505 (Standards Australia, 2012). Garage doors in wind region B1 and B2 remain vulnerable unless additional strengthening is applied.

Figure 7 – Failure of automatic sliding doors and roller doors

2.6 Wind-driven rainwater ingress to buildings

Damage investigations in many parts of the world (Sheffield 1994, Sparks, Schiff et al. 1994, Henderson, Ginger et al. 2006, Van De Lindt, Graettinger et al. 2007, Franco, Green et al. 2010, Boughton, Henderson et al. 2011, Gurley and Masters 2011, Boughton and Falck. 2015) have shown that significant amounts of water can be driven into buildings during wind events in all regions, even during events with winds less than the design wind speed.

Wind-driven rainwater can penetrate the building envelope and cause damage to internal linings. This damage can be caused by rainwater that enters the building:

- through parts of the building that have been lost or damaged
- through holes made in the building by wind-borne debris
- driven through small gaps in the envelope by a large differential pressure from the outside to the inside of the building, even without structural damage to the building.
- passing through cladding elements such as windows that have been rated for water penetration at a lower differential pressure.
- under flashings and gutters as the high velocity wind drives water up the cladding in a direction opposite to the direction for which the flashing has been designed.

Damage from wind-driven rain can also result in costly repairs, potential long-term durability concerns and mould growth, making parts of the building unusable.

Water penetration by any of these mechanisms can cause damage to linings and contents and interfere with the normal function of the building as shown in Figure 8. In a potential place of refuge, some water ingress, which doesn't result in structural damage, such as the failure of a ceiling, is not a significant problem. A ceiling failure would pose a significant risk of harm to the people sheltering in the building.

Figure 8 – Example of water damage to lower floor ceilings

2.7 Broken glazing

Unprotected windows and glass doors can be broken by either wind forces or debris. Figure 9 shows the shattered windward wall window float glass embedded into an interior wall. Glass fragments present an injury risk to people sheltering inside the building. In some cases, mitigation strategies to improve the resilience of glazing elements are a priority.

Figure 9 – Shards of broken glass

3. Assessing the suitability of buildings for places of refuge

This section presents a systematic process for assessing the suitability of buildings for classification as a place of refuge during a severe wind/cyclonic event. It does not offer a scoring system, but the answers to the questions will enable emergency managers to decide what mitigation strategies may help make buildings more appropriate as places of refuge for the large numbers of people to shelter during the passage of the event. It is important to remember the rigor of the assessment process is in place to provide assurance and confidence to decision makers and stakeholders that people should be safer inside.

Section 2.1 indicated that appropriate performance for a place of refuge includes:

- an envelope that remains substantially intact, to offer a measure of protection to those inside, and
- a structural system that survives the event, and
- minimising the chances of injury to those inside.

3.1 Overview

If possible, review the structural drawings and specifications for the building including:

- Construction plans
- Plans for all major renovations.
- Some specifications of more recent construction.

Undertake a wind study for the location of the building:

- Calculate design wind speeds for the 8 cardinal directions.
- Use the highest of these to find pressures on the building elements using $C_{p,i}$ = +0.7 OR – 0.65
- Find wind actions on crucial elements.

Review the as-constructed structural details on the building:

- Confirm that they are those in the construction plans, or document any differences.
- Estimate the design capacity of the as-constructed details using either Australian Standards or manufacturer's information.

Compare the capacities of key elements with the wind loads for three different wind speeds. Load/Capacity gives overstress. The following wind speeds are used:

- Cat 2 cyclone (40 m/s)
- Cat 3 cyclone (54 m/s)
- Cat 4 cyclone (70 m/s)

If the building satisfies the structural requirements, perform qualitative evaluations of:

- Potential wind-borne debris on the site or nearby
- Protection of glazing
- Door hardware
- Large vehicle access doors
- Ceilings
- Flashings and guttering
- Condition of roofing, wall cladding, gutters, and flashings

If a part of the building satisfies both the structural requirements and the qualitative evaluation and it is practical to use that part of the building as a place of refuge, then a management plan could be developed to utilise only that part of the building.

3.2 Structural Drawings and Specifications

This information may be used to find:

- Year of original construction, additions, renovations, or upgrades
- Design criteria including importance level, design wind velocity and internal pressures.
- Materials used in construction e.g., type of glazing, roof system, wall cladding system.
- Specific structural details for:
  - Cladding
  - Purlins, battens and girts.
  - Portal frames or trusses
  - Roof structure tie-downs from the edge of the roof to the footings

3.3 Wind study

Use the current edition of AS/NZS 1170.2 (2021) to evaluate the wind loads on the structural elements listed in 3.2.

- Find V_R based on the building importance level (as designed) – Table 3.1(A) in AS/NZS 1170.2
- For each of the 8 cardinal directions, find the velocity mulitipliers $M_{z,cat}$, M_s, M_t
- For each of the 8 cardinal directions, find V_R $M_{z,cat}$ M_s M_t
- Use the maximum value as the cladding design velocity and take 0.9 times that value as the structure design velocity.
- Use $C_{p,i}$ = +0.7 or –0.65 and calculate net pressure on the key elements listed in 3.2.

3.4 As-constructed check

The objective is to confirm that the building was built to conform with the approved drawings. A simple check should be enough. If there are discrepancies, a more detailed check should be used to note the materials used throughout the building. Areas to consider include:

- Identify cladding system and confirm purlin spacing and fastener spacing.
- Identify purlins used and measure purlin span (between trusses or portal frames)
- Identify main members used in portals or trusses and measure span.
- Identify system used to transfer roof uplift through the walls to the footings.
- Identify window systems and estimate glass spec – thickness and type of glass.
- Compare with drawings supplied and identify discrepancies.

3.5 Calculation of overstress ratios

Using the structural and cladding pressures from 3.3, evaluate the loads on key structural elements and divide these by the capacities of the elements identified in the as-constructed check in 3.4:

- Use roof cladding pressures together with local pressure factors to evaluate performance of the sheeting system (compare with manufacturer test data on the system installed).
- Use roof cladding pressures together with local pressure factors to evaluate performance of the purlins (compare with manufacturer design data including bridging requirements).
- Use structure pressures together with area reduction factors to evaluate performance of trusses or portals. Rough calculations only are required – Assume roof weight of 40 kg/m^2 above truss, rafter or portal and rough weight of truss, rafter or portal itself.
- Use structure pressures together with area reduction factors to evaluate performance of tie-downs between the roof structure and the footings. Rough calculations only are required – Assume roof weight of 40 kg/m^2 above truss, rafter or portal and rough weight of truss, rafter or portal itself.
- Use cladding pressures together with local pressure factors to establish the loads on individual panels of glazing and compare with either manufacturer information or generic information (Australian Window Association, 2010) on the pressure ratings of glass of the right type and thickness.

- For each overstress ratio complete the overstress table by multiplying the wind loads only (not the weight) by the tropical cyclone Category multipliers

$$OSR = \frac{\left[W\left(\frac{V_{TC}}{V_R}\right)^2 - G\right]}{Capacity}$$

OSR = overstress ratio

W = wind load calculated on the element under consideration based on regional velocity V_R

V_{TC} = Velocity for the cyclone category (see Table 1)

V_R = regional velocity used to calculate the wind action W

G = weight of roof above the element under consideration with the same tributary area used to calculate *W*

Capacity = capacity of the element under consideration

Item	Cat 2 overstress ratio	Cat 3 overstress ratio	Cat 4 overstress ratio
Velocity for cyclone category (V_{TC})	40 m/s	54 m/s	70 m/s
Roof cladding system			
Purlins or battens			
Trusses or rafters (incl portal frames)			
Roof tie-down to footings			
Window systems			

Table 1 – Overstress ratios for building components

The method described in 3.5 is meant as a minimum level expeditious path for comparing buildings and is not a comprehensive design approach. A detailed structural analysis would provide accurate answers for the overstress ratio comparison. The detailed analysis may be an easy choice if, for example, the design documentation and load calculations are available from the original building design.

3.6 Qualitative evaluation

This section includes questions that are intended to establish the robustness of some features that may endanger the safety of people sheltering inside an otherwise resilient building. In each case, the discussion presents reasons for the question, the question, some typical answers, and the potential mitigation that can be carried out to minimise the risk to people sheltering in the building.

3.6.1 Potential wind-borne debris on site or nearby

Question

Are there light items that could become wind-borne debris on this or neighbouring sites?

Reasons for the question

Light items near the building can become wind-borne debris during the event. Even though the building has been checked for its structural performance, including consideration of an opening in the envelope, debris striking an occupied building can cause problems for the occupants. At best, they will be alarmed at the noise and shaking that the impact causes, and at worst, some occupants may be injured if the debris penetrates or damages the building.

Answer options

- No
- A few light items that can easily be cleaned up.
- Lots of light items that can be removed.
- Lots of light items that cannot be cleaned up (e.g., on neighbouring properties)

Potential mitigation

- Before the cyclone season, clean up/ remove as many of the light items as possible. Trim trees to lessen the likelihood of branches becoming wind-borne debris.
- As part of the activation plan for the place of refuge, incorporate a time frame for cleaning up the last remaining light potential wind-borne debris.

3.6.2 Protection of injury from broken glass

Question

In the areas in which people are going to shelter, is there any unprotected glazing?

Reasons for the question

Accidental breakage of glass during a high wind event either from wind pressure or from debris impact has the potential to release flying glass fragments into the area where people are sheltering.

Answer options

- No glazing in the area to be used for shelter.
- All glazing in the area to be used for shelter is protected by debris screens.
- All glazing in the area to be used for shelter is either laminated glass or toughened glass.
- People are protected with solid screens (e.g., stainless steel heavy-duty security mesh) installed on the inside of the glazing.
- Temporary screens or shutters will be used to protect glazing while the area is used as a shelter.
- Some glazing in the area to be used for shelter is protected by debris screens.
- Some glazing in the area to be used for shelter is either laminated glass or toughened glass.
- No protection for glazing in the area to be used for shelter.

Potential mitigation

- Install permanent screens in front of vulnerable glazing.
- Make up and store temporary screens or shutters to be installed in front of or behind the glass as part of the activation plan for the building.
- Apply security film to unprotected glazing.
- Avoid using areas with unprotected glazing as shelter.

3.6.3 External swinging doors

Question

What is the strength of external swinging doors in the area/s used for shelter?

Reasons for the question

Few swinging doors are wind rated and can blow in if latches or hinges fail under the differential wind pressure across the door. These failures can present a safety risk to anyone near the door at the time and can reduce the area that is effective as a shelter due to the new opening. It is noted that doors are unlikely to fail when the wind is blowing against the direction that the door opens.

Answer options

- There are no external swinging doors in the areas used for shelter.
- All external swinging doors in the areas used for shelter open outwards.
- Any external swinging doors in the areas used for shelter that open inwards have heavy duty latches and hinges.
- External swinging doors in the areas used for shelter that open inwards have lightweight latches and hinges.

Potential mitigation

- Strengthen hardware on any swinging doors, especially inward opening external doors, in the space used for shelter.
- Fit bars across the inside of inward opening external doors in the space used for shelter as part of the deployment plan for the place of refuge. (Check fire requirements.)

3.6.4 Automatic glass sliding doors

Question

Are there external automatic glass sliding doors in the areas used for shelter?

Reasons for the question

Automatic glass sliding doors are not well supported at the bottom and often fail during high wind events. These failures can present a safety risk to anyone near the door at the time and can reduce the area that is effective as a shelter due to the new opening.

Answer options

- There are no automatic glass sliding doors in the areas used for shelter.
- There is 1 automatic glass sliding doors in the areas used for shelter.
- There are more than 1 automatic glass sliding doors in the areas used for shelter.

Potential mitigation

- Build a protection wall the full height of the door on the outside of the building around 1.2 m from the automatic glass door.
- Fit bars on the inside of the automatic glass doors in the space used for shelter as part of the deployment plan for the place of refuge. (Check fire requirements.)

3.6.5 Large vehicle access doors

Question

Are there vehicle access doors into the spaces used for shelter?

Reasons for the question

Most vehicle access doors installed in wind region A or B and older doors in wind region C are not wind rated. They can fail under wind pressure. They are also susceptible to debris damage. These failures can present a safety risk to anyone near the door at the time and can reduce the area that is effective as a shelter due to the new opening.

Answer options

- There are no vehicle access doors in the building.
- There are vehicle access doors into the building, but not into the spaces used as shelter.
- There are vehicle access doors into the spaces used as shelter and they are all appropriately wind rated.
- There are vehicle access doors into the spaces used as shelter and they are NOT appropriately wind rated.

Potential mitigation

- Install new wind-rated large vehicle access doors and strengthen the jambs to cope with the higher loads from the door guides.
- Purchase or construct wind-rated temporary braces and include the installation of these braces as part of the activation plan for the building as a place of refuge.

3.6.6 Ceilings in spaces used for sheltering

Question

What is the ceiling material in the spaces to be used as shelter?

Reasons for the question

In tropical cyclones, suspended ceiling panels can shake free and fall, inadequately fastened ceilings can be blown out under differential pressure and plasterboard ceilings can get wet, soften, and fall. Ceilings that fall can cause injury to people.

Answer options

- There are no ceilings in the areas to be used as a place of refuge. (The building is unlined, so the underside of the roofing or the bottom of the insulation or sarking can be seen from inside.)
- The ceilings are adequately fastened and durable (will not soften if they get wet).
- The ceilings are durable (will not soften if they get wet) but are inadequately fastened. This includes most suspended ceilings.
- The ceilings are plasterboard.

Potential mitigation

- Replace ceilings with durable materials that are well fastened.
- Install extra fastenings in durable but inadequately fastened ceilings.
- Install extra fastenings in plasterboard ceilings to prevent large areas of ceiling from falling.
- For plasterboard ceilings, make sure that flashings, gutters, and roofing are weathertight and will not allow water in.
  - See the remaining questions and implement mitigation if needed to improve the weathertightness of the building.

3.6.7 Flashings and guttering

Question

Are gutters and flashings well sealed and adequately fastened?

Check that flashings are screwed on each face at less than 500 mm centres.

Check that gutters are not damaged, have strong supports at less than 1 m centres and have appropriate overflows at a lower height than the back edge of the gutter.

Reasons for the question

Flashings and guttering contribute to how weather-tight the building is. Where the ceiling is not durable (e.g., plasterboard), it is important to stop water from coming into the building at the roof level. If a little water comes in, this may not interfere too much with the role of the building as a place of refuge. If a lot of water enters the building, it can cause concern to the people sheltering there and lessen the usefulness of the building.

Answer options

- All gutters, flashings and roof edges are strongly fastened and well-sealed. All gutters have appropriate overflows.
- All gutters, flashings and roof edges are strongly fastened but NOT well-sealed. Gutters DO NOT have appropriate overflows.
- Gutters, flashings or roof edges are NOT strongly fastened.

Potential mitigation

- Upgrade gutters and flashings so that they are strongly fastened, and well-sealed. All gutters should have adequate overflows below the level of the back of the gutter.

3.6.8 Condition of roofing and fastener system

Question

What is the condition of the roofing and fastening system?

Reasons for the question

Roofing performance is crucial to providing shelter. Deteriorated cladding or fastener systems can cause premature failures.

Answer options

- Both roofing and fasteners are in ‘as-new’ condition.
- Both roofing and fasteners are in generally good condition.
- Roofing is in good condition, but fasteners are starting to deteriorate.
- Both roofing and fasteners are starting to deteriorate.
- Roofing is in good condition, but fasteners have deteriorated significantly.
- Both roofing and fasteners have deteriorated significantly.

Potential mitigation

- Replace roofing and fasteners.
    - While the roof is off, check that all of the structure under the roofing is OK and replace any elements that have deteriorated or need to be upgraded.
- Replace any deteriorated fasteners and check others for signs of deterioration below the sheeting.
- Regularly monitor condition into the future.

3.6.9 Condition of wall cladding system

Question

What is the condition of the wall cladding and fastening system?

Look for signs of corrosion in sheet systems, buckled or torn cladding, or cracks in concrete, blockwork or masonry systems.

Reasons for the question

The wall cladding system performance is crucial to providing shelter. Deteriorated wall cladding or fastener systems can cause premature failures and let in large volumes of wind-driven rain.

Answer options

- Both wall cladding and fasteners are in ‘as-new’ condition.
- Both wall cladding and fasteners are in generally good condition.
- Wall cladding is in good condition, but fasteners are starting to deteriorate.
- Both wall cladding and fasteners are starting to deteriorate.
- Wall cladding is in good condition, but fasteners have deteriorated significantly.
- Both wall cladding and fasteners have deteriorated significantly.

Potential mitigation

- Replace wall cladding and fasteners.
    - While the cladding is off, check that all the structure under the cladding is OK and replace any elements that have deteriorated or need to be upgraded.
- Replace any deteriorated fasteners and check others for signs of deterioration below the sheeting. Monitor condition in the future.
- Repair any damage to the wall cladding system.

3.6.10 Condition of gutters and flashing

Question

What is the condition of the gutters and the flashings?

Look for signs of corrosion, deterioration in sealants used or physical damage such as holes, dents or local crushing. Check that leaf material is not blocking gutters or lifting flashings.

Reasons for the question

Gutters and flashings are necessary to keep the building weathertight. If they have physically deteriorated or are full of leaves and twigs, they will not perform their function. If they start to be torn off the building, they could damage other building components. If they are not effective, they could let water into the building that may damage linings such as ceilings.

Answer options

- Both gutters and flashings are in ‘as-new’ condition.
- Both gutters and flashings are in generally good condition.
- Flashings are in good condition, but gutters are starting to deteriorate.
- Both gutters and flashings are starting to deteriorate.
- Flashings are in good condition, but gutters have deteriorated significantly.
- Both gutters and flashings have deteriorated significantly.
- Replace gutters and flashings. (Consider using closed cell foam under flashings and around valley and box gutters to prevent wind-driven rain from passing under the flashing or over the top of the gutters.)
- Replace any deteriorated gutters and flashings and check others for signs of hidden deterioration. Monitor condition in the future.
- Repair any damage to gutters and flashings.
- Have an ongoing maintenance plan including items such as cleaning out gutters.

4. Acceptance of a building as a place of refuge

The judgment on acceptability of a building as a place of refuge is mostly subjective. The assessment components outlined in Section 3 provide an overview the most optimum outcomes for each of the building areas which will contribute to a strong place to shelter during the passage of a severe wind or cyclone event.

It is likely that no building will meet all the performance requirements as they have not been designed and constructed to do so. The considerations in Section 3 aim to guide the decision and indicate where mitigation could be undertaken to improve the performance of a building or provide evidence and justification to not use the building as a place of refuge.

4.1 Structural performance – overstress ratios

The overstress ratios calculated in Table 1 provide some guidance on the likely performance of key elements that keep the roof on buildings. Low overstress ratios (yellow) are desirable and ratios significantly more than 1 (i.e., greater than 1.3) are not desirable (red).

Item	Cyclone Cat 2 overstress ratio	Cyclone Cat 3 overstress ratio	Cyclone Cat 4 overstress ratio
Velocity for cyclone category (V_{TC})	40 m/s	54 m/s	70 m/s
Roof cladding system			
Purlins or battens			
Trusses or rafters (incl portal frames)			
Roof tie-down to footings			
Window systems			

Table 2: Possible overstress ratios

- If the overstress ratios are NOT satisfactory AND are in red-shaded cells in Table 2, it would be strongly advisable to take steps to improve the structural performance of the building prior to using it as a place of refuge or avoid the part of the building in this zone.
- If the overstress ratios are ok for 40 m/s but are NOT satisfactory AND in orange-shaded cells in Table 2, you should consider undertaking mitigation to improve the structural performance of the building prior to using it as a place of refuge.
- If the overstress ratios are ok for 54 m/s but are NOT satisfactory AND are in yellow-shaded cells in Table 2, it could be considered as a place of refuge but ranked behind buildings that have satisfactory overstress ratios throughout the table.

4.2 Qualitative evaluation

Having determined the structural suitability of the building, the answers to the other questions can guide some other mitigation works that may make the building more workable as a place of refuge.

Again, the decision to mitigate any of these issues is not prescriptive.

4.2.1 Potential wind-borne debris on site or nearby

Question

Are there light items that could become wind-borne debris on this or neighbouring sites?

Comment

It makes sense to clean up as many light items as possible. This is “low-hanging fruit” and may reduce the number of wind-borne debris impacts on the building and other structures on neighbouring sites.

4.2.2 Protection of injury from broken glass

Question

In the areas in which people are going to shelter, is there any unprotected glazing?

Comment

This may assist in deciding what areas on the building to use as a place of refuge. If the best areas for shelter have lots of unprotected glass, then it may be desirable to offer some protection to it as indicated in the mitigation options in section 3.2.2.

4.2.3 External swinging doors

Question

What is the strength of external swinging doors in the areas used for shelter?

Comment

Swinging doors are important for access, both into the venue before the event and out of the venue after the event. Outward opening doors work best, as they have full jambs to carry the inward loads from wind or wind-borne debris. Make sure the hardware is robust. If swinging doors open inwards, they can be strengthened with bars on the inside.

4.2.4 Automatic glass sliding doors.

Question

Are there any external automatic glass sliding doors in the areas used for shelter?

Comment

If there are external automatic glass sliding doors, consider not having the shelter behind them or fit braces on the inside to hold them in place if they do break.

4.2.5 Large vehicle access doors

Question

Are there vehicle access doors into the spaces used for shelter?

Comment

Unless these doors have been designed with an appropriate cyclonic rating, they may fail under wind actions. Consider not having the shelter behind them or if the space behind them needs to be used fit wind-rated temporary braces and include the installation of these braces as part of the activation plan.

4.2.6 Ceilings in spaces used for sheltering

Question

What is the ceiling material in the spaces to be used as shelter?

Comment

People have been injured by ceiling panels that have been blown out of the ceiling. It is worth ensuring that the ceiling is not going to fall on people sheltering in the building. See mitigation options presented in section 3.2.6.

4.2.7 Flashings and guttering

Question

Are gutters and flashings well sealed and adequately fastened? Check that flashings are screwed on each face at less than 500 mm centres. Check that gutters are not damaged, have strong supports at less than 1 m centres and have appropriate overflows at a lower height than the back edge of the gutter.

Comment

Particularly where there are plasterboard ceilings, it is worth keeping water out of the roof or ceiling space to minimise the chances of the ceilings collapsing. If the ceilings can cope with a bit of water, then mitigation isn’t required.

4.2.8 Condition of roofing and fastener system

Question

What is the condition of the roofing and fastening system?

Comment

Repair any elements that show signs of deterioration before they compromise the performance of the building.

4.2.9 Condition of wall cladding system

Question

What is the condition of the wall cladding and fastening system?

Comment

Repair any elements that show signs of deterioration before they compromise the performance of the building.

4.2.10 Condition of gutters and flashing

Question

What is the condition of the gutters and the flashings?

Comment

Repair any elements that show signs of deterioration before they compromise the performance of the building.

4.3 Flowchart

Figure 10, below, presents a summary of the process to evaluate the suitability of a building or parts of a building for use as a place of refuge.

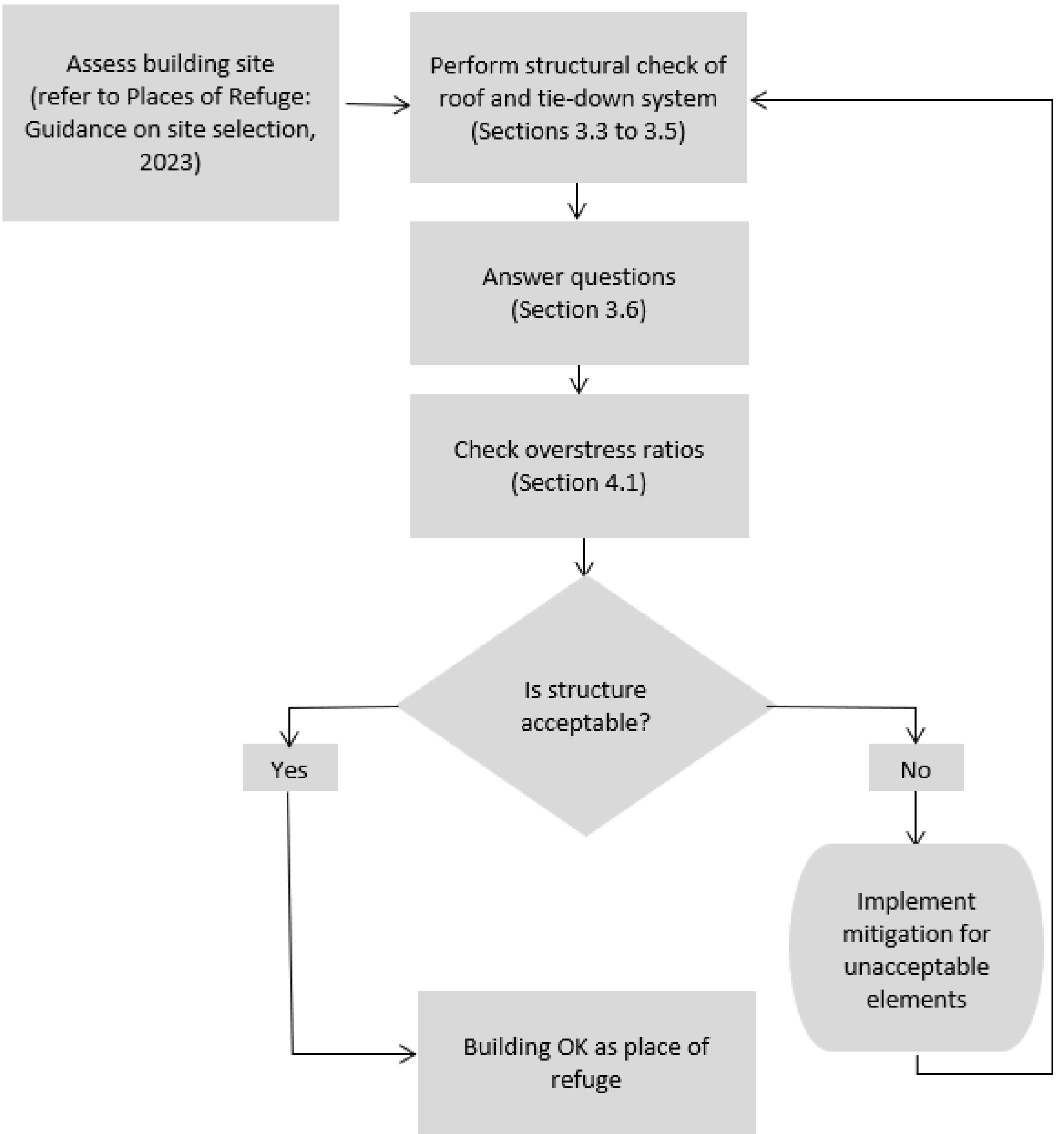

Figure 10: Assessment process.

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