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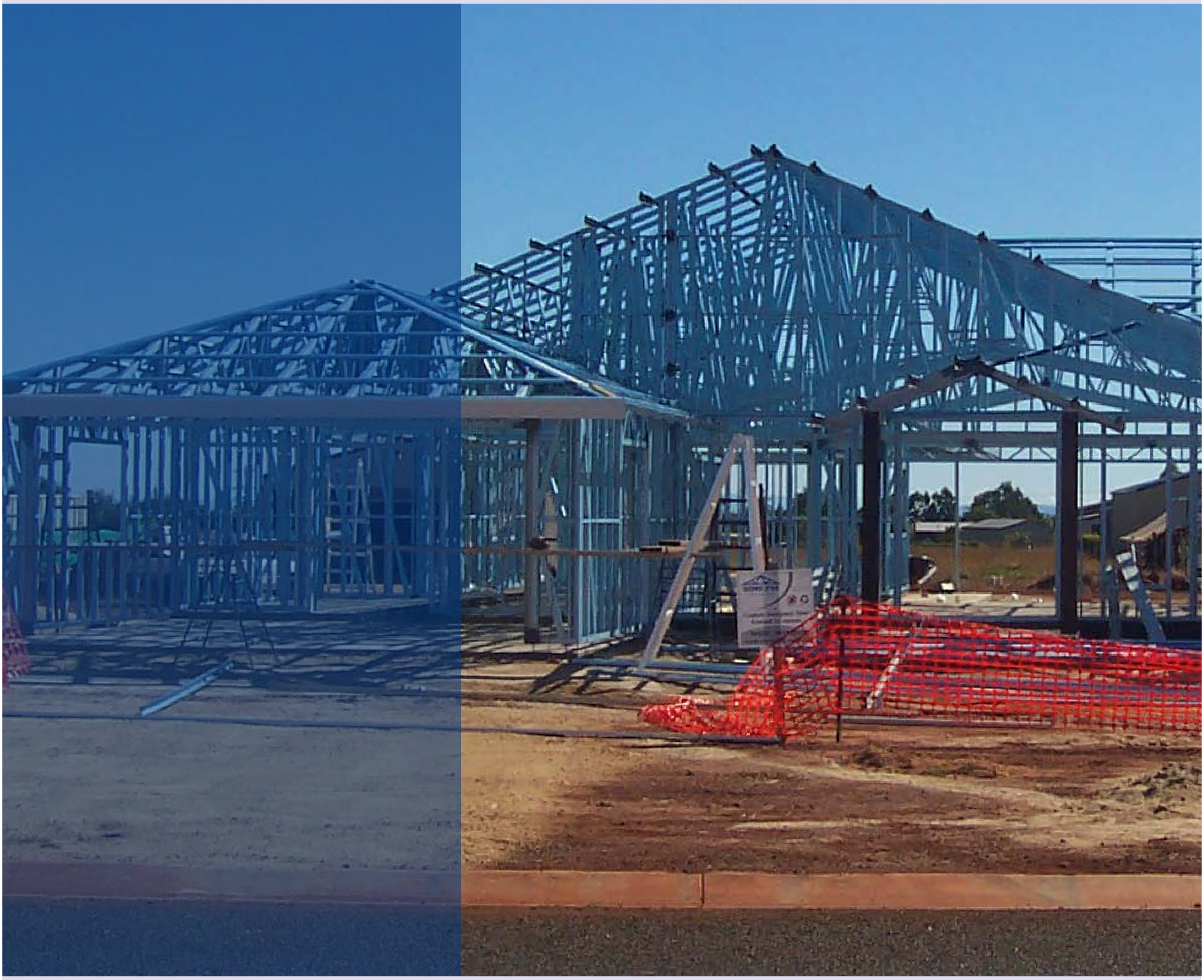
TECHNICAL NOTE 1

Structural Design of Buildings for Northern Australia



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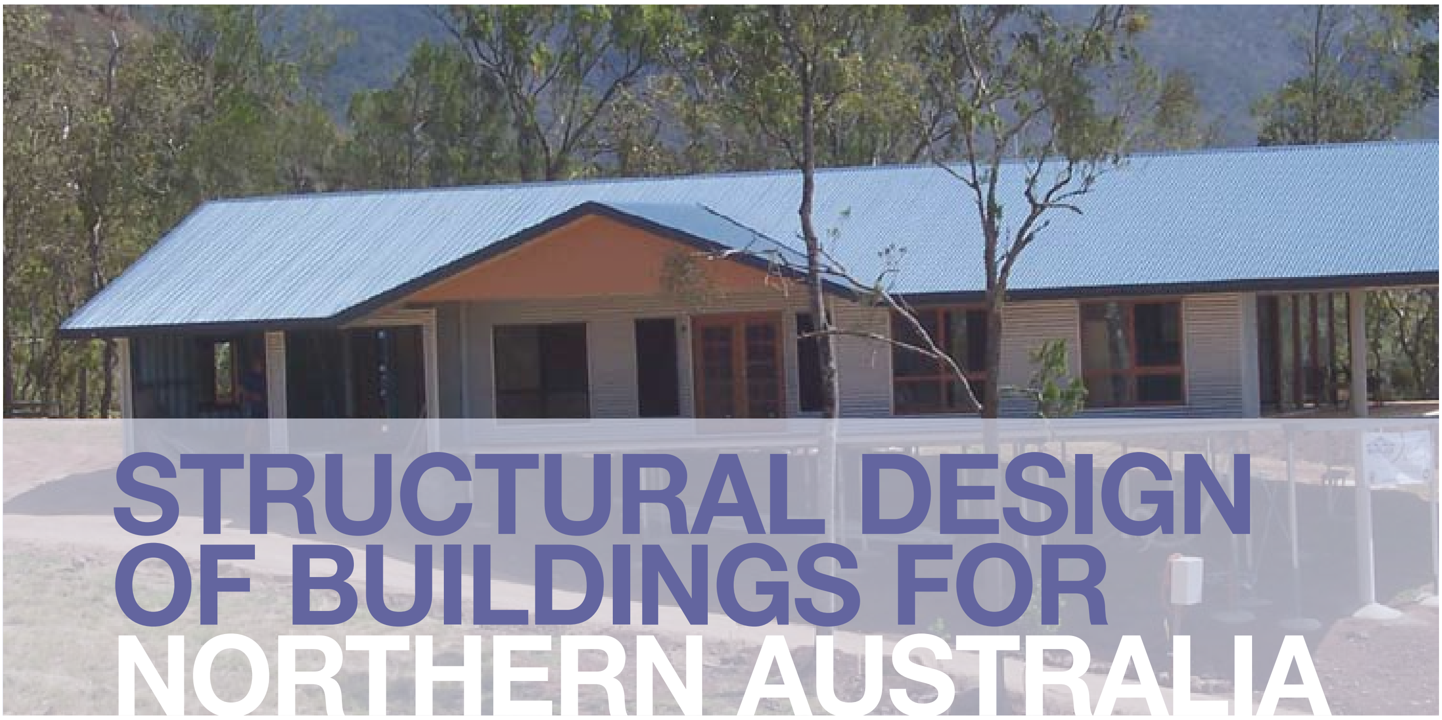

STRUCTURAL DESIGN OF BUILDINGS FOR NORTHERN AUSTRALIA

Due to the very high wind speeds associated with tropical cyclones, buildings in the northern parts of Australia require particular attention to both structural design and detailing to ensure that the applied actions can be resisted and transferred to the foundations. Wind pressures can be up to 6 times greater than those designed for in the southern parts of Australia due to:

- Higher wind speeds
- Greater internal pressure
- Lower terrain roughness due to disallowing the effect of vegetation in cyclonic regions.

DESIGN WIND SPEEDS

The NASH Standard for Residential and Low-rise Steel Framing Part 1 Design Criteria allows the use of the following two Australian Standards for determining wind forces on buildings:

1. AS 4055 Wind loads for housing

This Standard applies only to housing within the geometric limits specified within the Standard.

For the given wind region (A, B, C or D), terrain category (TC1, 2, 2.5 or 3), topographic class (where the house is located on a hill) and shielding class (where upwind buildings provide some protection), a table in AS 4055 gives the appropriate wind classification. In Non-cyclonic regions, the classifications are denoted N1 to N6 where the "N" means Non-cyclonic. In cyclonic regions the classifications are denoted C1 to C4 where the "C" means Cyclonic. In wind region D, and in very exposed sites in region C, the AS 4055 tables do not cover all cases and the designer is referred to AS/NZS 1170.2 for the design actions.

Earlier versions of AS 4055 referred to WXX where "XX" was the permissible stress wind speed. Today limit state design and hence ultimate wind speed is used in the design of houses. If the permissible stress wind speed is used to calculate pressures, the resulting wind pressure will only be two-thirds of the value using the ultimate wind speed. This terminology is unfortunately still quite common and can lead to a lot of confusion and potentially unsafe design. Wind speeds based on permissible stress design are inconsistent with Building Code of Australia (BCA) referenced standards and should not be used in design.

TABLE 1: DESIGN GUST ULTIMATE WIND SPEED (AS 4055)

Wind class	Design wind speed – ultimate limit state (Vhu) m/s
C1	50
C2	61
C3	74
C4	86

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2. AS/NZS 1170.2 Structural design actions – Wind actions

This Standard can be used for the design of all buildings less than 200 metres high and roof spans less than 100 metres.

To allow for uncertainties in the prediction of ultimate design wind speeds in regions C and D, the Standard requires that the wind speeds for ultimate limit state design be increased by 10% in region D and by 5% in region C.

The design wind speed may be reduced by 5% to allow for wind directionality when calculating wind actions on major structural elements and for overturning forces. This reduction does not apply for cladding or battens.

TABLE 2: REGIONAL WIND SPEEDS (AS/NZS 1170.2, 1:500 ANNUAL PROBABILITY OF EXCEEDANCE)

Region	Regional wind speed – ultimate limit state (m/s)
A (non cyclonic)	45
B (non cyclonic)	57
C (cyclonic)	69
D (cyclonic	88

IMPORTANCE LEVEL

The BCA requires that an importance level be assigned in accordance with Table 3 to determine the appropriate wind design criteria. Importance Level 1 buildings will be uncommon, and generally limited to isolated farm buildings.

Most buildings are importance Level 2, and in cyclonic regions there are a significant number of more important buildings. Note that AS 4055 is based only on wind events for importance Level 2 buildings.

TABLE 3: IMPORTANCE LEVELS OF BUILDINGS AND DESIGN SAFETY EVENT

Importance Level	Building Type	Annual Probability of Exceedance for Wind (Cyclonic Regions)
1	Buildings presenting a low degree of hazard to life and other property in the case of failure eg isolated farm buildings	1:200
2	Buildings not included in Importance Levels 1, 3 and 4	1:500
3	Buildings that are designed to contain large numbers of people	1:1000
4	Buildings that are essential to post-disaster recovery or associated with hazardous facilities	1:2000

INTERNAL PRESSURE

In cyclonic areas, internal pressure coefficients based on dominant openings (ie full internal pressure) should be applied unless the building envelope (windows, doors and roof and wall cladding) is capable of resisting impact loading as described in AS/NZS 1170.2. Shutters or protective frames over openings may be designed to achieve the required impact resistance.

Pressure coefficients for cyclonic areas selected from the NASH Standard Part 1 and AS 4055 are based on full internal pressure and AS/NZS 1170.2 specifies this in regions C and D.

CYCLIC TESTING

The BCA specifies additional fatigue loading criteria for claddings and their immediate supports. The critical factor may be the thickness of the batten, roof rafter or truss chord. Alternatively the batten spacing may be reduced to pass the testing regime.

The BCA has introduced a new testing regime, known as Lo-Hi-Lo, to replace the different testing regimes specified in Queensland and the Northern Territory. This has required that claddings, their supports and fixings be retested to the new requirements. This may change the span of the cladding, batten spacing and/or fixing specifications for currently available common claddings. The new requirements come into force on 1 May 2009.

STRUCTURAL SYSTEM

The design of the steel frame members and connections can be by calculation and/ or testing in accordance with the NASH Standard Residential and Low-rise Steel Framing, Part 1: Design Criteria and AS/NZS 4600. The design of the building is subdivided into three sub-systems; roof, wall and floor. All components in each sub-system act together to perform the specific function. The connections between the sub-systems should be designed to carry the forces to the foundations. Most failures in high wind events are initiated by failure of the connections between the sub-systems. This particularly applies at points of highly concentrated loading, eg girder truss supports and transfer of lateral forces into isolated bracing walls.

The ceiling and floors are generally assumed to act as rigid diaphragms in transferring the forces from the sub-system above to the sub-systems below, eg from the roof truss to the wall frames. Special attention needs to be given to the cases where the sub-system may not be able to form a rigid diaphragm, eg a suspended ceiling, or where there is no ceiling or floor, or where large voids are present.

Nominal bracing can be used to take up to 50% of the horizontal wind load.

a) Roof systems

The following areas of design and detailing need attention in all wind categories and especially in cyclonic areas:

- **Internal truss supports** - When additional supports are provided along the truss, they need to be included in the analysis as they can attract about two thirds of the applied actions. The support should be placed at a nodal point and the webs designed for the additional forces (upward or downward) created by the reaction point. Footing tiedown or bearing at the support point will also need to be considered.
- **Overhangs** - Overhangs need to be checked for serviceability and ultimate limit states for permanent and imposed actions (including concentrated action at the end of the overhang) as well as wind actions. This particularly applies at hip ends where there

is very little back span available, and also at gable end overhangs where roof battens form part of the overhang assembly system.

- **Gable end trusses** - The vertical web members of gable end trusses, which support the cladding, need to be designed to resist wind actions. This may require noggings for members to reach the required capacity.
- **Saddle trusses** - Where the general spacing of roof battens is less than the saddle truss spacing, consideration should be given to additional top chord restraint between saddle trusses. Where saddle trusses overhang the supporting structure, additional support may be required.
- **Tiedown load** - All elements in the load path need to be checked as part of the design. Bigger screws, thicker and/or stronger steels or closer spacing of members may need to be investigated so that the forces may be carried from the roof cladding through to the walls. Places of concentrated actions such as transfer to and from girder trusses should be carefully designed.

b) Walls

Forces from the roof on to the walls from wind actions can be both compressive and tensile. The net effect of internal and external pressures producing bending loads on the studs also needs to be taken into account. External walls that are set back from the truss or rafter support point will require restraint at the top of the wall.

- **Studs** - Generally the critical case for the design of wall studs is compressive axial force from permanent and wind action combined with bending from the wind action. The action combination factor Kc may be applied. The connections need to be designed for both the downward and uplift cases.
- **Window and door units - (aluminium, timber, etc)** The heads and sills of window units, and heads of door units, are normally designed to transfer the wind load from the window or door back to the jamb studs without applying any lateral load to head and sill members of the building structural frame. In addition, window and door units are normally not designed to resist vertical loads.
- **Garage doors** - Garage roller doors and shutters apply significant loads to the jamb studs. Due to the effect of catenary action, these loads are increased where wind locks or alternative emergency fixing devices are fitted. All designs should recognise the magnitude of these loads and the load path resisting them.
- **Bracing** - The horizontal and vertical bracing forces need to be transferred from the ceiling or floor diaphragm into the bracing walls from above and in turn transferred into the floor system below. Connection detail for an internal bracing wall to an external wall should be carefully designed.

c) Floors

Apart from the normal floor actions, the vertical forces from the roof and bracing need to be transferred to the floor supports. For instance if a bracing wall runs parallel to the floor joists, additional trimmers will be required to transfer the force to the floor system and in turn into the foundations.

CONCLUSION

Steel framed buildings have been shown to perform well when subjected to tropical cyclones. It is important to design, detail and construct all building structural elements to the relevant standards.

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