Government of **Western Australia**
Department of **Commerce**

Building Commission

FINAL REPORT

General Inspection Report One: A general inspection into metal roof construction in Western Australia

April 2016

BUILDING COMMISSION GENERAL INSPECTION REPORT ONE (GIR1)

ROOF CONSTRUCTION: A general inspection report into the construction of sheet metal clad timber framed roofing in Perth metropolitan and South West regions

Government of **Western Australia**
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Front cover: Building Commission image of a representative WA home building site inspected for this review.

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Executive summary

General Inspection Report No1 (GIR1) is a report to the Building Commissioner on the first comprehensive inspection by the Building Commission of how building standards are being applied in Western Australia (WA) under section 65 of the *Building Services (Complaint Resolution and Administration) Act 2011*.

GIR1 reports on how well sheet metal clad timber framed roofs are being constructed in WA. One of the main drivers to inspect these roofs was an analysis of all wind damage in the metropolitan region which indicated that changing materials and construction practice in WA's housing sector may mean that roofs do not meet the performance standards of the National Construction Code series (NCC). The NCC series comprise of the Building Codes of Australia (NCC Volumes 1 and 2 – referred to as the BCA) as well as the Plumbing Code of Australia (NCC Volume 3– referred to as the PCA).

Specifically, design and construction of lighter-weight metal roofing systems must allow for high wind 'up-lift' forces. In addition, appropriate building standards, manufacturers' instructions and guidelines, roofing system construction and new research findings must be applied to achieve best practice and safe buildings for WA's conditions.

The GIR1 is a preliminary snapshot of the quality of WA's sheet metal clad timber framed roof construction in 2014. Since the initial inspections in 2014 the Building Commission has engaged with key industry stakeholders and technical experts to carry out detailed technical analysis of the results. In some cases this has led to quick responses by the building industry to address compliance issues while this report has been prepared. A draft report was released to industry and consumer groups for consultation in May 2015 and feedback from this consultation has been incorporated in this final report.

The GIR1 findings address whether common construction practice in WA delivers the necessary performance in critical structural areas of sheet metal clad timber framed roofing systems and whether the existing controls established under the building services Acts (the Acts) are effective. The poor rates of compliance with Australian Standards referenced in deemed-to-satisfy solutions in the NCC (BCA Vol. 2) raise questions for the industry and government. However, industry's response to the proposed recommendations gives confidence that better quality assurance and training for trades involved in roof construction will ensure proper design and construction standards will be met.

The findings of this report may cause homeowners to question the construction of their metal roofs but the report notes that a failure to comply with a building standard does not necessarily mean the roof will fail to perform. If homeowners are concerned about a particular roof they should raise their concerns directly with their builder in the first instance. The Building Commission provides a dispute resolution service to assist parties if a satisfactory resolution cannot be achieved.

It is important that WA does not experience a worst-case systemic failure such as New Zealand's Leaky Building Syndrome where changes to construction methods were not identified quickly enough and the costs of repairing the damage continues to plague the industry, consumers and the government.

Overview

In 2011, the State Government comprehensively reformed building control in WA through the introduction of new building legislation, including the *Building Act 2011* (the Building Act), the *Building Services (Complaint Resolution and Administration) Act 2011* (the CRA Act) and the *Building Services (Registration) Act 2011* (the Registration Act).

The Registration Act establishes the system for registering building surveyors and builders, and disciplinary provisions for dealing with providers who fail to carry out a building service properly.

The CRA Act establishes the Building Commissioner with functions that include monitoring and reviewing the operations of the Acts, and the power to authorise persons to conduct general inspections to ascertain how building standards have been, or are being, applied.

These functions of the Building Commissioner were not available to the previous Builders Registration Board that only had functions to register builders and take action for offences against the (repealed) *Builders' Registration Act 1939*. Absorbing the staff and functions of the former Builders Registration Board and implementing internal reforms meant it was not possible to dedicate technical staff to general inspections under the CRA Act until 2014.

The Building Act establishes a building permit system to ensure registered building service providers design and construct buildings in accordance with the BCA and permit authorities (usually local governments) are empowered to monitor, investigate and enforce building permits and standards.

The Building Act sets the minimum technical requirements for buildings. Section 37 requires all buildings to comply with the applicable building standards. The Building Regulations 2012 (the Building Regulations) prescribe the performance requirements of the Building Code of Australia (BCA) as the applicable building standards. A registered building surveyor provides a Certificate of Design Compliance (CDC) that a proposed building will comply with the applicable building standards if it is constructed in accordance with the plans and specifications specified in the CDC. Section 29 of the Building Act requires the builder to complete the building in accordance with the specified plans and specifications.

All roofs in WA should be designed and built to the performance requirements of the BCA. Each building design must be verified against the performance requirements. To simplify this process the BCA provides a set of deemed-to-satisfy (DTS) building solutions that can be adopted with no further verification. Most houses use DTS provisions for some, or all, of their construction. DTS provisions often prescribe compliance with an Australian Standard.

The GIR1 reports on a preliminary inspection of 123 roofs under construction in Perth and the South West of WA during 2014. Because it was a preliminary inspection, the Building Commission did not check each roof against the plans and specifications specified in the applicable CDC. Nor did it assess each roof against the performance requirements of the BCA. The Building Commission assessed each roof for general workmanship and used Australian Standard AS 1684.2: 2010- Residential timber-framed construction; Part 2: Non-Cyclonic Areas (AS 1684) as a guide to appropriate construction standards. BCA DTS building solutions for timber roof framing require construction to comply with AS 1684.

It is clear from the general inspection that some construction practices for sheet metal clad timber framed roofs built in WA have moved away from the practices described in the BCA and the Australian Standards referenced as part of the DTS provisions.

While a number of designers and builders have documented some practices as performance solutions, it is not clear that these varied practices now used in WA meet the applicable performance standards in the BCA.

It is important for consumers to keep in mind that any finding that parts of a roof do not comply with AS 1684 does not necessarily mean the roof has not been built in accordance with the plans and specifications; fails to meet the performance requirements; is unsafe; or needs remedial work.

Roofs were inspected at various stages of construction and defects may have been remedied as part of completion work following inspection by the builder.

The Building Commission notified each builder when it found a significant workmanship issue or non-satisfactory level of compliance with AS 1684 during the general inspection. This allowed the builder to assess the situation and where necessary take remedial action or provide documentation supporting the methods and products used.

Finding that a representative sample of roofs did not comply with AS 1684 in a significant number of inspection points does not mean that all roofs contain this level of non-compliance, or that any particular roof is unsafe or unsatisfactory.

"Finding that parts of a roof do not comply with AS 1684 does not necessarily mean the roof has not been built in accordance with the plans and specifications; fails to meet the performance requirements; is unsafe; or needs remedial work."

Specifically, the general inspection addresses the question:

How are sheet metal clad timber framed roofs being built in Western Australia and is there any cause for concern that these roofs may not perform satisfactorily in high winds?

A number of factors prompted the general inspection:

- Expert analysis of high-wind events, together with Building Commission investigations into roof damage in WA, indicating that in most events damage was caused at less than the design wind speed.
- Specific public complaints lodged with the Building Commission regarding roof failures.
- General site inspections undertaken by the Building Commission in early 2014 indicating many sheet metal clad timber framed roofing constructions in the Perth metropolitan area varied from traditional reliance on AS 1684.
- Recommendations by the WA State Coroner in respect to faulty tie down systems following an infant death on Rottnest Island in 2009.

The GIR1 results from a general inspection during 2014 of sheet metal clad timber framed roof construction in WA. The general inspection compared construction practice in WA with AS 1684 and associated DTS provisions of the BCA as a commonly available reference. This allowed a preliminary, cost-effective, general assessment of sheet metal roof construction in WA to identify and highlight any possible areas of concern.

Twelve key general inspection point categories were defined and assessed over 123 construction sites in 2014. The inspection results identified a number of issues of concern in respect to construction practice within WA's sheet metal clad timber framed roofing sector.

Modern building construction methods in WA have seen a shift from the use of native timber hardwoods to lighter weight softwoods. In more recent years light-weight sheet metal roofing has also taken significant market share from the use of heavier tiles.

A heavier tile roof supported on native timbers must only resist gravity loads which tend to push joints together. In that case the role of fixings is less critical than in a sheet metal clad timber framed roof built from softwood where there is less gravity load to push joints together — and significant wind uplift loads operate in the opposite direction and tend to tear joints apart.

The introduction of new materials in roof construction, coupled with the drive for innovative and cost effective construction methods, has changed the way roofs are now built in WA and opens up new mechanisms for failure. Consequently, contemporary sheet metal clad timber framed roofs require all parts of the roof to perform correctly for the roofing system, as a whole, to maintain its overall structural integrity.

In March 2015, during Queensland's tropical Cyclone Marcia, communities were put at risk when the wind speeds caused building failures even though the recorded wind pressures were less than 55 per cent of the designed wind pressure. The large number of resulting building failures was an indication of unacceptable building performance where failure in one part of the construction allowed the wind to 'unzip' the whole roof structure (see Engineers Australia 2015).

During the general inspection nine of the twelve inspection points were considered more significant in maintaining structural capacity in the five key structural capacity areas identified by Boughton and Falck (2008). Failure in any of these five key structural areas under high winds may result in structural roofing system failure (see Box 1: Design Winds Scenario, page 41). The general inspection found the most likely underlying causes for concern were a systemic unawareness of, and lack of attention to, the performance requirements together with the pressures of competitive market forces undermining quality construction practice.

"The introduction of new materials in roof construction, coupled with the drive for innovative and cost effective construction methods, has changed the way roofs are now built in WA and opens up new mechanisms for failure"

Effective quality control and quality assurance processes are needed to ensure that roofs are properly designed and constructed. The primary responsibility for quality control rests with the builder. Each builder has its own quality assurance and inspection regime to ensure that the finished building meets both statutory and contractual standards. At the end of construction the builder is required to provide a Notice of Completion (NOC) to the permit authority. This notice contains a statement by the builder that the building has been completed in accordance with the plans and specifications. The NOC and this process of self-certification were introduced by the Building Act—the previous legislation did not require the builder to report the end of construction or make any declaration of compliance.

Self-certification is widely adopted in occupational regulation such as for plumbing and electrical work. Whilst the current system in WA has a self-certification requirement for builders at completion of construction for class 1 buildings, this process could also be extended to include self-certification of critical stage inspections throughout the construction phase (eg roof tie downs). Mandatory 'critical stage' inspections can be independently certified by the relevant permit authority or a registered expert (eg a registered building surveyor). They can also be self-certified by a registered builder practitioner responsible for supervising construction.

Under the Building Act, permit authorities have powers to inspect completed buildings (and any work under construction) and to issue building orders to the builder (or owner) to rectify any non-compliance with the applicable building standards or the specified plans and specifications.

Unlike for commercial and multi-residential buildings, single-residential buildings do not need an occupancy permit and therefore there is no mandatory requirement for an independent registered building surveyor to issue a Certificate of Construction Compliance on completion of a single residential house. This reflects the requirements under the previous legislation where a certificate of classification was not required for single residential buildings.

Regulated processes can complement, but not replace, the builder's primary responsibility. Regulatory options to improve quality assurance include requiring occupancy permits for single residential buildings and/or requiring mandatory inspections during construction.

Two WA State Coroners' recommendations relate to tie-down systems – firstly following a 2009 infant death incident on Rottnest Island (Mulligan 2013) and, more recently, an investigation into Cyclone George in August 2015 which highlighted the links between 'mandatory inspections' and 'greater construction compliance' (Fogliani 2015, p. 120).

"Regulated processes can complement, but not replace, the builder's primary responsibility"

The general inspection raises doubts on the effectiveness of quality assurance (QA) practice in the industry during 2014. It is therefore reasonable to conclude:

- there is clear evidence from the general inspection in 2014 that quality control in the WA building construction industry does not appear to be working effectively;
- introducing mandatory inspections and certification can help improve this situation; and
- builders that already apply formal QA systems to ISO 9000, and are complying with them, should not find this adjustment troublesome.

New ideas and innovative approaches also involve increased risk and imply more attention is required to ensure effective training, quality supervision and access to online information (and applications) to assist roof carpenters and others with correct detailing of critical sheet metal clad timber framed roof connections while onsite.[1]

Key findings

1. Many of the inspected roofs had not effectively linked together all the related tie down elements within the structural 'chain' to provide confidence in the sheet metal clad timber framed roof's ability to resist uplift forces at design wind loads. Some of the key links in the structural chain were found to be weak and in some cases even missing.

2. The trades involved in constructing sheet metal clad timber framed roofs in WA did not appear sufficiently aware of the necessary minimum requirements because:
   - they may not have been provided with consistent, complete and adequate construction information by the builder; or
   - relevant trades people were not maintaining currency with modern construction materials and techniques.

3. In some cases plans and specifications did not have sufficient details or clarity to show how to build the sheet metal clad timber framed roof to meet the applicable performance standards.

[1] See ChippyIQ at www.chippyiq.com.au

4. In some cases industry supply chains did not provide WA builders with conforming options (including nails and tie down strapping); products were incorrectly labelled; or the correct products were unavailable and builders were not demanding conforming products. Some materials supplied for constructing the sheet metal clad timber framed roof were missing key components or include incorrect components, resulting in trades improvising or omitting necessary connections.
5. Builders' quality assurance processes and levels of supervision may be ineffective or may not be sufficiently focussed on the necessary high-risk parts of the building's roof.
6. Permit authority monitoring, investigating and enforcing of compliance with applicable building standards and plans was observed to be ineffective.
7. Australian Standards referenced by BCA Volume 2 (as acceptable construction manuals) may not reflect WA's building conditions and changing construction practice. At present the Australian Standards do not cover all the critical connections that are common in modern WA building construction of sheet metal clad timber framed roofs.

Report conclusions

1. Common practice for the design and construction of framed or 'stick' roofing over masonry walls in WA varies from the practices common in the eastern states and from those broadly covered by the DTS provisions and acceptable construction practices set out in the NCC. In states other than WA, timber roof trusses and timber wall framing are more prominent.
2. While some designers and builders have documented some local practices as performance solutions, it is not clear that the common practices in WA meet the applicable performance standards in the NCC. The general inspections carried out by the Building Commission in 2014 did not assess the performance of each roof inspected.
3. Where construction is intended to vary from the DTS provisions the common level of documentation for roof construction does not provide builders and roof carpenters with sufficient detail to show precisely how the roof is to be constructed to meet the applicable performance standards.
4. Even where builders and roof carpenters are informed about how the roof is to be constructed, there is an unacceptable high level of poor work and non-satisfactory compliance with the documentation or referenced standards.
5. Quality control and compliance enforcement processes are not working effectively.
6. There is an increased risk of structural failure in WA's sheet metal clad timber framed roofs during high wind events where there is poor workmanship or failure to meet performance standards.
7. The performance of common practice in WA that varies from the DTS provisions should be verified through inspection and research by relevant stakeholders and professionals.
8. There is a clear need for improved understanding of the applicable standards for WA sheet metal clad, timber framed roof construction — especially in areas where new materials and construction methods may reduce resistance to wind uplift.
9. Quality assurance processes applied by industry and regulators must be improved and integrated to prevent systemic failures to meet applicable standards. The areas of concern identified in the GIR1 indicate current processes may not be ensuring sufficient levels of compliance.
10. Australian Standards and codes could better reflect WA building conditions and changing construction practice.

Recommendations

There are a number of occupations, professions, suppliers and oversight bodies that combine to ensure WA's roofing systems are designed and constructed to meet the performance requirements set out in the BCA.

The following five recommendations have been developed by the Building Commission after considering the general inspection findings and stakeholder comment on the discussion draft circulated in May 2015. The recommendations address the issues identified during the general inspection and will deliver improvements across all the key construction system components associated with sheet metal clad timber framed roof construction in WA.

Recommendation 1: Include Western Australian construction practices in the NCC

The NCC is moving to a three-yearly amendment cycle from 2016. An *Acceptable Construction Practice* covering WA roofing practice for Class 1 buildings should be assessed and, where appropriate, developed and included in NCC 2019. The Australian Building Codes Board (ABCB) has prepared a timetable for amendments to be included in NCC 2019 that requires proposals for change to be lodged by 1 September, 2017.

Recommendation 2: Prescribe minimum standards of documentation for framed roof construction

Section 16 of the Building Act provides powers to prescribe what must be included in an application for a building permit. Section 19 provides powers to prescribe what must be included in a certificate of design compliance. The Building Regulations should be amended to prescribe the information about, and details of, framed roof construction for Class 1 buildings that must be included in the plans and specifications detailed in the applicable CDC. This will provide a minimum and consistent level of documentation for builders and roof carpenters and will provide a clear standard against which compliance can be measured and enforced.

Recommendation 3: Prescribe mandatory inspections of completed roof framing and tie-downs.

Section 36 of the Building Act provides powers to prescribe inspections during or at the completion of building work. The Building Regulations should be amended to require a registered building practitioner, or registered building surveyor practitioner, to inspect the completed roof framing of each Class 1 building and to certify that it has been completed in accordance with the plans and specifications specified in the applicable CDC. Section 33 of the Building Act provides that inspection certificates provided under section 36 must accompany the NOC. The inspection and certification may be carried out by any appropriately registered practitioner, including the person named as builder on the building permit or a person employed or engaged by the builder. These mandatory inspections can and should be included in each builder's quality control processes.

Recommendation 4: Require consistent compliance monitoring and enforcement by permit authorities

Part 8 of the Building Act provides comprehensive inspection and enforcement powers to permit authorities, which are usually local governments. The Building Commissioner should encourage permit authorities to undertake a consistent level of inspection of building work to ensure compliance with the building permit.

Section 132 of the Building Act provides powers to require permit authorities to provide prescribed information to the Building Commissioner. The Building Commissioner should require permit authorities to advise the Building Commissioner of building orders issued to rectify design or construction defects.

Recommendation 5: Establish an industry response group

Establish an Industry Response Group (IRG) drawing representatives from occupational groups; building, building surveying and engineering professional associations; suppliers; training providers; local government and the Building Commission to consider the following –

5.1 In respect to WA's construction practices (Recommendation 1) –

- Establish what constitutes common practice for framed roofs in WA.
- Investigate and confirm that this common practice delivers roofs that meet the applicable performance standards in the NCC.
- Draft of an acceptable WA construction practice document for submission to the ABCB as a proposal for change for inclusion in NCC 2019.

5.2 In respect to minimum standards of documentation (Recommendation 2) –

- Review current documentation standards and practices in WA.
- Determine minimum effective documentation standards applicable in WA.
- Advise the Building Commission in the preparation of necessary amendment regulations.

5.3 In respect to compliance monitoring and enforcement by permit authorities (Recommendation 4) –

- Establish a minimum effective sample size and inspection regime for permit authorities to monitor the compliance of roof construction for Class 1 buildings.
- Establish a reporting standard for providing compliance statistics to the Building Commission.
- Determine the cost base for carrying out and reporting inspections.
- Investigate whether the fees paid to permit authorities are sufficient to fund the cost of carrying out and reporting necessary inspections.

Where to next?

This report completes a three-phased approach to the Building Commission's general inspection response to improve WA sheet metal clad timber framed roof compliance for resistance to high wind uplift:

1. Phase 1 – carry out building site inspections to identify areas of concern with roof construction.
2. Phase 2 – provide the review's preliminary findings to key industry stakeholder bodies for comment and response.[2]
3. Phase 3 – the Building Commissioner to consider the recommendations and coordinate the necessary actions to achieve desired improvement.

[2] Refer to Appendix B for a list of stakeholders invited to provide comment and feedback on the preliminary findings of the general inspection into WA roof construction 2014.

The Building Commission will address those identified areas of concern which reside within the domains of legislation, regulation, codes and standards and will do so in consultation with industry.

In addition, the Building Commission will support industry associations, training providers and permit authorities to –

- Ensure wind classifications are calculated correctly and applied to dwellings in accordance with AS 4055: 2012- Wind loads for housing, or AS/NZS 1170.2: 2011- Structural design actions – Wind actions.
- Ensure tie-down straps are being installed into the masonry in a manner that can adequately resist design wind uplift force.
- Ensure there is a continuous chain of good connections from sheeting, battens, rafters, underpurlins, struts, strutting beams to top plates.
- Investigate the use of machine-driven nails and their capacities when used to fix light gauge metal connectors.
- Resolve concerns related to timber and metal battens being fixed to timber rafters with nails.

What did we do?

What are our powers?

- Section 86(h) of the CRA Act provides that it is a function of the Building Commissioner to provide, or facilitate the provision of, advice, information, education and training in relation to —

  a) building standards and codes; and
  b) consumer protection in relation to building services.

- Section 60 allows the Building Commissioner to designate —

  (a) a public service officer; or
  (b) a person employed or engaged under the *Public Sector Management Act 1994* section 100 by the employing authority of the Department, as an authorised person for the purposes of this Act.

- Section 65 provides that an authorised person may inspect any building or building service that has been or is being carried out to ascertain any or all of the following —
  (a) how building services have been or are being carried out;
  (b) how building standards (as defined in the *Building Act 2011*) have been or are being applied;
  (c) whether a building service Act is operating effectively.

General inspections are carried out in accordance with legislation and compliance and enforcement policy principles (see Department of Commerce 2015).

This general inspection's initial objective was to determine whether a small number of strategic inspections of active building sites in the Perth metropolitan and South West regions in early 2014 could identify any areas of concern warranting further investigation and possible need for improvement of industry practice and the regulatory framework.

Specifically the general inspection asked: *How are sheet metal clad timber framed roofs being built in Western Australia and is there any cause for concern that roofs may not perform satisfactorily in high winds?*

The following additional questions helped frame future quality assurance improvement recommendations:

- Are there risks that WA's current sheet metal clad timber framed roof constructions will not perform satisfactorily at design wind speeds?
- Are builders, supervisors and roof carpenters clearly informed and understand the specified standards and methods of construction required for each roof?
- How can quality assurance processes be improved by builders, certifiers, permit authorities and the Building Commission?

Other questions considered as a result of the initial inspections also helped frame future quality assurance improvement related recommendations:

- Are permit authorities' enforcement powers under the Building Act being used effectively?
- How well do current supply chains meet the requirements of the WA building industry?
- How well are the critical areas of roof construction being detailed in the design?
- How do these findings affect future Building Commission inspection strategies and priorities?

The general inspection focused on the construction activities for a representative set of WA building sites in respect to the sheet metal clad timber framed roofing construction systems.

The general inspection strategy was informed by data from the Building Commission's complaints and compliance information systems together with external research into roofing uplift risks in WA's sheet metal clad timber framed roofing systems during high wind events (see Boughton and Falck, 2008).

The general inspection was conducted in accordance with the Building Commission's operating policies and procedures and involved:

- Physical site inspections within the Perth metropolitan and South West regions.
- Reviewing relevant Building Commission files.
- Reviewing supplier inventories and installation instructions.
- Referral of potential compliance issues to builders and relevant permit authorities.
- Interviewing individuals in materials supply (suppliers) and construction systems (occupational trades, including builders).

Roofing construction in WA is typically undertaken under the supervision of registered builders or owner builders (see Appendix C – List of definitions). Where appropriate, the term 'builder entities' is used in this report to cover both groups.

How did we do it?

The Building Commission carried out a general inspection of 123 sheet metal clad timber frame roofed dwellings in WA's Perth metropolitan and South West coastal regions under the powers of s69 of the CRA Act. The general inspection environment is outlined in Appendix A.

Of these dwellings, 108 inspections were conducted in the Perth metropolitan area between January–September 2014 and 15 additional inspections were conducted in the broader South West region in October 2014.

As a preliminary inspection it was not possible for the Building Commission inspector to assess each roof against the applicable (performance) building standards. Nor did the inspector initially compare the roof against the plans and specifications specified in each applicable CDC to determine the actual construction requirements for each roof. Instead, the sample of roofs was assessed using the provisions of AS 1684.2: 2010 as a standard of good, commonly-applied roof construction practice which implies the roof is deemed-to-satisfy the performance requirements. This means no final conclusions can be made in relation to the performance requirements of the BCA from this general inspection.

When incidences of poor construction practice were observed during the general inspection the inspector then asked for the plans or specifications and used these to follow up any further areas of interest or concern.

In assessing each inspection point (see Table 2) the inspection protocol required that non-satisfactory compliance with AS 1684.2 and associated Australian Standards (or clear cases of poor construction practice) must be demonstrated consistently across the inspection point category for it to be classified as a non-satisfactory area of concern.

Under this inspection protocol, where an inspection point substantially complied with AS 1684, and there were no incidences of poor construction practice, the inspection point was then rated as having no concerns from a general inspection perspective. It is possible the roof at that inspection point should have been constructed to different details or standards as part of a performance solution.

All site inspections in this general inspection related to sheet metal clad timber framed roofed dwellings in WA. No commercial or industrial roofs were inspected during this general inspection as these roofs are usually constructed from large span steel sections which are outside of the scope of the general inspection. The general inspection did not include tiled roofs or roofs constructed from metal trusses. Nine timber truss roofs were inspected.

All sites reviewed were within either the N1 or N2 wind zones (see Table 9 in the 'Detailed Report' section, below). All inspection points were evaluated against the minimum N1 design standards. Therefore, failure to meet AS 1684 standards for N1 wind zones automatically implies failure to meet standards for N2 wind zones.

Inspection sample

Perth region inspections ranged from Yanchep in the north through to South Yunderup in the south and extended inland to within 15km of the coastline. The South West regional inspections included the area from Australind to Vasse extending inland to within 10km of the coastline.

Selection of the 123 sites for this general inspection was random and unstructured with a focus placed on current constructions with roofing at about the right stage for inspection — ie neither too early (so having nothing to see) nor too late (so everything is finished and covered up).

One inspector was used for all inspections to reduce possible variances introduced with assessing multiple inspectors' perspectives.

Lists of possible sites within a locality more likely to have new home constructions were created from multiple sources – eg service utility lists and local government building permit lists. In addition, any houses identified in the same area while undertaking the inspections which also met the criteria (eg metal roof) would also be inspected if possible.

The sites selected for inspection were predominantly Class 1a buildings although three roofs of Class 2 buildings were inspected.

The BCA Vol. 1 defines the following:

- Class 1a as a single dwelling being either “a detached house” or “one of a group of two or more attached dwellings, each being a building separated by a fire resisting wall, including a row house, terrace house, town house or villa”; and
- Class 2 as “a building containing 2 or more sole occupancy units each being a separate dwelling”.[3]

In this general inspection a total of 51 registered building contractors of varying sizes and two owner builders were responsible for the 123 sites inspected. Nine registered builders were responsible for the 15 properties inspected in the South West region. A total of 4,661 building contractors were registered with the Building Commission in 2014 during the general inspection. Therefore, the general inspection covers approximately one per cent of registered building contractors operating in WA during 2014.

We assume approximately 60% of roofs being constructed in WA during 2014 used sheet metal material supported by a timber roof frame.[4] Therefore, it is estimated that just less than one per cent of all sheet metal timber framed roofs being constructed in WA during the review period 2014 were inspected during the general inspection.

Twelve inspection points

Where possible, the inspector aimed to inspect the roofs after the roof carpenters had completed their work but prior to roof sheeting being installed. Viewing the sheet metal clad timber framed roofs at this stage of completion provided the most accurate opportunity to assess construction and workmanship practice.

Initial field data, supply samples and related expert advice were analysed and the general inspection was focused on 11 critical areas of sheet metal clad timber framed roof construction. A twelfth category was subsequently included to capture any other related issues considered relevant to assessing sheet metal clad timber framed roof construction for resistance to wind uplift forces.

These 12 categories (listed in Table 1) form the basis for the individual inspection reports summarised in the detailed section of this report.

[3] BCA Volume 1; Part A3- Classification of Buildings and Structures.

[4] Based on feedback from tile manufacturers and major building companies and observations made by Building Commission inspectors.

12 inspection points	Description
1	Tie-down corrosion rating
2	Tie-down correctly installed
3	Timber roof batten within 1200mm of roof edges
4	Timber roof batten connection in general roof areas
5	Metal batten
6	Rafter connection to top plate
7	Connections for the remainder of the roof
8	Collar ties present where required
9	Timber truss correctly installed
10	Timber roof beams correctly installed
11	Steel roof beams correctly installed
12	Other sundry areas

Table 1.Reviewed inspection points

The inspection data represent an assessment of the relevant inspection points for each of the 123 building construction sites considered in this inspection, from the perspective of the DTS. Any inspection point found not to be relevant (eg a site with only one type of truss or rafter) was subsequently excluded from any final general inspection assessment score.

Inspection point assessments were coded where possible as either definitely ‘satisfactory’ or ‘non-satisfactory’. This inspection point assessment process used the AS 1684 as a proxy standard and this determination does not refer to compliance with the applicable building standards. Where an inspection point assessment could not be clearly determined then the assessment was categorised as either ‘unable to determine’ or ‘not applicable’.

What did we do to respond to non-satisfactory inspection points?

Letters were sent to building entities in connection with 118 buildings in response to non-satisfactory inspection point findings.

In all cases builders were notified in writing about the specific issues identified in the general inspection and requested to rectify the non-satisfactory work. Initially, concerns were either resolved directly via informal communication with the builder or referred to the relevant permit authority for follow-up action under the Building Act as required. The Building Commission amended its approach in response to the industry asking for an opportunity to respond to matters before referral to the relevant permit authority. The amended approach required the builder to confirm that the non-satisfactory work had been rectified or that an alternative solution applied. This approach applied to 70 of the 118 letters sent to builders.

“In all cases builders were notified in writing about the specific issues identified in the general inspection and requested to rectify the non-satisfactory work”.

Of the 70 letters requiring follow-up from the builder, formal responses were received in 59 instances. Of this 54 respondents confirmed that remedial work had been completed as indicated necessary by the Building Commission inspector, without claiming a performance solution applied. Five (5) responses of the 59 received, claimed to have an alternative solution. The 11 non-responses resulted in the matter being referred to the relevant permit authority for appropriate action under the Building Act.

The roof was coded based on the original inspection, regardless of whether the builder advised that remedial work would be or had been carried out or whether the builder claimed an alternative solution applied. In all instances where a builder claimed an alternative solution applied, it was determined that it had not been approved as part of the building permit notwithstanding it may have met the performance requirements of the BCA. In this case the coding remained 'non-satisfactory'.

> *"The roof was coded based on the original inspection, regardless of whether the builder advised that remedial work would be or had been carried out or whether the builder claimed an alternative solution applied".*

What performance requirements apply?

The following terms are recognised in international agreements and by standards and conformance authorities:

Technical standard/regulation: A technical standard is developed and approved by an authorised body to describe the specifications and performance of a product along with the accepted testing methods or procedures to ensure the product is safe, reliable and consistently performs as intended. Standards are published documents that establish the common language which defines quality, safety and performance criteria. Standards may be voluntary or mandatory. Mandatory standards or technical regulations are applied by laws relevant to electrical safety, consumer safety, building and plumbing activity.

Conformity/conformance: The terms conformance or conformity relate to the extent to which products meet or comply with applicable law, regulation and/or specified industry codes, national or international standards. A non-conforming product does not meet the minimum technical requirements or performance as specified by the relevant standard, regulation or law.

Conformity assessment: Conformity assessment means the systematic examination to determine the extent to which a product, process or service fulfils specified requirements.

Compliance: The term compliance relates to the extent to which products are applied or installed by the building practitioner to fit the purpose as intended by the manufacturer. A non-compliant product is one that is misapplied or installed in a manner that is not fit for the purpose intended by the manufacturer.

Accreditation: Accreditation is the procedure by which an authorised independent body gives formal recognition that a conformity assessment entity is competent and proficient to carry out calibrations, tests, inspections and/or certifications.

Frameworks for general inspection assessment

Building Commission general inspections assess how building services have been, or are being, carried out; how building standards have been, or are being, applied; or whether a building service Act is operating effectively.

As outlined previously, several types of roof constructions are set out in AS 1684.2. As an overall general guide to understanding the WA sheet metal clad timber framed roofing practices being inspected:

- Roofs are either ‘flat’ or ‘pitched’ and the general inspection looked at pitched roofs.
- Flat roofs are subject to even more wind uplift, and whatever is good for a flat roof is almost certainly also good for a pitched roof.
- For this general inspection a ‘metal deck roof’ normally infers a flat roof, rather than a pitched roof, and a ‘metal clad roof’ infers a sheet metal clad, pitched roof.
- Metal deck roofing describes more the type of roof used on industrial buildings.

The general inspection was focused on timber roof framing where it supports metal roof sheeting, either on a pitched or a flat roof – eg gable, hip, skillion (flat), cathedral, trussed and pitched roofs. In these types of roof construction, the joints in the timber are usually constructed on site and may be very variable. Metal roof framing is usually prefabricated in a workshop and connections are usually installed correctly.

The general inspection assessed sheet metal clad timber framed roofing construction practice in WA against the following codes and Australian Standards:

- Building Code of Australia.
- Referenced Australian Standards (AS) – specifically:
    - AS 1170.2: 2011- Structural design actions; Part 2: Wind actions
    - AS 1720.1: 2010- Timber Structures; Part 1 - Design methods
    - AS 1684.2: 2010- Residential timber framed construction
    - AS/NZS 2699.2: 2000- Built-in components for masonry construction; Part 2: Connectors and accessories
    - AS 3700: 2011- Masonry structures
    - AS 4055:2012- Wind loads for housing
    - AS 4773: 2010- Masonry in small buildings; Parts 1 & 2

In addition to the above, the following sources of information and expertise were also used to assist with the assessment:

- Building permits, plans and specifications.
- Instructions and guidelines provided by manufacturers and suppliers.
- Recognised expert opinion and technical research.

Assessment report summaries for each of the 12 inspection points are provided in the detailed report section below – including (a) how assessment of roofing construction was being carried out; and b) how standards were being applied by builders for a specific aspect of sheet metal clad timber framed roof construction. Assessments were made with reference to the various relevant codes and standards outlined above.

Building Code of Australia (BCA)

The assessments chiefly refer to the BCA Vol. 2; Part 2.1- Structure; Performance Requirements; P2.1.1: Structural stability and resistance to actions; which states:

> "(a) A building or structure, during construction and use, with appropriate degrees of reliability, must—
>
> (i) perform adequately under all reasonably expected design actions; and
>
> (ii) withstand extreme or frequently repeated design actions; and
>
> (iii) be designed to sustain local damage, with the structural system as a whole remaining stable and not being damaged to an extent disproportionate to the original local damage; and
>
> (iv) avoid causing damage to other properties, by resisting the actions to which it may reasonably be expected to be subjected.
>
> (b) The actions to be considered to satisfy (a) include but are not limited to—
>
> (i) permanent actions (dead loads); and
>
> (ii) imposed actions (live loads arising from occupancy and use); and
>
> (iii) wind action; and……..".

An owner, designer or builder must develop a building solution that will meet this performance standard. A building solution must be able to be verified and permit a building surveyor to certify that the proposed building, when completed, will indeed meet this performance standard. The different methods available to verify a performance solution are set out in the BCA Volume Two, Section 1: General Requirements, Clause 1.0.8: Alternative Solutions.

To assist in completing performance solutions, the ABCB has produced the Development of Performance Solutions document to assist practitioners with the development and approval of performance solutions – including information on the correct process for assessing alternative solutions.[5]

One accepted verification method is to use the DTS solutions. As a DTS solution, the BCA Volume Two, Part 3.4.3: Timber Framing, Section A: Acceptable construction manuals; states: [note: items a – f are blank in the original]

> Performance requirement P2.1.1 is satisfied for a timber frame if it is designed and constructed in accordance with the following, as appropriate:
>
> (g) AS 1684.2.
>
> (h) AS 1684.4.

Australian standard

The primary standard for timber framed roof construction is AS 1684.2-2010: Residential timber-framed construction: Part 2: Non-Cyclonic Areas.

[5] See NCC_Performance_Based_Code.aspx (Version 2.0) at www.abcb.gov.au

AS 1684.2 has been used in this general inspection in preference to AS 1684.4 (Australian Standard 1684.4: 2010 - Residential Timber Framed Construction; Part 4: Simplified – Non-cyclonic areas) which is a simplified version of AS 1684.2 and is therefore more generic in the solutions provided. AS 1684.2 generally provides a solution reflecting the roof construction methods used on each inspected WA building site, though individual variations may occur.

Assessment process

Following a process of on-site inspections and file reviews the general inspection assessment of how construction was being carried out and how standards were being applied by the builder was made against the provisions of the Australian Standards referred to in the DTS solutions.

Where suitable details were not available in Australian Standards then relevant manufacturer installation instructions and guideline recommendations were used as a basis to assess adherence with relevant manufacturers' recommendations.

Some of the roofs inspected may have used performance solutions. Where possible, roofs that did not comply with the DTS provisions on initial assessment were then assessed against plans and specifications provided by the builder or the permit authority. The general inspection assessment process did not include any attempt to verify if the roof, as actually constructed, met the relevant performance requirements – a more complex process requiring greater levels of Building Commission resources, higher intervention impact on builders and the possible commissioning of a range of technical professionals.

While it is reasonable to assume that a roof which met all the requirements of the DTS solution also complied with the applicable building standards it is not possible to state conclusively that a roof that does not meet all the requirements of the DTS solution also does not meet the applicable building standards.

In respect to assessment and the implications of the findings it is important to note the units of measure being used. Broad overall general inspection assessment scores are made using the aggregated assessments of a set of individual roofing system inspection point elements with a focus on whether they can be considered satisfactory or not.

Certain conclusions can be drawn from these aggregated data which relate to workmanship; supervision (and by implication, management); the relevance of the various codes and standards in WA's construction context; and finally, whether legislation and regulations may need reviewing.

However, what must be clearly understood is these general inspection data findings, in themselves, cannot be directly used to definitively answer questions related to broader roofing system performance. In this respect, the general inspection data analysis, together with other relevant anecdotal and contextual information on industry practice, can inform and influence the Building Commissioner's levels of confidence with WA's building construction environment.

Two basic analysis frameworks assist the Building Commissioner to form an appropriate conclusion:

1. roof frame system capacity to accommodate design wind speeds; and
2. assessment of where responsibility for issues lay in respect to regulation or industry.

In respect to assessing a roof frame system's capacity to accommodate design wind speeds the 'chain' of structural elements involved in transmitting and anchoring roof uplift forces to the ground can be evaluated. This assessment approach helps inform the development of risk assessment in respect to worst case design wind scenarios.

In respect to assessing the likely overall responsibility for non-satisfactory issues the data can be further evaluated by informed expert opinion across four key domains: workmanship; management and supervision; standards and codes; and legislation and regulation. This assessment approach helps inform the development of conclusions and response strategies.

Roof frame system construction

The general inspection assessed WA's sheet metal clad timber framed roof construction against the items contained in AS 1684.2.

Figure 1 (below) has been adapted by the Building Commission from the AS 1684.2 to present the typical roof system elements assessed during this general inspection.

Boughton and Falck (2008) identified a 'chain' of five key critical structural capacity elements which, working together, form the highest deficiency risk in structural capacity for wind uplift:

1. Batten to rafter connections
2. Rafter to top plate connections
3. Roof structure connections
4. Top plate to masonry connections
5. Veranda details

On the 20th February 2015 a severe tropical cyclone (Cyclone Marcia) over central Queensland caused around A$140 million worth of damage.[6] James Cook University Cyclone Testing Station (CTS) subsequently warned there is a need to remain vigilant in ensuring Australian buildings are designed and built to withstand extreme weather events referencing Engineers Australia comments in respect to Cyclone Marcia:

> As with previous cyclones, most of the damage in Cyclone Marcia arose from issues with the way structures were tied together. If there is any weak link in the load path, the wind will invariably find it and often unzip the structure. (Engineers Australia 2015, pp. 13-14).

[6] See www.themorningbulletin.com.au/news/marcia-could-cost-insurer-140-million/2626815/

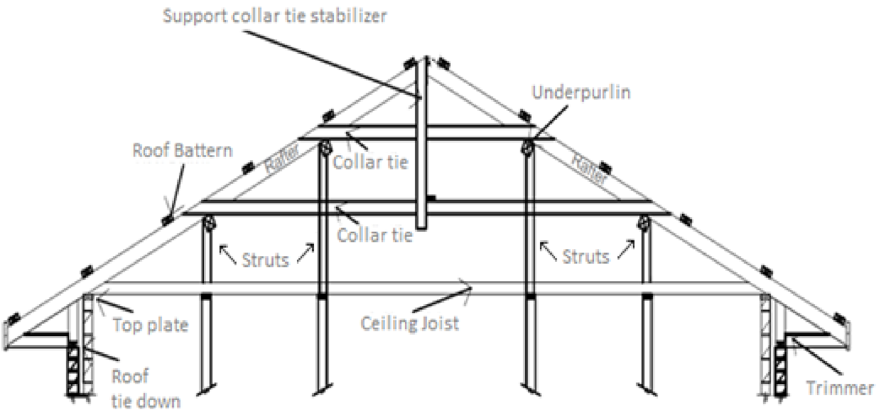

Figure 1. Roofing elements & critical structural capacity outline

Table 2 (below) lists the typical sheet metal clad roofing system components inspected during this review and describes their purpose.

Element	Purpose
Batten	Supports and connects the roof sheeting to the rafters.
Ceiling joist	Usually 90 mm x 35 mm member seated on the top plates used to support the ceiling lining and tie the rafters together at plate height.
Collar tie	Member tying rafters together at the level of the underpurlins.
Rafter	Members installed on a slope that extend from the ridge or hip to the wall plate that support the battens and roof sheeting.
Ridgeboard	A member to which the tops of the rafters are fixed.
Strut	A member supporting the Underpurlin.
Strutting beam	A beam that supports struts where no wall is available.
Top plate	Usually 90 mm x 35 mm member installed on the top course of brickwork or along beams.
Underpurlin	Support member installed under and at right angle to the rafters.

Table 2. Typical roofing elements

Responsibility for issues identified in building construction

Following stakeholder feedback, the Building Commission's inspectors compiled an agreed impact assessment score across four domains (workmanship; management and supervision; standards and codes; and legislation and regulation) to determine where, in their expert opinion, the main responsibility for the 'non-satisfactory' findings lay for each of the 12 general inspection point elements detailed in this report.

Although a more detailed 'gap' analysis of any difference of opinion between stakeholders (and the Building Commission inspectors) may be useful to inform implementation strategies (eg see Recommendation 5) the purpose of the initial analysis was to assist the Building Commission to assess the final general inspection recommendations.

The agreed impact assessment scores for each of the 12 inspection point elements are included in the respected conclusions section at the end of each detailed report.

Table 2a summarises these 12 impact assessment scores and presents a final general inspection score card assessment of where any remedial action should likely be focused – ie of where the 'solutions' lay.

Problem responsibility assessment scorecard	**Regulation**		**Industry**		**Total**
	Standards / Codes	Legislation / Regulation	Workman-ship	Management / Supervision	
1. Tie-down corrosion rating	20	20	0	60	100
2. Tie-down correctly installed	20	20	25	35	100
3. Timber roof batten within 1200 mm	10	20	30	40	100
4. Timber roof batten general area	10	20	30	40	100
5. Metal batten correctly installed	30	20	20	30	100
6. Rafter connection top plate	10	20	30	40	100
7. Connections remainder roof	15	20	25	40	100
8. Collar ties	0	20	35	45	100
9. Timber truss correctly installed	0	20	35	45	100
10. Tie down timber roof beams	20	20	25	35	100
11. Tie down steel roof beams	0	20	35	45	100
12. Other compliance	0	20	35	45	100
Inspection item total	135	240	325	500	1200
Responsibility domain total	375		825		1200
Inspection item % of total	11%	20%	27%	42%	100%
Responsibility domain % of total	31%		69%		

Table 2a. Responsibility impact assessment scores

Building control

The Building Act, Registration Act and CRA Act introduced a new comprehensive system of building control in WA. In this framework risk is managed through a system of building and occupancy permits; registration of key practitioners and contractors; audit and enforcement of compliance; and a process of complaint resolution. Low-risk buildings do not require a building or occupancy permit.

Moderate-risk buildings such as Class 1 and 10 (single residential and incidental) buildings require a building permit but do not require an occupancy permit. Higher-risk buildings such as Classes 2 to 9 (multi-residential and commercial) buildings require both a building permit and an occupancy permit. Other controls such as mandatory inspections and reporting can be applied where necessary subject to regulatory gatekeeping principles.

Permit authorities

Under the Act, a permit authority issues and monitors compliance with building permits and occupancy permits. The permit authority for a building has full discretionary powers to inspect work under construction (or occupied); investigate a suspected contravention of a permit; and issue a building order remedy for non-compliance.

Permit authorities are normally local governments although the State of Western Australia is a permit authority for government owned buildings and can also become the permit authority in other special circumstances. Special permit authorities can also be created to provide conjoint building control services or deal with special precincts spanning multiple local government areas.

Permit authorities collect building permit fees and these can be applied for the purposes of carrying out their functions under the Act. The amount of the fee is established in the Building Regulations. The fee for an uncertified application for a Class 1 building is calculated based on the estimated value x 0.32% with a minimum amount set at $92.00. Certified applications for a Class 1 building incur a fee of the estimated value x 0.19% with a minimum amount also set at $92.00.

Building surveyors

Where a building permit is required, the Building Act requires a registered building surveyor to assess the plans and specifications for the proposed building and to issue a CDC confirming the building will conform to each applicable building standard if constructed in accordance with the plans and specifications. The applicable building standards are the performance requirements of the BCA. Registered building surveyors also issue certificates of construction compliance and certificates of building compliance for Class 2 to 9 (multi-residential and commercial) buildings that require occupancy permits.

Building entities (builders)

Under the Building Act a person named as the builder on a building permit must ensure that the building, or incidental structure to which the permit applies, is completed in accordance with the plans and specifications detailed in the applicable CDC and applicable building standards.

Building Services Board

The Registration Act enables the Building Services Board to take disciplinary action against a registered building surveyor or registered builder who fails to comply with the obligations set out in the building service Acts.

Building Commissioner

The Building Commissioner's functions are established in the CRA Act. These functions include dealing with building service complaints, home building work contract complaints, disciplinary complaints, the monitoring and review of the operation of the building service Acts and auditing the work and the conduct of registered building service providers. The Building Commissioner also administers the Building Services Board which is responsible for the registration regime for registered building service providers.

The Building Commissioner relies upon the collection of occupational registration and licence fees to register, investigate and audit registered building service providers. In addition, the Building Commissioner relies upon the collection of the building services levy to fund the management of complaints lodged under the CRA Act and for carrying out general inspections. The building services levy rate is set at either 0.137% of the value of the building work or an amount of $61.65 for values up to $45,000.

Building service complaints system

In WA a person may make a complaint to the Building Commissioner about a regulated building service not being carried out in a proper and proficient manner, or being faulty, or unsatisfactory. Accepted complaints are investigated and outcomes may include dismissal of the complaint; the issue of a building remedy order; referral of the complaint to the State Administrative Tribunal (SAT); or a conciliation between parties.

By far the majority of complaints captured under the Building Commission's disputes service outlined above relate to 'finishing trades' – eg faulty painting or plaster work. It is uncommon to receive complaints about the type of structural defects in roofs identified during this general inspection. Therefore, data from the Building Commission's complaints systems may not be a good indication of the overall quality of the building.

The Building Commissioner is also able to receive and investigate disciplinary complaints about a registered building service provider. Complaints about structural defects are more likely to occur during a disciplinary process and remedial action in relation to negligent conduct, or a failure to manage and supervise the work, is taken. Complaints are generally triggered by a specific event such as a structural failure or a subsequent building inspection report.

Other Australian jurisdictions

In Victoria, Queensland, New South Wales (NSW) and the two Australian Territories, the traditional building control role of the local government has been transferred to private sector building surveyors- including the issue of permit, the inspection of building work and the enforcement of compliance. As part of this transition, private sector building surveyors are required to perform mandatory inspections in these states and territories.

Western Australia and Tasmania, unlike the remaining states and territories in Australia, do not mandate critical stage inspections in Class 1 buildings – see Queensland Building and Construction Commission (2014, pp. 41-42) for a summary of Australian jurisdictions.

In Tasmania, building inspections are not strictly mandatory although notification by the builder of certain stages of construction is required. The Certificate of Final Inspection requires the building surveyor to advise the reason they did *not* carry out an inspection, if that was the case.[7]

In WA, the Building Act retains the discretionary inspection powers of local governments (permit authorities), but adds an additional framework for prescribed inspections by appropriately qualified people as part of the quality control process. No prescribed inspections currently apply to class 1 buildings.

[7] Tasmanian Department of Justice (2014, p. 39).

Industry trends and concerns

Building activity trends

The long-term trend for private house construction (excluding units) in WA from 2003 to 2015 averages approximately 18,868 private houses per year (ABS 2016, Table 08. Number of Private Sector Houses Approved - States and Territories).

Housing Industry Australia (HIA, 2015) long-term average is 18,852 and forecasting an average of 18,405 out to 2019 – equating to a monthly average of 1,571 and 1,533 respectively.

Figure 2 below shows the rapid rise in WA housing construction during a period of high state-wide economic activity from a low of 15,675 houses per year in 2012 to the peak housing construction period in 2014 during the general inspection period – ie 23,658 (ABS 2016) and 24,050 (HIA 2015).

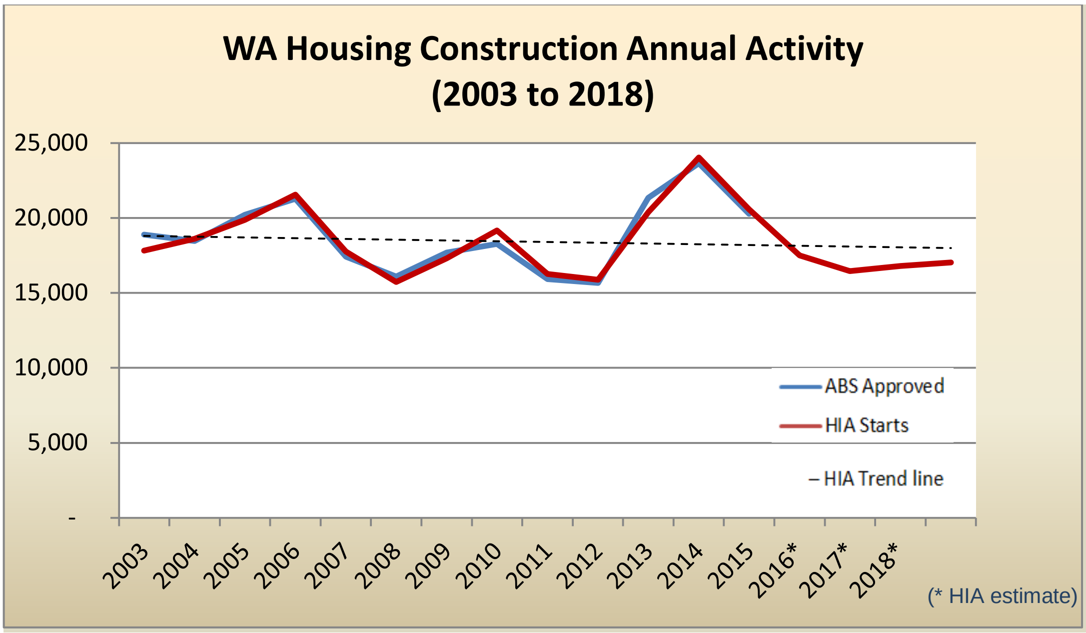

Figure 2. The trend estimate for total number of houses approved/started in WA

Housing construction activity surged 36% in 2013 compared to 2012. By the end of 2014 the industry accommodated a total increase of 51% in housing construction activity in just 24 months – ie an average of 25% per annum compared to the 2012 baseline.

However, while housing construction activity increased by an average 25% per annum for 2013 and 2014, the number of complaints lodged with the WA Building Commission remained relatively steady – ie increasing by approximately 7.4% over the period.[8]

The relatively low growth in complaints received by the Building Commission compared with the growth in residential building approvals was considered in the context of the general inspection findings.

[8] Department of Commerce Building Complaints Information systems.

In the absence of onsite inspections, the relative low-level of complaints data may indicate buildings are being built to the applicable Australian Standards and are meeting customer expectations, including builders having effective systems to manage customer dissatisfaction. Alternatively, the data could indicate a lack of industry monitoring and inspection and the low number of complaints recorded regarding abnormalities with structural features may be due to these aspects normally being less obvious to non-technical owner/customers.

A changing construction environment — innovation and risk

Innovation in roofing systems can involve change in materials and construction practice leading to higher productivity. However, innovation can also increase risk where new materials, accepted standards and traditional construction practices are not in alignment.

Extended periods of rapid economic growth leading to higher building construction activity and labour shortages through competition for limited skilled resources, such as was experienced in WA leading up to and during the general inspection in 2014, can also negatively affect the quality of management and supervision of critical areas of roof construction.

Building industry innovation

Table 3 (below) summarises the typical types of innovation and risk that may be relevant to WA roofing systems.

Category	Innovation trends	Risk trends
Materials (manufacture & supply)	From traditional hardwoods and tile to softwoods and metal.	• Higher net up-lift forces • Softwoods have lower strength and nail capacities.
Practice	Move from hand driven to machine driven nails.	Greater variety in quality and capacity of nailed joints.
Knowledge	Changes in materials and construction methodologies.	Not keeping up to date with latest materials and technologies.
Technology	Use of trusses, metal battens purpose made metal connectors. Use of IT Apps to improve information efficiency.	Failure to install in accordance with the manufacturers' instructions may lead to failure at below design wind speed.
Legislation/ regulation	From government checking to emphasis on self-regulation. Changes in roof construction and associated standards.	Failure to keep up to date with the current construction requirements.
Inspection	Local governments withdrawing from construction inspection.	Failure to detect non-compliance.
Environment	Potential changing of weather patterns.	Potential for greater number of high wind events.
Future trends (economics, demographics, etc)	Projected 100% increase in Perth population by 2050.[9] Increase demand on builders. Building supervisors and workers from outside WA.	Reduced familiarity with WA construction methods.

Table 3. WA roofing system and risk trends

The impact of changes to construction methods is not always immediately obvious. A recent example of a worst-case systemic failure was documented in the Hunn Report into "weathertightness" (Hunn, Bond & Kernohan 2002) or, as it is more commonly known, as 'New Zealand Leaky Building Syndrome'.

[9] ABS (2014). *3218.0 – Regional Population Growth, Australia, 2012-13: Feature Article: Capital Cities: Past, Present and Future*.

A subsequent Select Committee inquiry and Government review (Yates 2003) into the implications for residential housing – including a latter PricewaterhouseCoopers review into escalating cost estimates (PriceWaterhouseCoopers 2009) – indicate the potential magnitude and economic impact of such structural problems in the building industry should not be ignored.

The consensus forecast of the costs associated with the weathertightness issue was calculated at just over $11M which does not include Government costs. An extreme view estimate put the costs in excess of $22M.

Another relevant example in respect to poor roof tie-down construction practice in WA occurred in October, 2009 when a brick pier not properly connected to a roof beam collapsed and resulted in the death of a young child. The State Coroner subsequently recommended the government consider making it a requirement for local governments responsible for building permits to require details of all tie down connections for homes to be included as part of an approval process before construction – specifically:

> Recommendation No.1
>
> I recommend that Government consider making it a requirement for local governments responsible for issuing building permits under the *Building Act 2011* (WA) to require the details of all tie down connections for residential buildings to be submitted on plans provided to local government as part of the approval process preceding the construction of a residential building.
>
> Recommendation No.2
>
> I recommend that the Government consider making it a requirement for local governments responsible for issuing building permits under the *Building Act 2011* (WA) to undertake inspections during the construction of a residential building to ensure roof tie downs are adequately constructed, placed and fitted. (Mulligan 2013, p. 57)

The Building Act 2011 responded to these recommendations with provisions to prescribe documentation standards and introducing a new provision for mandatory inspections.

Following two deaths in Cyclone George (March 2015) in WA's North West the State Coroner (Fogliani 2015) again noted the importance of complying with correct structural design standards which “exist to take account of the rare, severe and/or unpredictable occurrences” especially in reference to wind regions near the WA coast line.

In this respect the Coroner recommended:

> Recommendation No. 1
>
> I recommend that the Western Australian Government consider introducing mandatory inspections in Wind Regions D and C in order to achieve greater construction compliance with the applicable building standards set out in the Building Regulations 2012.
>
> Recommendation No. 2
>
> I recommend that the Australian Building Codes Board explore methods by which a large scale electronic map that is prepared in accordance with the smoothed coastline and the delineated wind regions be made accessible through the Web. This map is to be updated if and when the Australian Standards change the delineated wind regions.

The Building Commission is examining options to introduce mandatory inspections in cyclonic areas. The Australian Building Codes Board has examined the preparation of a large-scale map and has asked Standards Australia to include relevant provisions in revised standards to set out how to delineate the wind regions.

Finally, perhaps the most poignant of all systemic building failures was experienced in Darwin on Christmas Day, 1974 when the city was hit by the tropical weather depression given the name of Cyclone Tracy. In addition to the terrible death toll and casualty rate, 70% of Darwin's homes were destroyed or suffered severe damage and all public services were severed (see National Archives of Australia, *Cyclone Tracy, Darwin – Fact Sheet 176*).

Risks for consumers

The Building Commission's complaints process outlined earlier in this report provides consumers with a six-year period in which to lodge a complaint about faulty or unsatisfactory building services. Home indemnity insurance provides cover if a consumer is unable to obtain the benefit of an order made by the Building Commissioner or the State Administrative Tribunal because of the death, disappearance or insolvency of the builder.

Latent defects can become apparent many years after the building is actually completed and a consumer can always proceed with a civil claim through a court of competent jurisdiction at any time within six years of the defect becoming apparent (refer to the *Limitations Act 2005*).

Poor workmanship and supervision in respect to roof framing may well be considered to be a latent defect.

However, as discussed previously, consumers are very unlikely to identify the type of non-compliance in roof structures covered by this general inspection unless their house actually experiences structural failure caused by a high wind event which results in damage to, or loss of, the roof.

Other potential risks to consumers, in addition to the risks associated with the costs of damage or loss of a roof, include:

- Higher insurance costs.
- Other structural damage.
- Injury or death from structural failure.
- Structural damage to neighbouring properties.

What did we find?

The results for satisfactory construction varied across the 12 general inspection points from very low (11%) in relation to corrosion protection to moderate (63%) for battens properly tied down within 1200 mm of the edge of the roof. Overall, when the results from the 12 inspection points were averaged, this achieved an overall satisfactory rate of 33%.

The results for satisfactory construction for roofs inspected in WA's South West regional areas at the end of the review period in October 2014 was estimated at 31% – similar to the Perth metropolitan area.

Only two construction sites were found to be satisfactory across all the relevant inspection points and 14 sites were identified with zero satisfactory relevant inspection points.

Throughout the general inspection a steady improvement was observed. This improvement trend may be attributed to positive industry response to inspector feedback provided at the time of site inspections and via subsequent written communication with builders as part of the broader general inspection process.

"Throughout the general inspection a steady improvement was observed".

Analysis of the general inspection environment and assessments

A total of 123 building sites were inspected from January to October 2014 covering 26 Perth suburbs and WA's South West coastal region (see outline in Appendix A: General Inspection environment).

All building sites inspected were Class 1a home buildings with the exception of one multi-unit Class 2 site.[10] Table 4 summarises the number of inspections and date completed.

General Inspections	N^o.	Start date	Completion date	Comment
1 thru 8	8	20 January	28 January	Perth region – files & sites
9 thru 46	38	20 January	13 May	Perth region – files & sites
47 thru 108	62	13 June	25 August	Perth region – sites
109 thru 123	15	1 October	2 October	South West region – sites

Table 4. General inspection dates during 2014

Each construction site/dwelling was assessed and rated across 12 possible inspection points which created a potential total of 1,476 inspection point values generated for assessing overall general inspection rating scores.

[10] One site was a Class 2 multi-unit development whereas four other sites were Class 1a multi-unit developments.

Inspection results were listed and rated in a spread-sheet by an expert Building Commission inspector using one of the following four codes:

- Y – yes, satisfactory
- N – no, non-satisfactory
- U – unable to determine
- Z – not applicable

Only the Y and N rating values were used during the general inspection analysis to calculate overall construction rating statistics – ie U and Z values were excluded from any final general inspection point rating assessment (see Table 5 and Figure 3 below).

Roofing system inspection point element inspected	**Rating code**	**Assessment of inspection points**	**% of total inspection points**	**Assessment score**
Yes – found satisfactory	Y	308	21%	Included
No – found not satisfactory	N	628	42%	Included
Unable to determine	U	143	10%	Excluded
Not applicable	Z	397	27%	Excluded
Total:		1,476	100%	936 included

Table 5. General inspection results 2014

In summary:

- 123 houses were inspected and (in theory) if each construction site/dwelling contained all the 12 general inspection points being assessed then a maximum of 1,476 inspection points could have been assessed and rated.
- However, not every construction site/dwelling assessed contained all 12 inspection points in its design or construction – therefore, in practice, only 1,079 inspection point assessments were actually obtained in this general inspection.
- Of these actual 1,079 inspection point assessments, 143 assessments were unable to be clearly determined and rated due to various site-specific reasons and this resulted in a total sample size of 936 completed inspection point assessments being rated.
- Of the total 936 assessments only 308, or 33%, were assessed as complying with the test standard AS 1684.2 and other relevant standards in the DTS solutions set out in the BCA.

"Of the total 936 assessments only 308, or 33%, were assessed as complying with the test standard AS 1684.2 and other relevant standards in the DTS solutions set out in the BCA."

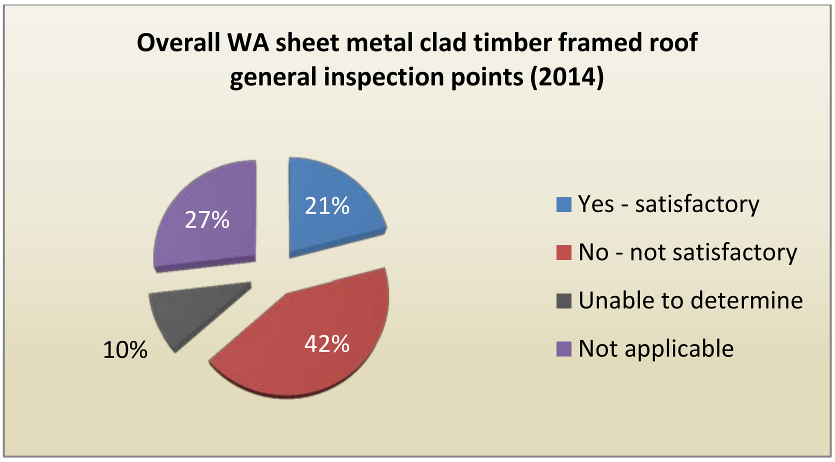

Figure 3. WA sheet metal clad timber framed roofing system general inspection analysis

What percentage is this sample of WA's total annual WA building construction?

According to the Australian Bureau of Statistics (ABS) (2014a, p.12) there were 23,602 houses/dwellings approved in 2013-14. This represents an annual possible total of approximately 283,224 relevant comparable general inspection points being constructed in WA during the 2014 general inspection.

Based on discussions with manufacturers, builders, and a Building Commission estimate of the percentage of metal roofs compared with tiled roofs observed while undertaking construction site inspections, it is estimated that approximately 14,161 (60%) of WA house constructions used sheet metal clad timber framed roofs during 2014.

Therefore, assuming 60% of WA's annual house approvals are in-scope sheet metal clad timber framed roofs, the total number of theoretically possible annual 'on-the-ground' in-scope inspection points for this general inspection is estimated at approximately 169,934.

However, although a single dwelling can have all 12 inspection points within its design, the general inspection found the average overall number of applicable inspection points was only 73%. When this 'like-for-like' comparative factor is applied to the ABS (2014a) data then the total number of comparable inspection points for WA's 14,161 houses constructed during 2014 is therefore reduced from 169,934 to around 124,052 inspection points.

In addition, 10 of the GIR1's 123 inspection sites were multi-unit constructions which are not included in the ABS statistics cited above.[11] Therefore, in order to better compare a 'like-for-like' inspection sample size with ABS (2014a) WA building construction data only a population of 113 inspection sites is used to determine how these data represent the broader overall WA situation – ie 1,476 comparable inspection points for 123 houses is reduced to 1,356 for 113 houses and when adjusted down to 73% to account for non-applicable theoretical inspection points to comparable sample size becomes 990 inspection points.

[11] Seven buildings in five Class 1a multi-unit development sites and three buildings in a two Class 2 multi-unit development site were inspected.

Therefore, the adjusted comparative general inspection point sample represents approximately 0.8% of WA's annual sheet metal clad timber framed roof construction activity during 2014. Statistically, this gives a 95% confidence interval that the audit results can be assumed to represent WA's sheet metal clad timber framed roof construction during 2014.

Independent expert opinion was commissioned to verify the relevant confidence interval for generalising these results to the broader relevant WA housing population in 2014. The advice confirmed there is good reason to have a high degree of confidence in the results being a fair representation (see Box B1: Expert statistical opinion in Appendix B):

> The distribution of the bootstrap estimates has a standard deviation of 2.0 and this leads to a 95% confidence interval of 32.8% ± 3.9% (Lower Confidence Limit = 28.9%, Upper Confidence Limit = 36.7%). This indicates that if the sampling activity were repeated many times (with the same population), the subsequent overall compliance rate estimates would fall between 28.9% and 36.7% for 95 out of 100 samples. (Data Analysis Australia 2015)

What the analysis tells us

Two levels of analysis are included in this general review:

1. assessing overall construction practice against test Australian Standards, manufacturers recommendations and expert opinion (directly below); and
2. assessing roof system structural capacity deficiency risk against maximum design wind conditions for a subset of critical determining elements (see Design winds scenario – risk analysis of deficiencies in structural capacity, page 41).

Analysis of variations from referenced Australian Standards

Analysis of variations from referenced Australian Standards involved understanding what was known about the applicable building standards for each building site inspected – primarily:

- A certain number of sites were built to comply only with the DTS;
- A number of builders claimed that one or more performance solution applied to nine buildings although none of the nine alternative solutions claimed were found to be approved in accordance with the Building Act; and lastly
- we do not know what was required for a small number of buildings where the builder did not respond to the invitation to provide advice about an alternative solution.

In analysing the results it was determined that, after inspection letters and site visit communications were followed up with builders, that the status of the small number of remaining 'unknowns' (last dot-point above) would not affect the final overall assessment score to any meaningful degree.

For the purpose of the general inspection the nine claims about alternative solutions were coded as non-satisfactory against the DTS requirements as the alternative solutions were not approved in accordance with the Building Act.

At the conclusion of the general inspection it was assessed that 92% of buildings did not have an approved alternative solution.[12] The remaining 8% were not further verified for this general inspection due to limited Building Commission inspection resources and the minimal impact on the final overall assessment from this relatively small percentage.

If necessary, the undetermined status of the remaining 8% of site inspections could be assessed by further analysis of documented alternative solution claims lodged with permit authorities. However, given the small number of roofs involved (n=10), it is assumed that any approved alternative solutions within this undetermined 8% would not significantly alter the overall assessment rate.

The inspection samples have been further analysed where possible to detect patterns and trends (see Figure 4).

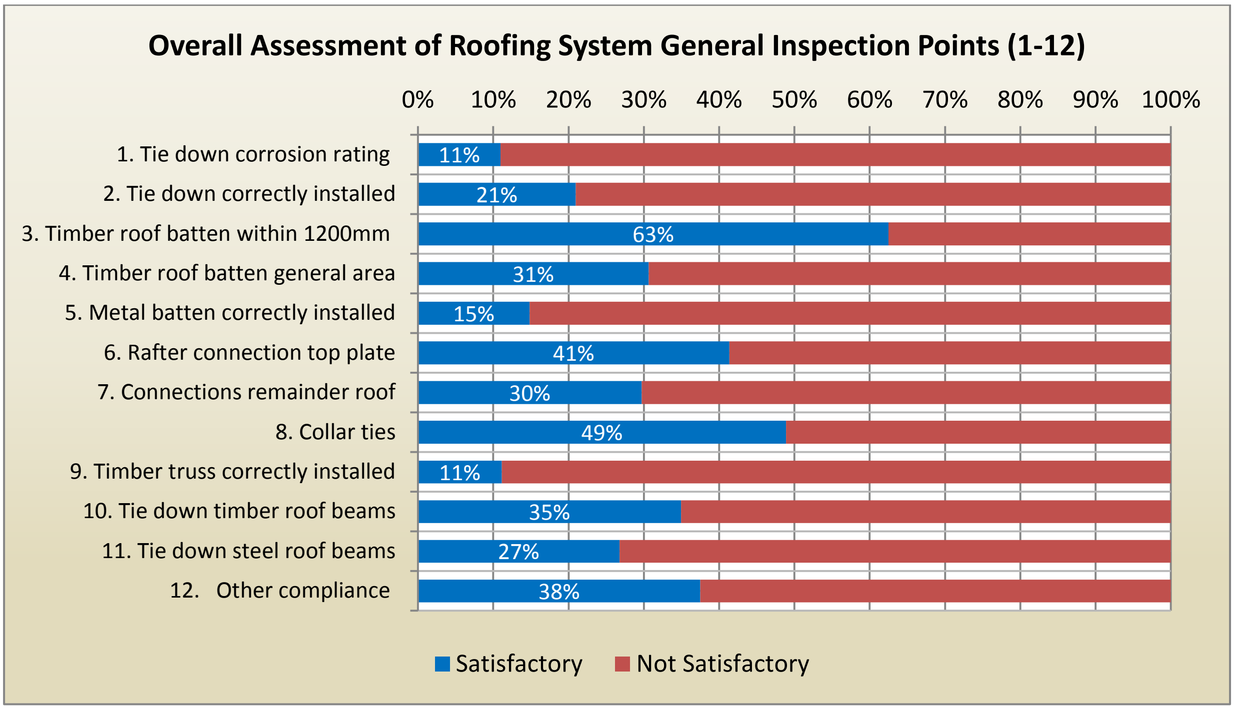

Figure 4. Overall assessment of roofing system general inspection points (1-12)

[12] Based on 54 of the 59 responses received to the 70 letters sent by the Building Commission that did not claim to have an alternative solution.

The assessments of the 12 key general inspection points in WA sheet metal clad timber framed constructions are summarised in Table 6 below.

Twelve general inspection points	Total	Satisfactory		Not Satisfactory	
1. Tie down corrosion rating	73	8	11%	65	89%
2. Tie down correctly installed	105	22	21%	83	79%
3. Timber roof batten within 1200 mm	64	40	63%	24	38%
4. Timber roof batten general area	62	19	31%	43	69%
5. Metal batten correctly installed	54	8	15%	46	85%
6. Rafter connection top plate	104	43	41%	61	59%
7. Connections remainder roof	101	30	30%	71	70%
8. Collar ties	90	44	49%	46	51%
9. Timber truss correctly installed	9	1	11%	8	89%
10. Tie down timber roof beams	83	29	35%	54	65%
11. Tie down steel roof beams	71	19	27%	52	73%
12. Other compliance	120	45	38%	75	63%
Total number of inspection points:	936	308	33%	628	67%

Table 6. Extent of satisfactory and not satisfactory general inspection points

The detailed assessment reports for each of these 12 general inspection points are included in the detailed report section of this report.

Analysis of assessments based on Building Commission inspection zones and local government areas

General inspection point assessment results were analysed by broad Building Commission inspection zones and local government areas. Refer to Appendix A: General Inspection Environment for the outline of these zones and areas used in this general inspection.

Building Commission general inspection zones

General inspection point assessments indicate broadly uniform levels of rating across Building Commission general inspection zones with the city area and northern coastal area rating slightly higher rates of satisfaction (see Figure 5 & Table A2).

Although this high-level summary does not account for possible detailed variations within the general inspection data it does appear reasonable to assume there is no meaningful underlying variation in rating satisfaction scores based on physical location or Building Commission inspection zone.

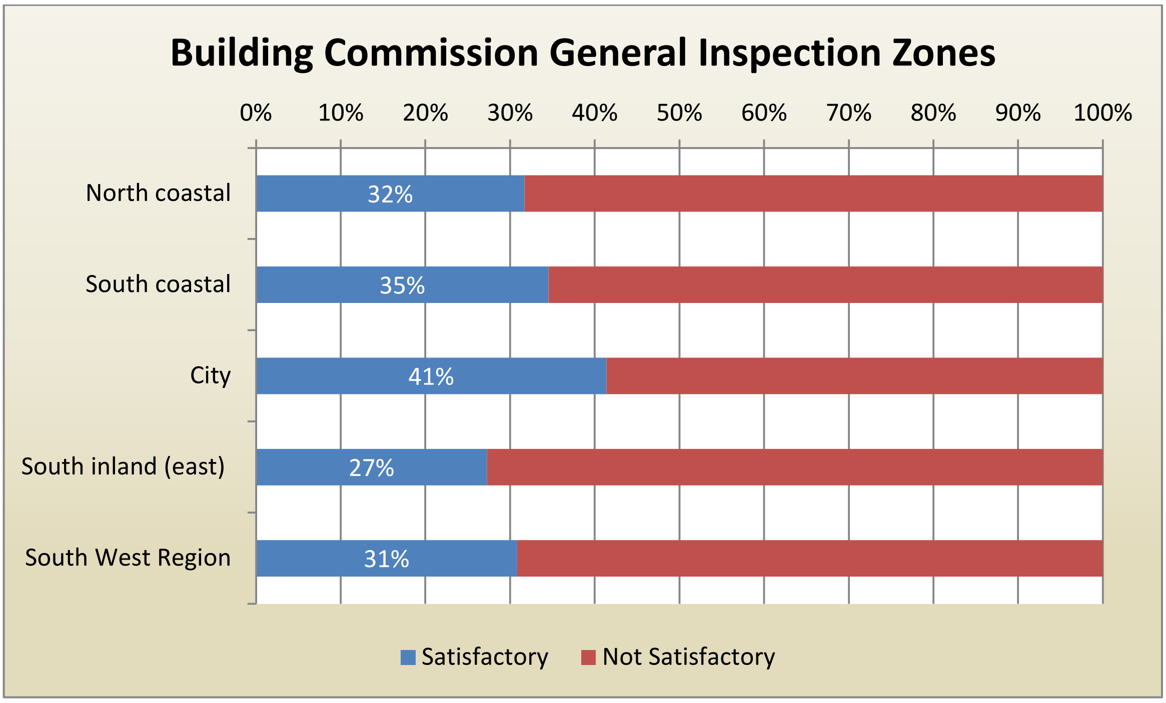

Figure 5. General inspection assessments across Building Commission inspection zones

Local government areas

General inspection point assessments indicate broadly uniform levels of rating across the local government areas (i.e. permit authorities). Slightly higher aggregated 'satisfactory' assessment scores above 40% were found within the City of Cockburn, City of Mandurah, Shire of Capel and Town of Cambridge[13] areas (see Figure 6 & Table A3).

Although this high-level analysis does not explain possible detailed variations within the general inspection data for a single permit authority, some meaningful reasons may exist for the underlying variation observed in assessment ratings across permit authorities. These variations observed in assessment ratings can be explored further if appropriate during subsequent phases of the general inspection project.

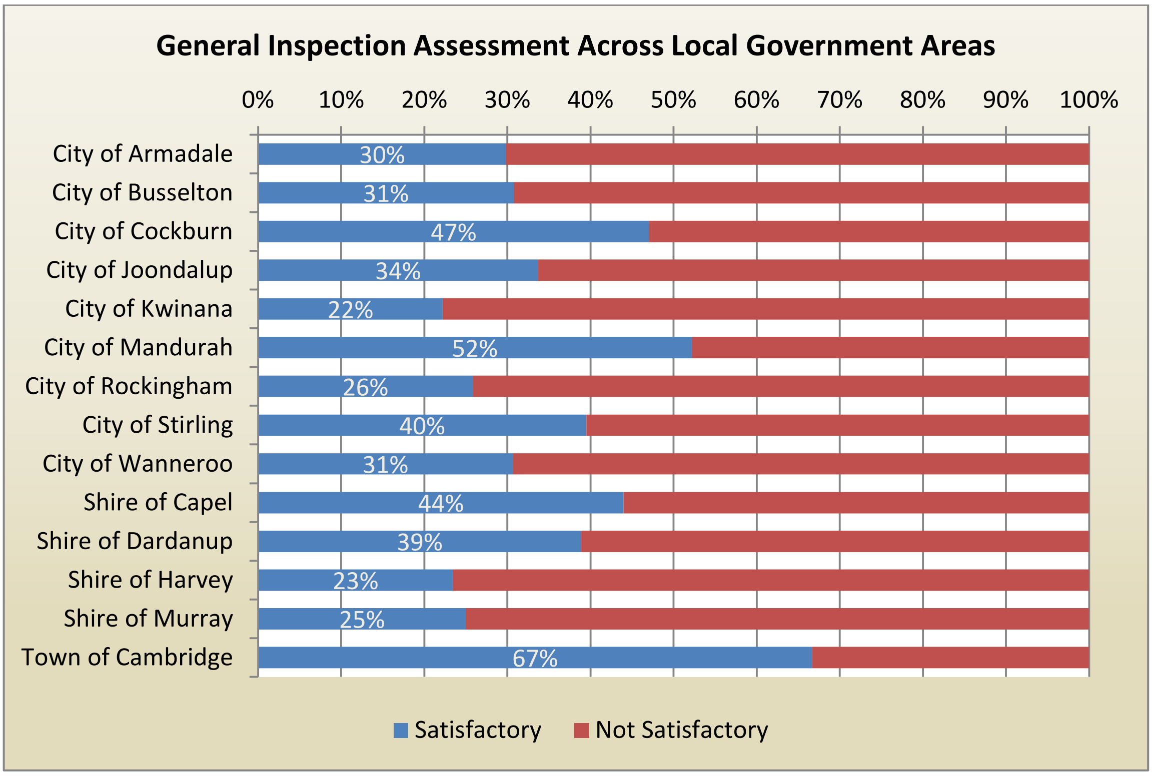

Figure 6. General inspection assessments across local government areas

[13] Note: Town of Cambridge score represents a relatively small data sample – see Table A3.

Analysis of inspections based on registered building entities

The 123 building construction sites investigated during the general inspection represented 53 distinct building entities/companies.

In respect to the overall general inspection point population assessment:

- 28 building entities were assessed at 33% satisfactory, or above. This group represents 43% (n=403) of the total general inspection points assessed.
- 25 building entities were assessed at below 33% satisfactory. This group represents 57% (n=533) of the total general inspection points assessed.
- 17% (n=16) of building entities were assessed at 50% or higher overall satisfactory on their general inspection assessments for their respective building sites. This building entity group represented 163 general inspection point assessments.
- 83% (n=37) of building entities were assessed at below 50% overall satisfactory on their general inspection assessments for their respective building sites.
- The maximum number of 'non-satisfactory' assessments for a single building construction site was nine out of a possible 12 inspection points (achieved at five building construction sites).
- The average 'satisfactory' assessment score across all 123 building construction sites for the 12 inspection points was 2.5 while the average 'non-satisfactory' score was 5.1.
- The most common 'satisfactory' assessment score across all 123 building construction sites for the 12 inspection points was one (for 28 sites) while the most common 'non-satisfactory' score was seven (for 23 sites).
- The highest 'satisfactory' general inspection point assessment result for a single building construction site was seven points out of the possible 12 inspection points (a score which was achieved at only two building construction sites).
- These two sites were rated with an overall assessment of 100% 'satisfactory' although the assessments were based on a very small sample of inspection point results from non-typical construction designs.
- Fourteen individual building construction sites were assessed as 'non-satisfactory' across all applicable general inspection points.

In respect to the 53 building entities represented in the general inspection data:

- 49% of the total inspection points represented a group of 11 building entities with between a minimum of 30 inspection points and a maximum of 80 inspection points per building entity (average = 42, mode = 37).
- 29% of the total inspection points represented a group of 14 building entities with between a minimum of 15 inspection points and a maximum of 29 inspection points per building entity (average = 19, mode = 17).
- 21% of the total inspection points represented a group of 28 building entities with between a minimum of 2 inspection points and a maximum of 14 inspection points per building entity (average = 7, mode = 8).

Building entity general inspection point assessment is summarised in Table 7.

- A small group of three building entities were responsible for the 3% of those inspection point assessments rated greater than 69% 'satisfactory'.
- 13 building entities were responsible for the 15% of those inspection point assessments which were rated between 50–69% 'satisfactory'.
- The remaining 37 building entities were responsible for the 83% of the inspection point assessments rated below 50% 'satisfactory'.

Inspection rating	Builders	Observations	Percentage
70% or above	3	26	3%
50–69%	13	137	15%
Below 50%	37	773	83%
Total:	53	936	100%

Table 7. Builder assessment scorecard

In summary, 25 building entities were assessed at being at, or above, the overall aggregated average general inspection point assessment rating of 33% 'satisfactory' while 28 building entities were rated below the average inspection point assessment rating. This result indicates no large variations were identified in general inspection assessment scores observed across building entities.

Correlation with complaints

An analysis of complaints trends for the period January 2012 to December 2014 (listing 51 building entities with the highest number of registered complaints) was reviewed for any meaningful correlations between a building entity's ranking in the general inspection point assessment and the number of complaints lodged against them with the Building Commission over the previous three-year period.

The number of complaints lodged with the Building Commission is a general indicator only and does not always indicate faulty and non-satisfactory work by the building entity – eg a builder may be found not liable at the closure of the complaint file or the complaint may also relate to contractual or non-structural issues such as paint work.

During this 3-year period, 125 complaints were lodged against 12 building entities with overall general inspection assessment scores above 32% – ie at or above the industry average for this general inspection. This result compares with 196 complaints against 14 building entities with overall general inspection assessment scores below 33% - ie below the industry average for this general inspection. This comparison indicates there are an average of 10 complaints per building entity scoring above 32% compared with 14 complaints per building entity scoring below 33% – ie a 40% higher average number of complaints per building entity that rated below the general inspection's 33% average assessment mark in this general inspection.

As part of the general inspection methodology any areas assessed as 'non-satisfactory' compared with Australian Standards were communicated to the respective building entity and their response further assessed to determine if any original general inspection point assessments should be revised. The building entity's willingness to accept constructive feedback in line with the standards was also assessed through this interaction process. In some cases, further building site visits occurred to assess whether construction practices had subsequently improved.

In general, it was observed that those building entities scoring below the average 33% compliance mark generally also appeared less willing to engage in constructive discussions with the inspector during the general inspection on issues related to meeting standards than those building entities with higher ‘satisfactory’ ratings.

At the conclusion of the physical site inspection stage, as part of the general inspection process, follow-up letters were sent by the Building Commission in relation to 118 buildings. Of the 70 letters that required a response twice as many building entities scoring below the 33% ‘satisfactory’ mark did not respond to these letters compared with those building entities scoring overall above the 33% ‘satisfactory’ mark. This difference in response rate between the better and the poorer scoring building entities appears consistent with trends in complaint data and subjective opinion formed by the Building Commission inspector during the general inspection process.

In summary, a lower level of general inspection point assessment score for a building entity appears to correlate with higher resistance by the building entity staff on site to accept the advice of the Building Commission inspector on meeting applicable standards.

Structural capacity deficiency risk evaluation

Box 1: Design winds scenario – risk analysis of deficiencies in structural capacity

While overall ratings in the general inspection are based on the assessment of up to 12 roofing elements as satisfactorily meeting design standards and codes, a smaller number of the key elements in the roofing systems form part of a critical link which allows the roof to resist high wind speed uplift forces.

Boughton and Falck (2008) identify five critical areas in structural capacity of roofs which, all working together, transmit wind uplift forces from the roof to the ground. Structural roof failure under high design wind speeds may occur if any one of these critical links in the 'chain' is deficient and fails.

Table 8 indicates how these five critical structural capacity deficiency risk areas are represented in the 12 inspection points assessed in this general inspection.

	Critical Structural Capacity Areas	Inspection Points	Number of Observations	Rated Satisfactory	Rated Not-Satisfactory
1.	Batten to rafter connections	3, 4, 5	180	37%	63%
2.	Rafter to top plate connections	6, 9	113	39%	61%
3.	Roof structure connections	7	101	30%	70%
4.	Top plate to masonry connections*	2	105	21%	79%
5.	Veranda details	10, 11	154	31%	69%
	Total:		653	32%	68%

Table 8. General inspection points associated with structural capacity deficiency risk (Boughton and Falck 2008)

Based on the 653 general inspection points identified as representing overall structural capacity deficiency risk the assessment sample is estimated to be 32% 'satisfactory' in this critical structural area – roughly in line with the overall average result.

However, any roofing system failure usually happens at the weakest link in the uplift force 'chain.' The lowest 'satisfactory' assessment in the five key structural capacity areas identified by Boughton and Falck (2008) occurred at 21% in top plate to masonry connections; followed by 30% compliance in roof structure connections.

Therefore, from this general inspection it is possible to infer that around 80% of sheet metal clad timber framed roofed houses built in WA around 2014 may be at a higher risk of top plate masonry connection failure when placed under maximum design wind conditions. The extent of this risk cannot be quantified.

Analysis of the 105 inspection points in the lowest scoring structural capacity area (ie 4.- "Top plate to masonry connections" or the general inspection point 2 . - "Tie-down correctly installed") indicates that:

- Twelve building entities rated 50% or higher with a 'satisfactory' assessment which represents 27% of the total 105 inspection points for this category.
- Five building entities rated between 11–49% with 'satisfactory' assessments which represents 24% of the total 105 inspection points for this category.
- The remaining 36 building entities rated zero 'satisfactory' assessments which represents 50% of the total 105 inspection points for this category.

*Note: please refer to the following "Detailed inspection assessment reports" – Section 2. – "Tie-down installation" for a description of how this key general inspection point item was inspected and

Figure 7 is a private non-commercial photograph[14] taken on 19 July 2008 of remedial action following a tie-down failure of a skillion roof. The outcome of this failure to adequately tie down the skillion roof from a neighbour's property (not shown in the photograph) resulted in the roof landing on the neighbouring property during a wind event less than the applicable design wind speed.

Although a skillion roof is not necessarily representative of the majority of conventional roof framing found and analysed in this general inspection this event indicates both a failure to construct correctly and not supervise adequately. The result of this type of failure is a community concern with risk consequences beyond the failure of the specific roof system involved.

Figure 7. Photograph showing the result of a metal skillion roof lifting in high winds and landing on and damaging an adjoining property

The Queensland Building and Construction Commission (2015) considers at least 60% of reported seriously defective domestic building work is the result of poor supervision.

[14] Used here with permission of the copyright owner.

Detailed inspection assessment reports

The 12 reviewed general inspection points of WA's 2014 sheet metal clad timber framed roof tie down systems are detailed in this section of the general inspection report.

1. Tie-down corrosion rating
2. Tie-down correctly installed
3. Timber roof batten within 1200 mm of roof edges
4. Timber roof batten general area
5. Metal batten correctly installed
6. Rafter connection top plate
7. Connections remainder roof
8. Collar ties
9. Timber truss correctly installed
10. Tie down timber roof beams
11. Tie down steel roof beams
12. Other related inspection issues

Each detailed inspection point assessment follows a standard format in which the inspector outlines the relevant background, referenced standards, inspection approach, inspection comments, and any conclusions reached – including informed opinion of where the main responsibilities (and therefore likely solutions) lay for any situation of concern.

Final assessment of responsibility detailed in Table 2a in respect to the 12 general inspection points is a consensus of the Building Commission. This table identifies where the responsibility for driving improvements resides.

The primary purpose of the assessment is to assist the Building Commissioner frame recommendations and follow up strategies.

History of roof construction in WA

In WA, roofing systems designed and built in accordance with the DTS of the BCA must be built to withstand maximum design wind events calculated according to Australian Standards AS 4055 or AS 1170.2.

Table 9 lists the two AS 4055 design gust wind speed categories covered in this general inspection survey which are most relevant to roofing system design in Perth and WA's South West regions:

Wind class	Ultimate limit state design gust wind speed	
	($V_{h,u}$) [m/sec]	($V_{h,u}$) [km/hr]
N1	34	123 km/hr
N2	40	144 km/hr

Table 9. AS 4055 design gust wind speed categories

The predominant timber used to construct roofs in WA has shifted from native hardwood to softwood. Machine Graded Pine (MGP) 10 pine is now the most common timber used in roof construction for rafters and other roof components in WA. The same number and type of nails have less capacity in a pine roof compared to in the typical hardwoods previously used for WA roof construction (refer Table 9.25 of AS 1684.2).

In addition, there has also been a trend towards increasing numbers of buildings being sheeted with light-weight sheet metal roofing. WA building industry feedback suggests up to 60% of new roofs in WA are now being constructed with metal sheeting.[15]

Winds can produce 'up-lift' forces on roofs and a light-weight metal roofing system (at 10 kg/m^2 mass) is not sufficient by itself to counteract the up-lift force under high winds. This compares to tiled roof construction at approximately 60 kg/m^2 mass, approximately 500 per cent heavier than a sheet metal roof, which is better able to counteract wind uplift.[16]

To demonstrate the total weight difference between sheet metal and tile roof coverings a typical new project home was used as a reference. A typical new project home contains a double garage, alfresco, theatre room and 4 bedrooms with a roof area of approximately 385 m^2. In this case the roof's design and construction must accommodate a 3,850 kg mass for a sheet metal roof compared to 23,100 kg mass for a tiled roof.

According to Boughton and Falck (2008), a sheet metal clad timber framed roof, is less forgiving under wind uplift compared to tiled roofs. The greater weight of tiled roofs – the predominant design used historically in WA until recently – better counteract wind uplift and therefore result in less roof failures from high wind forces.

It should be noted that individual tiles subject to high wind uplift can be blown from a roof, thus relieving the load on the supporting structure. Sheet metal clad timber framed roofs are more likely to fail as a unit.

Increased use of sheet metal clad timber framed roofing in WA therefore increases the risk of roof structure damage in high winds where those roofs are not constructed in accordance with the applicable building standards.

The future costs of roofing system failure will likely rise in respect to insurance costs. Risk to life may also increase if new housing is not constructed in accordance with the applicable building standards.

[15] Based on feedback from tile manufacturers and major building companies and observations made by Building Commission inspectors.

[16] *AS 1684.2; Table A1.1- Mass of typical roof construction,* indicates a value of 10 kg/m^2 for a steel sheet roof 0.50 mm thick and battens compared with 60 kg/m^2 for a terracotta tiles and battens.

Change in construction materials demands clearer documentation and a greater onsite focus on construction standards in order to resist wind uplift on light-weight sheet metal clad timber framed roofing. The general inspection assessed how well this risk was understood by all parties involved in building and certifying processes in WA.

Overview

In general, unless otherwise specified, all 123 general inspection reviews and inspections for the following 12 roofing areas were carried out between January and October, 2014.

Inspection sites were predominately located in high construction activity areas in Perth's outer metropolitan areas as these sites provided the best opportunity to locate a number of dwellings with roofs at a stage suitable for tie down installation inspection.

General inspection data are divided into 3 groups (based on the dates they occurred):

- Group A: 46 sites in the Perth metropolitan area between January and May 2014.
- Group B: 62 in Perth metropolitan area between June and August, 2014.
- Group C: 15 roofs in WA's South West during October, 2014.

An interim internal Building Commission roof construction report was produced in May 2014 based on analysing Group A data. Interim report findings informed and focused the general inspection strategy for the following Group B and Group C inspections.

1. Tie-down corrosion rating

Background

Tie-downs are typically:

- A metal strap embedded into a masonry bed joint and brought up the cavity and fixed to a roof member – ie rafter, or top plate or roof batten.

Installed around the perimeter of a dwelling to prevent the roof and roof structure from lifting off when subjected to wind loads.Tie-down straps are required to be:

- Protected from corrosion via a suitable protective coating (ie galvanising) or manufactured from corrosion resistant metal (ie stainless steel).
- Indelibly marked to indicate their durability classification as required by AS 2699.2: 2000.

In addition:

- Tie-downs may also be constructed from round steel bar or rods.
- In new homes, vertical tie-down rods are usually installed for tying down timber and steel beams such as those over alfresco areas.
- Rods may also be used retrospectively to fit tie-downs – eg in a roof that has been converted from a tiled to a sheet metal roof where the tie-down system needs upgrading.[17]
- For timber truss roofs on a timber supporting framework the tie-down is achieved via the timber frame – ie tie-down rods and long straps are not normally used in this situation.

Tie-downs are required to withstand a calculated wind uplift force. Metal tie-downs will fail if the cross-sectional area of the tie-down is reduced sufficiently by damage or corrosion so that the tensile stress in the tie-down exceeds its capacity. To ensure tie-downs remain effective for the life of the building the tie-down may be specified to be made of corrosion-resistant material (ie stainless steel); have a corrosion-resistant treatment (ie galvanised coatings); or have an excess cross-sectional area with a specifically designed corrosion allowance.

This section should also be read in conjunction with the following section titled “Tie-down correctly installed”.

[17] No roof conversions from tiled to metal sheet contributed to the inspection data.

Referenced standards for deemed-to-satisfy solutions

Straps type and coating:

- The requirements for tie down compliance are derived from the BCA which refers to a number of masonry standards that in turn refer to AS/NZS 2699.2: 2000.

- The deemed-to-satisfy requirements for tie-down straps manufactured from sheet steel are summarised as:

  For a coastline with breaking surf [18]

0 to 1 km	Stainless steel
1 to 10 km	Galvanised to 470 g/m^2
10 km plus	Galvanised to 300 g/m^2

- Corrosion protection requirements for tie-down straps may be lowered to 300 g/m^2 where exterior walls are weatherproofed in accordance with the standards.

- Rods used for a tie-down are required to be coated with 470 g/m^2 of galvanising or stainless steel rods are required for distances less than 1 km from breaking surf.[19]

Strap dimensions:

- The BCA references Australian Standard 4773.2: 2010 - Masonry in small buildings; Part 2 – Construction, which nominates two straps sizes of 30 mm x 0.8 mm or 25mm x 1.0 mm as being acceptable for perimeter tie downs.

Inspection approach

- 56 roofs in the Perth metropolitan area were inspected and tested for appropriate tie-down strap coating type and minimum dimensions.

- 15 roofs in the South West region were tested for tie-down strap size and coating mass.

- Inspections focused on the tie-down straps rather than rods.

- Tie-down straps were examined for appropriate strap type dimensions and corrosion resistance – ie either stainless steel or protective galvanised coating thickness.

- A digital caliper was used to measure the size of the tie-down straps.

- Tie-down strap coating thickness was measured via an Elcometer 456, dry film thickness gauge, under the direction of a coating measurement expert.

- Approximately 10 building construction groups were provided with feedback regarding the tie-down strap testing to enable them to self-assess whether they were meeting the required standards. Feedback indicated that several subsequently contacted their supplier regarding sourcing of compliant tie-down straps.

[18] This is the basis for the corrosion categories chosen as most of the areas inspected were adjacent to a coast line with breaking surf.

[19] Refer to relevant standards 470 g/m^2 is the minimum requirement for bar regardless if the walls are weatherproofed.

Compliance in respect to appropriate strap type (corrosion protection):

- Group A and Group B – 13% of the Perth metropolitan sites were found to have satisfactory compliant tie-down straps.
- Group C – 7% of the South West sites were found to have satisfactory compliant tie-down straps.
- The range of galvanised coating mass on straps tested varied from 20 g/m^2 to 600 g/m^2 with the median across 65 samples of 154 g/m^2 – this being approximately 50% of the expected minimum coating mass of 300 g/m^2.
- Excluding those sites where stainless steel tie-down straps had been used, only 4% of Perth metropolitan sites were compliant (6 Perth metropolitan sites and one South West site had used stainless steel).

Compliance in respect to minimum dimensions:

- 64% of the tie-down straps inspected in the Perth metropolitan area were found to be under the minimum dimensions specified in the relevant Australian Standards.
- 100% of the tie-down straps inspected in the South West were found to meet the minimum dimensions specified in the relevant Australian Standards.
- AS 4773 and AS 3700 nominate a tie-down strap size of 30 mm x 0.8 mm or 25 mm x 1.0 mm. This provides for a cross dimensional area of 24 mm^2 and 25 mm^2 respectively. This compares to some commonly used non-conforming straps of 25 mm x 0.8 mm with a cross-dimension area of 20 mm^2 which is approximately 17% smaller than the deemed-to-satisfy requirements.
- Eleven of 65 samples inspected measured 30 mm x 1.0 mm and 25 mm x 1.2 mm which are above the minimum dimension requirements – thereby indicating the correct sized tie down strap product is available from suppliers in WA.
- 100% of the tie-down straps inspected with a compliant level of galvanising also either met, or exceeded, the minimum strap dimensions required by the Australian Standard.
- No engineering details were found to nominate tie-down strap sizes inconsistent with the relevant Australian Standards.

Inspection comments

- Galvanised tie-down straps were found with a coating mass of as little as 20 g/m^2 of galvanising – ie this being only 6% of the minimum strap coating mass of 300 g/m^2.[20]
- In a number of cases, where the 20 g/m^2 tie-down strap was used, the standard required a stainless steel strap – ie the corrosion resistance of the installed straps were significantly below the minimum standard requirements.

[20] Coating of 300 g/m^2 can be used for distances greater than 10 km from breaking surf or in a cavity where the exterior wall has been weatherproofed in accordance with the requirements of AS 3700 and AS 4773.1.

A dwelling (Figure 8) inspected in connection with a building service complaint was found to have severely corroded roof tie-down straps, only 4 years after installation. The degree of corrosion is consistent with the use of non-compliant tie-down straps for buildings within 0–1 km distance of a coastline with breaking surf and may lead to premature failure of the roof/roof components.[21]

Figure 8. Photograph showing the result of installing a strap without the correct corrosion protection

- The 2011 BCA Volume Two and preceding versions included a galvanised tie-down strap installation diagram. No reference was included to inform the reader of the differing weights of galvanising or when stainless steel straps may be required. References have been made to the masonry standards AS 4773.1 & .2 and AS 3700 that more clearly define the corrosion resistance requirements of the straps included in the 2012 (and subsequent) BCA.

- Many of the industry stakeholders were not aware of the change in 2012 until this Building Commission general inspection into roof tie-down straps drew attention to the new BCA requirements. Subsequent discussion with industry resulted in an educational Industry Bulletin IB032/2013 (Nov 2013).

- Concerns were expressed by some builders during the general inspection review that, due the thickness of the base metal, it is difficult to coat straps to 470 g/m^2 – ie as required by the standard in the 1-to-10km from breaking surf zone. The Building Commission acknowledges there is a difficulty in sourcing a compliant product.

[21] This inspection has not been included in the 123 buildings reported in the final report. Information about the inspection is included to demonstrate the effects of corrosion on a non-compliant tie down strap.

Conclusions

Inspection samples and tie-down strap testing during 2014 indicate very high overall non-compliance in spite of appropriate tie-down strap size and coating mass being available in the WA market.

The high degree of tie-down strap non-satisfactory compliance appears related to a combination of the following factors:

- Lack of identification markingon straps (colour coding, stamping or labelling) making identification and selection of the appropriate tie-down strap more difficult.
- Difficulty in determining whether the galvanised coating is compliant.
- Supplying a strap with a non-compliant coating only technically becomes a non-compliant material when it is built into a building requiring higher construction standards.
- A belief amongst some stakeholders that there is nothing wrong with the type of tie-down straps that have been used in the past.
- Lack of information on drawings on the appropriate corrosion resistance for the tie-down strap required at the specific construction site.

A sample of tie down strap shelf-stock in a major WA hardware chain was examined in September 2014 and found to be approximately 17-microns – ie indicating a nominal thickness of Z275 (or approximately galvanised to 137 g/m^2) compared with the minimum coating thickness of Z600 (or 300 g/m^2) nominated by the standard. However, there was no signage to indicate that the Z275 straps were not suitable for use as tie down straps in WA's N1 and N2 building construction environments. A coil of tie down strap was found in a second area within the same store with a sticker attached nominating it as Z600 or 300 g/m^2.

Officers from the Building Commission subsequently consulted three major suppliers of tie down strapping including the supplier referenced above. All suppliers communicated a difficulty in sourcing a compliant product for the 1-10 km distance of a coastline breaking surf that needs to be galvanised to 470 g/m^2.

One supplier advised they were concerned about losing market share if they switched their stock to a more compliant (and therefore more costly) option. However, overall the Building Commission has observed a growing willingness on the part of suppliers to assist industry via the supply of compliant products and better labelling.

The Building Commission also met with two prominent construction engineering companies that have examined how to deliver compliant tie down strapping solutions for the 1-10 km zone as well as provide a more affordable alternative solution to the requirement for stainless steel in the 0-1 km zone. The use of a new product developed by one of these companies is now penetrating the WA building industry and its use is being detailed as an approved alternative solution under the Building *Act.*

Both companies have also agreed to provide more details in roof plans regarding the required connectors and corrosion protection and will assist trades involved in the construction of roofs.

The following assessment is made on the approximate apportionment of responsibility for where the problems (and therefore solutions) lay in respect to this general inspection point.

Responsibility impact assessment scores for tie-down corrosion rating:

Standards / Codes	Legislation / Regulation	Workmanship	Management / Supervision	Total
20	20		60	100

2. Tie-down installation

Background

- Perimeter roof tie-down is typically achieved via a metal strap embedded into a masonry bed joint and brought up through the cavity and fixed to a roof member (ie a rafter, top plate or roof batten) via nailing.
- Perimeter tie-down is installed to prevent the roof and roof structure from lifting/rising when subjected to design wind loads.
- Failure to ensure the perimeter tie-down straps are correctly installed can result in movement between the rooftop and wall connection. This movement may result in cracking of the cornice and even loss of the roof in high design wind speeds.
- Round steel bar, both threaded and unthreaded, can also be used as tie-downs. In a new home, round steel bar is usually installed for tying down timber and steel beams such as those over alfresco areas.
- Round steel bar is also used retrospectively to fit tie-downs – eg in roofs converted from tiles to metal sheeting requiring the tie down system to be upgraded.[22]
- Tie-downs (round steel bar and straps) are not usually used in timber truss roofs installed on a timber supporting framework – ie the tie down is normally through the timber frame in this situation.
- Tie-down straps and round steel bar tie-downs are normally installed by the bricklayer and fixed to the timber work by the carpenter or to steel beams by a welder.
- The design codes AS 4773.1 & .2 - (Masonry in small buildings) include diagrams on the installation of tie-down straps into the masonry. Where the strap is attached to the timber roof frame the AS 1684 series is referred to. The fixing details of tie-down straps to the roof structure are not, however, clearly laid out in AS 1684.2. This lack of detail of the critical connection makes it more difficult to determine and assess what is an appropriate connection.

Tie-downs are required to withstand a calculated uplift force. If the tie-down is not adequately fixed at each end it cannot transmit the required force. The bottom end of a tie-down is connected into the masonry, usually through a right angle bend with a short length embedded into the mortar bed joint. Resistance to uplift at the bottom of the strap is a combination of bearing close to the bend and adhesion of the strap in the mortar. The top end of a tie-down is connected to a roof member by a combination of folding the strap over the timber and nailing it into position.

Resistance to uplift at the top of the strap is a combination of bearing close to the first bend and the shear resistance of the nail. The strap must be vertical and pulled taut before fixing at the top to ensure that the uplift is resisted without significant displacement of the roof.

This section should also be read in conjunction with the preceding detailed report section covering tie-down corrosion rating.

[22] No roof conversions from tiled to sheet formed part of the roofs were inspected in this review.

Referenced standards for deemed-to-satisfy solutions

- AS 1684.2: 2010 – Residential timber-framed construction; Part 2 – Non-cyclonic areas.
- AS 2699.2: 2000 - Built-in components for masonry construction; Part 2 - Connectors and accessories
- Australian Standard 4773.1: 2010 - Masonry in small buildings; Part 1 – Design; Clause 6.6 - Design for uplift, requires perimeter tie-downs to be installed at a maximum of 1200 mm centres.

It is noted that AS 4773.1 and 4773.2 were updated in 2015. The 2010 versions were the applicable versions during the GIR1. The updated versions have not changed in the areas applicable to the GIR1.

Inspection approach

The use of machine driven nails to fix the tie-down strap has been assessed by the Building Commission for the purpose of the general inspection as acceptable for tie-down installations on the basis that: [23]

- An approved quantity of nails is used.
- The strap has not been damaged during the installation process.
- Nails are of the correct material and type – ie the heads will not fail under design load.
- Nails are corrosion protected and compatible with the strap being fixed – eg galvanised fixings for galvanised straps and stainless steel/Monel metal fixings for stainless steel straps.[24]

Inspection findings

Inspections for correct tie-down included the whole perimeter connections (ie including more than just top plate tie down connections) and focused on the following five inspection criteria:

1. The spacing of the straps around the perimeter.
2. Number of nails used to connect the strap to the roof structure.
3. Corrosion resistance of the nails.
4. The manner in which the strap was installed to the roof frame.
5. Any aspect of poor installation likely to reduce the capacity of the tie-down installation.

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[23] There is no Australian Standard that refers to the type of nails that are to be used for the connection of tie-down straps to the roof structure. AS 1684.2 refers to the use of a corrosion protected connector nails. AS 1684.2: 2010 - Residential timber-framed construction; Clause 9.2.7 - Framing anchor and strap nails, states: “All nails used for framing anchor and straps shall be corrosion protected flat-head connector nails. Clout shall not be used for this purpose.” (sic)

[24] This is an area where further investigation is warranted to ensure the nails are appropriate.

Compliance (based on the five inspection criteria listed above):

- Group A – 18% of the tie-downs were found correctly installed and assessed as satisfactory.
- Group B – 21% of the tie-downs were found correctly installed and assessed as satisfactory.

(Refer 'Overview' section for reference to the groups.)

Inspection comments

In respect to the spacing of the straps around the perimeter:

- A number of engineering details were examined and found consistent with the standard requiring straps to be fixed at 1200 mm maximum centres.
- A number of perimeter areas were found without tie down for up to 8000 mm and in these cases the ability to install tie down straps was not prevented by the building's design – eg openings.
- In most cases there appeared to be no reason why the tie down straps were omitted.
- High levels of non-compliance were observed in garage walls and dwelling areas with raised sections of masonry or unusual construction.

In respect to the number of nails used to connect the strap to the roof structure:

- The type of nails used varied from 75 mm long x 3.06 mm diameter shank, general roofing nails to 32 mm long x 2.5 mm diameter twisted shank nails (which are often sold as hardened connector nails).
- There are manufacturers that produce nails designed as connector nails with reinforced heads specifically made for use in critical connections. These nails types are not available as machine driven. The use of the hand-driven nail types is rare (possibly due to the additional time taken to fix the straps).
- Prior to 2012, the BCA included details on the fixing requirements of the tie down straps to the roof structure. This detail has since been removed and currently there is no detail in the standards specifying the fixing of the tie-down straps to the roof.
- A number of engineering details reviewed specified fixing of the straps with three connector nails, indicating an expectation for a minimum of three suitable nails per roof tie-down strap connection.
- Site investigations revealed a number of cases where as little as one nail was used to connect the tie-down strap to the roof frame.
- In some cases machine driven nails were over driven and the tie-down strap became damaged/deformed thereby reducing the connection capacity.
- Figure 9 below demonstrates a typical example of the type of damage to the tie-down strap roof connection observed during the general inspection).

Figure 9. Photograph showing a metal tie-down strap fixed to a batten via the use of machine driven nails. The over-driving of nails has damaged the strap, greatly reducing the connection capacity.

In respect to corrosion resistance of the nails:

- AS 1684.2: 2010 requires nails used for straps to be corrosion protected flat-head connector nails – ie clouts should not be used.
- AS/NZS 2699.2: 2000 requires tie-down straps and accessories to have a design life of not less than 50-years.
- There are a number of roofs where the tie-down straps were fixed with uncoated nails; typically the same type of nail used to fix the roof frame (eg 75 mm x 3.06 mm).
- The connection may not meet its intended design life when untreated nails are used on galvanised tie-down straps – ie risk of premature failure is increased where the tie down straps have a level of galvanising below the minimum standard requirements.
- Bi-metal corrosion issues may exist where non-compatible fixings are used on stainless steel tie-down straps – eg in cases where the builder has used correct stainless steel straps but has fixed the straps with an incompatible nail type.[25]

[25] Stainless steel nails are available that could be used with the stainless steel tie-down straps.

In respect to the manner in which the tie-down strap has been installed to the roof:

- AS 4773.1: 2010, Figure 6.3 and AS 4773.2: 2010, Figure 10.13, show the tie-down strap being fixed to either the side of the rafter or the top plate. Other methods of achieving perimeter tie-down are being achieved – eg some builders are installing a timber roof batten above the cavity specifically as a tie-down for the roof straps. The advantage of fixing to a timber roof batten is that the roof batten can be located above the cavity enabling the tie-down strap to be installed taut and vertical and thus maximise the connection's capacity. [26]

- The use of specific battens for top fixing tie-down straps, has its benefits. Tie-down battens of this type are not catered for within the AS 1684 standard series and require design by a suitably qualified structural engineer. A number of tie-down straps were fixed to the roof-frame in places not immediately above the cavity (see Figure 10). In this situation, the loose straps are not able to provide a vertical resistance force at that point. Unless the roof is restrained at other places it is free to lift and/or move sideways until the strap is entirely vertical and taut.

Figure 10. Photograph showing poor tie down strap installation (strap being fixed down the roof line)

[26] Some builders install a timber batten above the cavity to specifically act as a tie-down batten.

Other aspects of poor installation practice of tie-down straps observed include:

- Failing to pull the strap taut when fixing it off.
- Pulling the strap along the cavity at excessive angles in order to reach a fixing point – eg the rafter.
- Not connecting the strap adequately when looping it through a lintel – eg see Figure 11. In this instance only one leg of the strap has been nailed off, with the other end just turned up after placement through the slot. This strap would have no capacity to prevent wind uplift and is typical of a lot of sites inspected where there seemed to be a lack of understanding of the importance of adequate tie-down strap installation.

Figure 11. Photograph showing tie-down strap looped through a slot in a lintel

- A strap connected to a lintel (when the lintel is supporting a limited weight of masonry) may not be able to resist the design wind uplift forces (see Figure 11).

Figure 12. Photograph showing tie-down wrapped around metal batten (Note: the tie down is loose)

- Straps installed but not fixed-off to the roof frame by the carpenter.
- Fixing to metal battens where the batten may crush or distort when loaded during peak design wind events (see Figure 12).
- Carpenters commented that when they sought to tension the strap prior to fixing it to the roof frame on occasion the strap pulled out of the masonry. This indicates that in some cases the straps may not be installed within the brickwork to adequately resist the uplift loads.
- Figure 13 indicates a typical example of poor workmanship observed where the tie-down was not pulled tight and has an incorrect nail type with no corrosion rating. This strap is also below the requirements for minimum size and galvanised coating thickness.

Figure 13. Photograph showing poor installation of tie-down straps

Conclusions

- The majority of non-satisfactory compliance appears related to a failure of the relevant tradespeople to understand the importance of these critical tie-down connections and their function in preventing roof uplift failure under high design wind conditions.
- This view was often supported by comments given during the general inspections – eg typically "It's the apprentice's job to make these connections".
- Builders are generally failing to inspect these critical roofing system connections.
- It is more difficult to ensure correct installation when details on how to correctly fix the tie-down strap to the roof frame are not found in the relevant standards.
- Considering the ease with which some straps pull out of masonry, greater focus is needed on effective anchorage of tie-down straps.

The following assessment is made on the approximate apportionment of responsibility for where the problems (and therefore solutions) lay in respect to this general inspection point.

Responsibility impact assessment scores for tie-down installation:

Standards / Codes	Legislation / Regulation	Workmanship	Management / Supervision	Total
20	20	25	35	100

3. Timber roof battens within 1200 mm of roof edges

Background

- Roof battens connect the roof sheeting to the rafters and are either timber or metal.
- Roof batten to rafter connections are a critical roof construction connection as wind uplift force is transferred from the roof sheeting to the roof battens and then to the rafters.
- Appropriate connections enable load to be transferred through the roof-frame, to the walls and ground.
- Roof batten and rafter connections are common points of roof failure. This has been demonstrated in the *Cyclone Testing Station report TR54* that describes the wind damage to roofs in Shoalwater and Roleystone, WA in 2008. Further supporting evidence was found in a number of roof failure investigations by the Building Commission after high wind events in WA during 2014.

Batten spacing is related to the bending capacity of the roof sheeting. If the batten spacing is too great the sheeting may fail by plastic deformation, or in some cases, by fatigue. Roof sheets usually act as continuous beams, where end spans are subject to greater bending stresses and deflections. One way of equalising bending stresses in a continuous beam is to make the end span shorter than the middle spans.

Roofs have higher wind pressures near discontinuities in a smooth shape, such as at the edge of the roof and at ridges and hips. This higher wind pressure at the edge of the roof causes greater loading on the roof sheeting end span than on internal spans.

The combination of higher wind loading pressures and higher bending stresses in end spans usually means that the required batten spacing at the edge of a roof is closer than that required in the middle parts of the roof. The connections of the battens to the rafter must be able to transfer the wind load. This may require stronger connections in the edge zone battens compared to those used in general roof areas.

Referenced standards for deemed to satisfy solutions

- When assessing the requirements of roof batten tie down AS 1684.2 divides the roof into two areas: (a) within 1200 mm of edges (eaves, ridges and hips); and (b) general area.
- This section focuses on the first area (within 1200 mm of edges) as there are greater wind uplift forces at the edges of the roof requiring higher capacity connections.

Inspection approach

- Inspection sites were predominantly located in high activity areas in Perth's outer metropolitan locations as these sites provided the best opportunity to locate a number of dwellings with roofs at a stage suitable for general inspection.
- This section only refers to timber battens installations within 1200 mm of the edges.

Inspection findings

- Group A – 61% of edge batten connections were found to be satisfactorily compliant.
- Group B – 71% of edge batten connections were found to be satisfactorily compliant.
- Group C – all timber batten roofs inspected had non-satisfactory compliant edge fixing.
- The relative improvement in Group B followed Building Commission discussions with builders which led to at least 4 building construction groups reviewing and upgrading their fixing details to be compliant with the requirements of AS 1684.2.

(Refer ‘Overview’ section for reference to the groups)

Non-compliance was assessed as:

- Incorrect batten spacing.
- Not using the required capacity connection between the batten and the rafter.
- Incorrect connector installation – installing the screws too close to the edge of the batten.

Inspection comments

In respect to the required capacity connector:

- Two plain shank machine driven 75 mm x 3.05 mm nails are often used to connect 35 mm thick battens to the rafters. AS 1684.2: 2010; Section 9 - Fixings and tie-down design, (Tables 9.14 and 9.25) indicate that roof battens and rafters spaced at 900 mm centres in wind rating N1 zones, with joint group JD5, fixed with 75 mm x 3.05 mm nails, do not provide a compliant edge or general area batten to rafter connection.
- AS 1684.2 (Tables 9.14 and 9.25) provides connection details for roof battens up to 38 mm thick. However, if the battens being used are thicker than 38 mm (45 mm thick batten) then the details in the standard do not apply. In this case, the fixing method must be assessed and determined as satisfactory for the site by a qualified person such as a structural engineer.
- Some timber suppliers and manufacturers provide fixing details for 45 mm thick battens that may be appropriate.
- Roof carpenters and builders commented that screw fixings are more expensive to purchase and slower to install when compared to using nails.
- Figure 14 shows a typical situation where timber battens are fixed to rafters.

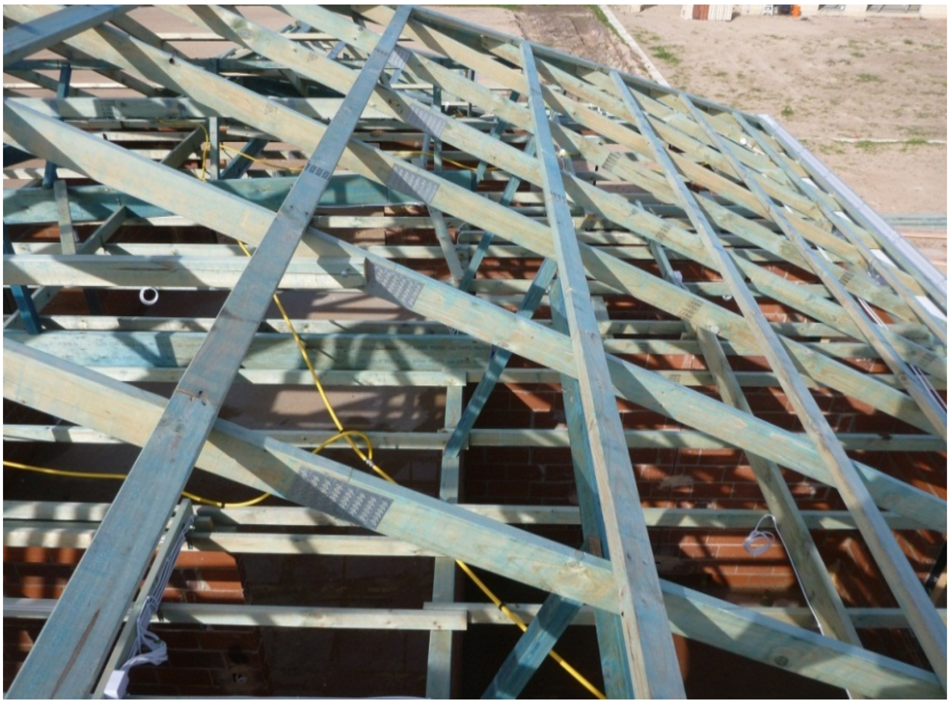

Figure 14. Photograph showing typical timber battens fixed to rafters

In respect to extending the connection to 1200 mm from edges:

- In a number of cases, while the eaves, ridges and hips battens were fixed with a 1 mm x 75 mm long No. 14 Type 17 screw, the fixing generally only extended to the first batten and did not extend to 1200 mm from the edges.

- Many roof carpenters and builders who were questioned generally understood the need for a higher fixing requirement for the perimeter battens but not for the requirement for this additional capacity connection to extend in 1200 mm (or two battens on a roof with battens at 900 mm centres).

In respect to installing the screws too close to the edge of the batten:

- AS 1720.1: 2010, Section 4.3, requires a screw fixing to be located 5 times the shank diameter from the edge of the timber. AS 1684.2, Table 9.25, where a single screw is required, shows the fixing in the centre of the batten. Roof carpenters should install the screw as close to the centre of the batten as possible.

- Figure 15 (below) shows a screw fixed within 12 mm of the batten edge compared to the standard requirement of a minimum edge distance of approximately 26 mm.

Figure 15. Photograph showing a batten non-compliant screw close to the edge of the batten

Conclusions

- Reasons for non-satisfactory compliance appear related to education of the builders; supervisor and carpenters; the cost of the higher capacity connector; and the additional install time required when using screws versus nail fixings.
- When provided with information by the Building Commission there was general acceptance and improvement by a number of building construction groups indicating some areas of industry are receptive to advice – eg as evidenced in the average 10% improvement in the level of assessed compliance from the first to the second group of general inspections.

The following assessment is made on the approximate apportionment of responsibility for where the problems (and therefore solutions) lay in respect to this general inspection point.

Responsibility impact assessment scores for timber roof battens within 1200 mm of roof edges:

Standards / Codes	Legislation / Regulation	Workmanship	Management / Supervision	Total
10	20	30	40	100

4. Timber roof battens in general roof areas

Background

- Roof battens connect roof sheeting to the rafters and are either timber and or metal.
- Appropriate connections enable load to be transferred through the roof-frame to the walls and ground.
- Roof batten and rafter connections are common points of roof failure. This has been demonstrated in the *Cyclone Testing Station report TR54* that describes the wind damage to roofs in Shoalwater and Roleystone, WA in 2008.
- Further supporting evidence was found via a number of roof failure investigations by the Building Commission after high wind events in WA during 2014.
- Roof battens are typically spaced at 900 mm centres.
- Connections between the roof battens and rafters are a common point of failure – a fact confirmed by a number of roof failures after wind events investigated by the Building Commission during 2014.

Each metal roof sheet is usually fixed to a batten with multiple screws along the length of the batten. This fixing provides a distributed load along the batten with relatively small loads on each screw. Except in unusual situations, such as fatigue failure in cyclonic winds, it is rare for sheeting to batten connections to fail.

The load along each batten is concentrated at the batten to rafter joint. If all of the fixings on a batten are not strong enough the roof sheeting and batten may separate from the rafters and cause a major roof failure. A single weak joint may allow the load to spread to adjacent fixings and members, thus preventing a major failure, but a systemic weakness through lack of the specified number or type of nails or screws in multiple joints is a serious concern.

Referenced standards for deemed-to-satisfy solutions

- AS 1684.2 Table 9.14 can be used to calculate uplift forces that determine the required capacity of the batten to rafter connections. Table 9.25 provides a variety of batten to rafter connections and their capacities. The capacity of the connections in Table 9.25 must be equal to or greater than the values determined from Table 9.14.
- The deemed-to-satisfy values are based on battens with a maximum thickness of 38 mm.

Inspection approach

- When assessing the requirements of roof batten tie down AS 1684.2 divides the roof into two areas: (a) within 1200 mm of edges; and (b) general area.
- This section covers fixing timber battens to the rafters in the general area.
- Selected sites were predominantly located in high construction activity areas in the Perth outer metropolitan areas where a number of dwellings with roofs at a similar stage of completion could be inspected per construction site visit.

Inspection findings

- Group A – 20% of roofs were found to have satisfactorily compliant general area batten connections.
- Group B – 39% of roofs were found to be satisfactorily compliant.
- Group C – four timber batten roofs were inspected in the South West and 25% were found satisfactorily compliant.
- A number of building groups advised that the carpenters were paid extra to install the higher capacity edges batten to rafter connection across the whole roof. However, in some of these roofs, even where the carpenters were required to screw fix the whole roof, there was still evidence of non-satisfactory compliance.
- Non-satisfactory compliance mainly involved using incorrect fixings and, to a lesser extent, incorrect batten size- eg a 70 mm x 35 mm MGP 10 batten installed on 900 mm centred rafters and spaced at 900 mm centres across the roof.

Inspection comments

- Site inspection has shown the most commonly used non-satisfactory compliant fixing method for timber battens spaced at 900 mm centres on 900 mm centred rafters general area is 2 x 75 mm x 3.06 mm plain shank nails. Other non-satisfactory compliant fixing methods observed include only 1 x 75 mm x 3.06 mm plain shank nail.
- Some carpenters suggested using three plain shank nails as a way to increase the capacity of the batten rafter connection. However three nails are not complaint with the minimum edge distances recommended by AS 1720.1 on a 90 mm batten.
- Inspected approved engineering details demonstrated a wide variety of connection details for roof batten to rafter general area ranging from one 3.33 mm diameter x 75 mm plain shank nail with a capacity of approximately 0.3 kN through to 1 x 75 mm bugle/screw (with an uplift capacity of approximately 3.6 kN) for the same wind rating.
- The use of a single/ 2 No. plain shank nails to connect the batten to rafter in 900 mm x 900 mm batten rafter centres does not meet the minimum standard requirements.
- Discussions occurred with a number of engineers regarding plan details with the aim of improving the amount and clarity of information available to assist the builder and tradespeople in achieving satisfactory construction compliance. At the time of finalising this report there appears to have been some improvement in the quality of information on the plans.
- A number of inspected engineering plans included a requirement to comply with AS 1684.2 although some engineering details were not consistent with AS 1684.2 resulting in difficulty for building trades and supervisors to determine what was required.
- AS 1684 does not include a method of fixing 45 mm thick battens. Approved details on the plans do not always provide fixing methods that are suitable for 45 mm thick battens. Some suppliers have provided technical information on appropriate connectors for fixing 45 mm battens. The uplift capacity of the connection can be compromised when connectors specified for 35 mm battens are used on 45 mm thick battens.
- Carpenters often raised the issue of variations in the fixing details that make it difficult for them to understand what an appropriate fixing detail for a batten rafter connection is *in-situ*.

Conclusions

- Some approved solutions for fixing timber battens to the rafters do not include all the relevant information. This lack of relevant information results in higher levels of confusion and non-satisfactory compliance with relevant standards.
- Higher capacity fixings can be more expensive and slower to install when compared to nails so there maybe reluctance to use such a system.
- A number of building construction groups appear to have reviewed and upgraded their fixing details to be compliant with the requirements of AS 1684.2 following communications from the Building Commission regarding roof construction practice. It is believed this improvement is reflected in later Group B general inspection point data.
- Three key reasons for non-satisfactory compliance appear related to: (a) education; (b) detailing on the plans; and (c) cost in material and time.
- In a number of cases, even where a building construction group has paid extra costs and specifically directed the carpenters to install screw fixings across the whole roof, the specified work was still not carried out.

The following assessment is made on the approximate apportionment of responsibility for where the problems (and therefore solutions) lay in respect to this general inspection point.

Responsibility impact assessment scores for timber roof battens in general roof areas:

Standards / Codes	**Legislation / Regulation**	**Workmanship**	**Management / Supervision**	**Total**
10	20	30	40	100

5. Metal battens

Background

- Roof battens connect roof sheeting to the rafters and are either timber or metal.
- This section refers to metal battens connected to timber rafters.
- The typical metal battens are formed from sheet metal by a cold rolling process and are usually approximately 40 mm high with a base metal thickness (BMT) of 0.55 mm.
- Several metal batten manufacturers supply the WA construction market and some use a base metal manufactured by Bluescope. The base metal supplier for other battens found could not be identified during this general inspection.
- There are standards that detail the construction of cold formed metal frames - eg the National Association of Steel Framed Housing (NASH) Standard, Residential and Low Rise Steel Framing. Other standards detail the requirements for timber framed construction such as the AS 1684 series and AS 1720.1.
- Although there is no standard specifying fixing metal battens to timber rafters, some manufacturers include recommendations for fixing to timber rafters in their product design information.
- Some approved plans reviewed during the general inspection contained engineering details allowing nail fixing of the metal battens to the rafters.
- A metal batten metal sheet clad roof failed during a high wind event in Shoalwater, WA in 2008, by battens pulling over the nail heads.[27]
- The Building Commission has estimated that approximately 80–100 roofs with metal battens were being constructed per week during 2014 in the greater Perth metropolitan area.[28]

The load along each batten is concentrated at the batten to rafter joint. The use of cold-formed light-gauge steel battens is relatively new and no Australian Standards have been prepared to set out good practice. The common failure mechanisms of a nail through light-gauge steel are either the nail pulling out from the timber, or the nail head pulling through the light-gauge steel. This latter mechanism is dependent on the size and stiffness of the nail head and the extent of any damage to the light-gauge steel by the nailing process. It is also influenced by the geometry of the batten and how close the nail is to the edge or a fold.

[27] Further research on roof failure due to high winds can be found from the Cyclone Testing Station, James Cook University, technical reports - ie *Report TR 54*

[28] Assessment by G. Flowers of metal battens fixed to timber framed roofs in the Perth Metropolitan area in 2014.

Referenced standards for deemed-to-satisfy solutions

- The Australian Standards 1684 series detail the fixing of timber battens to timber rafters.
- NASH 2005; Residential and Low-rise Steel Framing; Part 1 – Design Criteria, provides details of fixing metal battens to metal roof framing.
- There appears to be no specific standard detailing the connection of metal battens supporting metal sheet roofing onto timber rafters.

Corrosion requirements of the battens:

- The BCA Volume Two; Part 3.4.2- Steel framing, Clause 3.4.2.2- General, contains details on the corrosion requirements of steel framing and the distance various types of corrosion protected steel framing should be from breaking surf.

  The BCA Volume Two; Part 3.4.2.2, provides guidance regarding the use of steel framing that is similar to the steel used by metal batten manufacturers. This requires that when the steel work is protected by the building envelope it must be greater than 300m from breaking surf and not used in an industrial location.

Manufacturers' recommendations:

- Due to the variety of protective coatings on the metal strip stock being formed into the roof battens, the manufacturer should be contacted for advice regarding their product and its suitability for the intended purpose and location.
- The metal batten manufacturers contacted by the Building Commission during this general inspection review advised the recommended fixing is via screws and generally they will not warrant their product if any other fixing method is used.
- One manufacturer will not warrant its product where it is installed on timber rafters.

Inspection approach

- Group A general inspection point data was initially captured and analysed to produce an interim internal BC Roof Construction Report in May, 2014.
- Inspection sites were predominantly located in high residential building activity areas in the Perth outer metropolitan areas as these sites provided the best opportunity to locate a number of dwellings with roofs at a stage suitable for inspection.
- For clarity, the installation of the metal battens has not been divided into the roof edge and general area zones in this section. Metal battens in roof edge zones also require higher fastener capacity than those in general areas.
- Some details on approved plans, endorsed fixing of the metal battens with nails. In this general inspection, nail fixing of metal battens were assessed as having non-satisfactory compliance due to (a) the reasons identified in the inspection comments (below); and (b) these nail fixing details being inconsistent with metal batten manufacturers' recommendations.

Inspection findings

- Group A – 13% of inspected roofs were found to be satisfactorily compliant.
- Group B – 14% of inspected roofs were found to be satisfactorily compliant.
- Group C – 18% of the 11 metal battened roofs inspected in the South West were found satisfactorily compliant.
- The last 62 roofs inspected in Group B (predominantly south of the Swan River) had a higher rate of metal batten usage than north of the river – ie approximately 45% compared to 30% respectively.
- Group C (the South West) had the highest usage of metal battens at approximately 73%.

The main areas of non-satisfactory compliance were:

- Methods of installation not being in accordance with manufacturers' recommendations.
- Fixings used with no corrosion protection.

In addition, tie down strength may be reduced by:

- Over-driven fixings damaging the metal batten.
- Under-driven fixings sitting above the face of the batten.

Inspection comments

- A variety of connectors used to attach metal battens to the rafters were observed including hex-head screws and a variety of nails from 32 mm to 75 mm long – Figure 16 (A) represents a manufacturer's recommended screw for fixing metal battens and Figure 16 (C & D) were the most frequently used nail fixings identified in the audit.

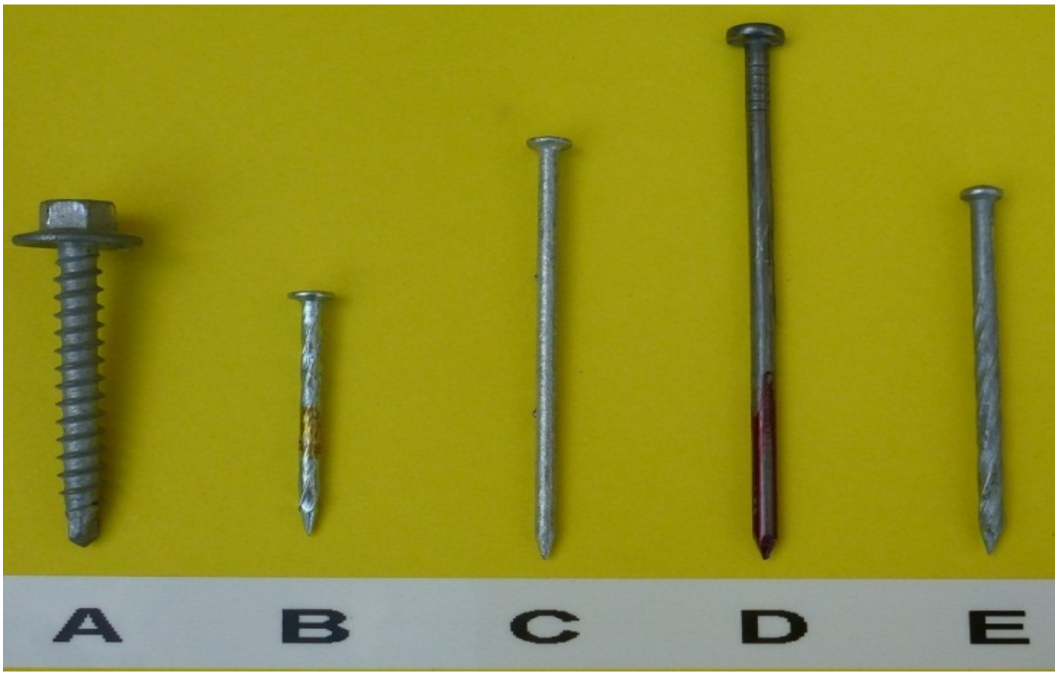

Figure 16. Typical examples of fixing of metal battens observed

- Metal batten manufacturers generally recommend using two hex-head screws per batten rafter connection – Figure 17 (A) is a 15 mm diameter head (as recommended by manufacturers). The commonly used nails have head diameters (B) – 5.5 mm; (C) – 5.6 mm; (D) – 5.5 mm x 7 mm; and (E) – 5.4 mm head.

Figure 17. A comparison in the size of the fixing heads between the screw fixings

- A large percentage of the approved plans nominated a 57 mm long x 2.6 mm diameter nail that typically has a head diameter of approximately 5.6 mm.

- Nails with smaller head sizes than the batten manufacturers' recommended screws have a smaller surface area to resist pulling through the batten – eg allowing for the reduced shank area, the 15 mm screw has a cross-sectional area of approximately 146 mm^2, compared to a 5.5 mm diameter headed nail having an area of approximately 19 mm^2.

- Engineering calculations were provided to the Building Commission during the general inspection to justify nail fixing of metal battens to timber rafters. Some aspects of the calculations used to specify the nail fixing were not clear.

- Often 75 mm roof framing nails were observed over-driven into the metal batten, which may weaken the batten rafter connection and make the 0.55mm thick batten more susceptible to pull-through failure (see Figure 18 for a typical example of an over-driven nail fixing on metal battens).

Figure 18. Photograph showing a 75mm x 3.06mm nail over driven when used to fix a metal batten

- In some roofs, more often when fixed with the 57 mm long x 2.6 mm diameter shank, the nails are under-driven – ie sitting up above the face of the metal batten and in some places observed by as much as 10 mm. Where this occurred it was often commonly found throughout the whole roof – eg see Figure 19 for typical examples of under-driven nails on metal battens observed during the general inspection.

Figure 19. Photograph showing a typical under driven nail fixing a metal batten around this roof

- Under-driving the nail is undesirable as less of the nail is embedded into the receiving rafter. The reduced nail penetration may give lower withdrawal capacity due to nail strength being a function of embedment depth.

- No evidence of over-driving or under-driving (or damage and deformation of the metal batten) was observed when the metal battens had been fixed with screws.

Fixings with no corrosion protection:

- The nails used to fix the metal battens in a number of inspected roofs were machine-driven roof framing nails that typically have no corrosion protection. Battens are generally protected against corrosion by an aluminium zinc alloy coating of 150 g/m^2.
- When in contact with an untreated steel nail the metal batten may sacrifice its own protective coating to protect the nail. This may lead to accelerated corrosion of the batten adjacent to the nail and a reduced service life.
- These corrosion reactions will vary depending on the microclimate characteristics within the roof space and the distance from breaking surf or sources of industrial air pollution.

Conclusions

- In general, engineers' nail fixing details for metal battens that were sighted, do not appear to have been assessed using a thorough verification method.
- In a number of cases, building surveyors appear to have approved details (not consistent with manufacturers' recommendations) on the basis of engineering certification that lacked reviewable calculations or evidence of testing.
- A variety of nails have been used on the sites inspected, often resulting in less capacity than the nail nominated on approved plans would achieve.
- There is increased risk of damaging the metal batten and reducing the capacity of the connection when machine-driven nails are used. This is due to the different densities of the timber rafters causing variance in the nail embedment depth.
- Engineers and building certifiers need to be better informed on the risks associated with using nails to fix metal battens to a timber rafter in lieu of the manufacturers' approved details.

The following assessment is made on the approximate apportionment of responsibility for where the problems (and therefore solutions) lay in respect to this general inspection point.

Responsibility impact assessment scores for metal battens:

Standards / Codes	Legislation / Regulation	Workmanship	Management / Supervision	Total
30	20	20	30	100

6. Rafter connection to the top plate

Background

- Rafters support battens and span between combinations of the perimeter of the dwelling, the ridge, hip or valley and underpurlins. For this section, the focus is on rafters that span between the perimeter of the dwelling where they are supported on a timber top-plate and underpurlins or hips.[29]

- Roof battens are connected to the rafter and transfer wind uplift force from the battens to the rafters where the majority of the resistance to the uplift is achieved via the rafter top plate connection.

- Hip rafters generally carry a larger roof area and are subject to greater wind uplift force. They consequently require a greater hold-down connection at the wall plate (see AS 1684.2: Table 9.12- Net Uplift Force- Underpurlins, Ridge-boards, and Hip Rafters-to Tie-Down Walls or Floors).

- WA's typical metal roof construction is timber frame above masonry walls, where most of the wind uplift resistance must be achieved through tie-down straps in the perimeter walls of the dwelling.

- Typical timber rafters are MGP 10 (pine) installed at 900 mm centres.

- Wind uplift force resistance can be achieved through a number of common methods:

  Method I – Tie-down straps fixed to the top-plate with a specific connection between the top plate and rafter.
  Method II – Tie-down straps fixed directly to the rafter.
  Method III – Tie-down straps fixed to a timber extra batten installed over the rafters – a method which is not provided in the standards as a deemed-to-satisfy solution and therefore requires confirmation for suitability on a case-by-case basis by a qualified engineer.

- Several different types of rafters exist in a timber stick framed roof. For clarity this section will only refer to: (a) the hip rafter; and (b) those other rafters supported at the perimeter of the dwelling by a top-plate.

- Only Method I (above) requires a specific rafter to top plate connection.

Terracotta and concrete tiled roofs in N1 wind regions generally have a net downward load, even in high winds. The forces in the rafter to top plate connection will push the joint together, particularly if the rafter is birds-mouthed and the nails or other connectors are generally under low stress.

The wind loads exerted on sheet metal clad roofs are transferred to the battens and then through to the rafters. These upwards loads are concentrated in the rafters and must be transferred through the connections at the end of each rafter as well as at any intermediate support. The net uplift due to wind loading, causes the joint to pull apart and relies on the fixings to hold it together.

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[29] For clarity, the most common type of common rafter has been discussed here. Other examples include rafters in cathedral roofs designed to carry both roof and ceiling loads. For further details refer to *AS 1684.2: 2010, Section 2 - Terminology and Definitions*.

Although rafters are nominally analysed as a sloping beam the way a typical roof is tied together (through the wall plate to ceiling joists) can make the roof structure behave more like a large truss. This increases the load in (and importance of) the rafter to top plate connection. A single weak rafter connection along the line of a wall plate may not result in major failure as load can be shed to adjacent rafters. Systemic weakness is, however, likely to lead to a major failure of the roof at high design wind speeds and pressures.

Referenced standards for deemed-to-satisfy solutions

Hold-down connections requirements – AS 1684.2:

- The required capacity of the rafter top-plate connection varies depending on a number of factors including roof width, rafter spacing, joint group and wind load.
- In WA, where it is more difficult to achieve tie-down through the body of the roof and internal walls due to solid masonry construction, it may be appropriate to assess the perimeter tie down as per a truss roof where the entire tie-down is achieved at the perimeter (refer to AS 1684.2; Section 9.6 - Specific Tie-down Fixings, Clause 9.6.3).
- AS 1684.2: 2010; Table 9.21 provides nine different types of rafter tie-downs to the topplate. The triple grip (or similar) was the most common metal connector observed.
- Some metal connector manufacturers provide a range of metal connectors designed for timber-to-timber connections – eg MiTek and Pryda.

Manufacturers' recommendations:

- The *Pryda: Timber Connectors & Tie-Downs Guide* shows the triple grip with four nails per face (Pryda 2014, p. 18).
- In addition, Pryda clearly states that 20% more additional nails may be required, or alternately the connections capacity should be downgraded by 20%, if machine-driven nails are used in place of standard recommended Pryda nails (Pryda 2014, p.3).
- The *MiTek Guide Edition 2* (Mitek 2010) shows four nails per face plus two nails down into the top plate totalling 10 nails for similar connectors.
- Where certified capacities are required, MiTek advises that the level of accuracy required during installation makes the use of pneumatically driven nails in their products impractical to meet certified capacities. See MiTek (2010) for further information on MiTek's fixing requirements and recommendations.

Inspection approach

- Inspection sites were predominantly located in high activity areas in the Perth outer metropolitan areas as these sites provided the best opportunity to locate a number of dwellings with roofs at a stage suitable for inspection.
- The rafter to topplate connection has been assessed as requiring only a nominal fixing where an extra batten of an appropriate size and stress grading has been used as the tie- down point (and where this batten runs across the top of the rafters).

Inspection findings

- Group A – 23% of roofs inspected were assessed as satisfactorily compliant.
- Group B – 47% of roofs inspected were assessed as satisfactorily compliant.
- Group C – 60% of roofs in the South West were assessed as satisfactorily compliant.
- Of the sites visited in the Perth metropolitan area nearly 100% of the rafters were tied together at the ridge in accordance with AS 1684.2-2010 Table 9.24 (A) and assessed as satisfactorily compliant.

The main areas of non-satisfactory compliance for Method I tie-downs occurred where:

- Rafter top plate connections were not adequately tied together to resist wind uplift forces – eg using two 75 mm gun nails when metal connectors were also required.
- Metal connectors were often not installed in accordance with the requirements of the Australian Standard 1684.2 and the manufacturer's recommendations.
- Hip rafters were often installed with a lower capacity connection to the top-plate than the standards require, despite supporting a greater area of roof.

Inspection comments

Some sites were observed where the metal connectors used to increase the capacity of the rafter top plate connection were not installed in accordance with either AS 1684.2 or the manufacturer's recommendations.

The main areas of non-satisfactory compliance were:

- Installation of the connector horizontally (or other ways) which lowered the capacity.
- Less nails to each face of the plate than required by AS 1684.2 or the manufacturer.
- Use of nail types not approved by the metal connector manufacturer.

In respect to installation of the connector horizontally:

- Metal connectors were often observed laid on their side and in some cases nailed with as little as one nail per face (see Figure 20) compared with AS 1684.2 Table 9.21 (b) which shows four nails to each end.
- Failing to install metal connectors in accordance with the standard (or the manufacturing recommendations) may reduce connector capacity to resist wind uplift force.

Figure 20. Photograph showing a poorly installed metal connector making the connection between an alfresco beam and rafter

- When the tie-down strap is fixed to the rafter (*Method II*) there is no requirement for a metal connector between the rafter and top plate to resist uplift. In a number of roofs inspected this was how the rafters were tied down. However, when the tie-down strap did not reach the rafter, and was then fixed to the top plate, the required metal connection between the rafter and top plate was not installed.
- Another area of non-satisfactory compliance is where perimeter beams have been installed – eg across an alfresco area. The beam may have been adequately tied down at the ends but to bring the top of the beam up to the same alignment as the perimeter brickwork a double top plate (or packer) was placed under the rafters. Often the rafter connection to the top plate (or packer) was made using a metal connector but the connection between the top plate (or packer) and the tie-down beam was not adequate to prevent separation at the design wind loads.

Conclusions

- The failure to adequately tie down the rafters by not using the metal connectors in accordance with the manufacturers' details appears to primarily relate to a lack of awareness and education.
- Decisions to use nails other than those recommended by the respective metal connector manufacturer, appear to be made due to the drive for speed and cost savings associated with the use of machine driven nails as compared to hand driven nails.

The following assessment is made on the approximate apportionment of responsibility for where the problems (and therefore solutions) lay in respect to this general inspection point

Responsibility impact assessment scores for rafter connection to the topplate:

Standards / Codes	Legislation / Regulation	Workmanship	Management / Supervision	Total
10	20	30	40	100

7. Connections for the remainder of the roof

Background

- This section assesses the rafter to the underpurlin, underpurlin to strut, and strut to internal top-plate connections.
- AS 1684.2 has been designed based on typical timber-framed wall construction methods in the eastern states where the roof can normally be tied down through timber-framed internal walls.
- The ability to tie down the roof area is more difficult in typical WA construction methods which consist of internal masonry walls where the top plate is fixed via nails driven into the mortar joints.
- Compensating for the difficulty in obtaining internal wall tie-down involves using the weight of the ceiling construction to resist uplift or special ties to mobilise the weight of internal walls.
- Connections between the underpurlin and struts, and connections between struts and internal wall top plates, shall be adequate to resist wind uplift loads using either of the tie-down mechanisms.
- Suitable connections need to be made through the roof general area down to the top plate to activate the ceiling load – eg applying a chain analogy can help describe the unbroken connection needed from the rafters through to the top plates.
- Some builders use stainless steel wire looped above beams or underpurlins, taken down the interior masonry wall and looped through (or bolted to) the lower courses of masonry to create this chain effect and use the weight of the internal brickwork – eg see Figure 21 and Figure 22.

Like the rafter to top plate connection, rafter to underpurlin and underpurlin to strutting beam loads are most likely to be subject to upward forces from wind loads on sheet metal clad timber framed roofs. Similar connections are therefore appropriate to transfer upward loads across the joint.

Figure 21. Photograph showing an internal hold-down wire fixed over underpurlin

Figure 22. Photograph showing a hold-down wire attached into the internal masonry

Referenced standards

- AS 1684.2: 2010; Clause 9.6.1 summarises this section regarding the requirement for effective tie down: “Continuity of tie-down shall be provided from the roof sheeting to the foundations.”

Rafter to underpurlin connections:

- The rafter to underpurlin connection detail is provided in AS 1684.2; Table 9.23- Uplift Capacity of Underpurlin Tie-down Connections.
- AS 1684.2; Table 9.12 provides values for the uplift forces.
- The use of 2 x 75 mm plain shank nails to connect the rafter to the underpurlin typically will not meet the required connection capacity of the commonly used timber stick framed roof member spacings.

Underpurlin to strut connections:

- AS 1684.2 does not detail a path of roof tie-down via the struts. However, Table 9.23 shows the underpurlin tied down with a strap to the top-plate and five 2.8 mm diameter nails for JD5 timber.
- AS1684.2; Section 7.2 and 9.5, suggest a minimum connection of 2 x 75 mm x 3.05 mm nails where the struts are vertical or perpendicular to the rafters and the underpurlin is halved or birdsmouthed. This joint may require a greater capacity connection depending on the roof area supported by the strut.
- Where the strut is not birdsmouthed or halved, AS 1684.2:2010; Subclause 7.2.15.1- Roof struts, indicates that the underpurlin should be connected to the strut using a strap or framing anchor when in a position between vertical and perpendicular to rafters.

Strut to top plate connections:

- AS 1684.2 does not provide connection details for the strut to top plate. The strut to top plate connection is typically skew nailed with limited tie down capacity.
- When the strut is used as a path of tie-down the capacity of the joint to the top plate should be upgraded by using a metal connector or metal strap as for the connection between underpurlin and strut.
- Connection requirements vary depending on the roof area supported (eg the number of underpurlins and frequency of struts or tie-downs) and each roof may need to be assessed to determine adequate connection capacities.

Manufacturers’ recommendations:

- Pryda’s *Guide for Western Australian Builders on Prefabricated Timber Truss and Frame, November 2010* (Pryda 2010), Section 8: Achieving compliant tie down for stick built construction, provides appropriate solutions regarding the connections of the rafter to underpurlin, underpurlin to strut, and strut to top plate.
- MiTek’s *Guide to Connectors for AS 1684.2 and AS 4440 Compliance,* also provide appropriate connection solutions (see Mitek 2010).

Inspection approach

- Inspection sites were predominantly located in high activity areas in the Perth outer metropolitan areas as these sites provided the best opportunity to locate a number of dwellings with roofs at a stage suitable for inspection.

Inspection findings

- Group A – 47% of the roofs inspected were assessed as satisfactorily compliant.
- Group B – 25% of the roofs inspected were assessed as correctly made and satisfactorily compliant.
- The difference of approximately 22% in satisfactory compliance between Group A and Group B appears related to both location and timing of the inspections – ie Group A sites were primarily located in Perth's northern suburbs while Group B sites were predominantly in Perth's southern suburbs.
- Group C – 13% of South West sites had satisfactorily compliant rafter to underpurlin, underpurlin to strut and strut to top plate connections.

The main area of non-satisfactory compliance observed related to:

- A failure to ensure all of the three connection points had the required capacity to transfer the design wind uplift loads down into the dwelling and to the ground.

Inspection comments

- It is unclear if the use of wire, as a tie-down installed across masonry surfaces that are to be rendered, will adversely affect the performance of the render.
- In a number of cases due to the manner in which the wire had been installed, it is questionable if it will act as an effective tie-down if subjected to peak design wind loads.

Conclusions

- Some non-satisfactory compliance in this area may relate to industry change from when WA roofs were predominantly constructed to resist the gravity loads from tiles and hardwoods to a new situation where light weight sheet metal clad timber roofs now have the greatest market share.[30] Therefore roof framing must now be constructed to also resist wind uplift forces by connecting to suitable mass deeper in the structure.

- This section reinforces the need for internal roof connections in terms of an unbroken chain activating the internal top-plates held down by the weight of the ceiling construction.

The following assessment is made on the approximate apportionment of responsibility for where the problems (and therefore solutions) lay in respect to this general inspection point.

Responsibility impact assessment scores for connections for the remainder of the roof:

Standards / Codes	Legislation / Regulation	Workmanship	Management / Supervision	Total
15	20	25	40	100

[30] Assessed by BC Inspector, G. Flowers, following discussions with manufacturers, builders and an assessment of metal roofs compared with tiled roofs while carrying out site inspections.

8. Collar ties

Background

- Collar ties are timber members fastened to rafters above the underpurlins and connect one side of the roof to the other.

- Collar ties strengthen the roof using the principles of triangulation and enable it to more satisfactorily resist wind loads.

- The size, stress grading, and how the collar tie is fixed to the rafters depends on the span of the collar tie and whether the roof is designed in accordance with AS 1684.2 2010 clause 9.6.3 – ie where all collar ties are required to be bolted.

- Collar ties are required in all coupled roof constructions (ie no underpurlins) and are required above each set of underpurlins where they are installed.

- Collar ties are typically required in all coupled roof constructions even where there are no underpurlins. Where there are multiple rows of underpurlins, collar ties are required to be installed above each set (Refer to AS1684.2: 2010; Clause 7.2.16).

The primary function of a collar tie is to balance the horizontal forces at the joint between the underpurlin and a sloping strut. It is essential that the connections at each end are capable of transmitting significant forces.

Referenced standards for deemed-to-satisfy solutions

- AS 1684.2: 2010; Clause 7.2.16- Collar ties, contains requirements for collar ties – specifically:
  - Collar ties shall be provided in all coupled roof construction.
  - Size of collar ties shall be in accordance with Table 7.6.
  - Collar ties shall be fitted to opposing common rafters at a point immediately above the underpurlins.
  - Where underpurlins are not required, the collar ties shall be fitted to opposing rafters at a height above the top plate not greater than two-thirds of the rise of the roof.
  - Collar ties shall be fitted to every second pair of common rafters, or at 1200 mm maximum spacing, whichever is the lesser.
  - Collar ties shall be fixed to rafters with one M10 bolt for ties greater than 4.2 m long; or min. 2/75 hand-driven nails or 3/75 × 3.05 mm Ø machine driven nails for ties up to 4.2 m long.
  - Collar ties that exceed 4.2 m in length shall be fixed in accordance with Figure 11, Appendix I.

Inspection approach

- Inspection sites were predominantly located in high activity areas in the Perth outer metropolitan areas as these sites provided the best opportunity to locate a number of dwellings with roofs at a stage suitable for inspection.

Inspection findings

- Group A – 39% of sites inspected were assessed to be satisfactorily installed in accordance with AS 1684.2
- Group B – 52% of sites inspected were assessed to be satisfactorily installed in accordance with AS 1684.2.
- Group C – 50% of the 15 roofs in the South West were assessed to be satisfactorily installed in accordance with AS 1684.2.

The main areas of non-satisfactory compliance related to:

- Failure to install the collar tie directly above the underpurlin.
- Failure to use the correct sized timber dimensions for the span of the collar tie and correct fixing to the rafter.
- Failure to install a collar tie above each set of underpurlins.

Inspection comments

- AS 1684.2-2010 provides details requiring collar ties to be fitted to every common rafter (opposing rafters that extend from the ridge to the perimeter of the building) at a maximum of 1200 mm centres.
- Typical WA practice is to classify timber stick built construction as coupled roofs. AS 1684.2-2010 states that where possible both the ceiling joists and collar ties should be fixed to the rafters for the roof to be considered coupled.
- As typical WA practice is for the ceiling joists not to line up and be attached to every rafter, the roof construction appears not to strictly meet the AS 1684.2-2010 definition of coupled. However the roof will act as a coupled roof rather than as a cathedral or skillion roof.
- There may be a need to upgrade other aspects of the roof construction to make up for the lack of ceiling joist to rafter connections where coupled roof designs are being used but not actually being constructed in accordance with coupled roof requirements – ie collar ties may be required in the roof construction regardless of whether the rafters are common and extend from the ridge to the plate on both sides of the roof.
- The 13% improvement between the Group A roofs inspected in the northern suburbs and the Group B roofs predominantly inspected in the southern suburbs may be due to:
  - A positive change in behaviour being generated by inspector feedback and inter-builder communication between Group A and the latter Group B roof construction projects.
  - A larger number of dwellings in the southern suburbs having less complex roofs (than northern suburbs) may have resulted in more easily achieved compliance.
- There is evidence that roof package suppliers do not always allow enough material to install the collar ties in accordance with the standard.

- In Figure 23 below the orange arrow (A) indicates location of collar ties compared to the red arrow (B) where the underpurlin is located.
- Collar ties should be located immediately above underpurlins as outlined in Figure 24 below.
- Figure 24(A) shows the standard method of fixing collar ties when two underpurlins are necessary.
- Figure 24(B) shows the standard method of fixing scissor collar ties when two underpurlins are necessary.

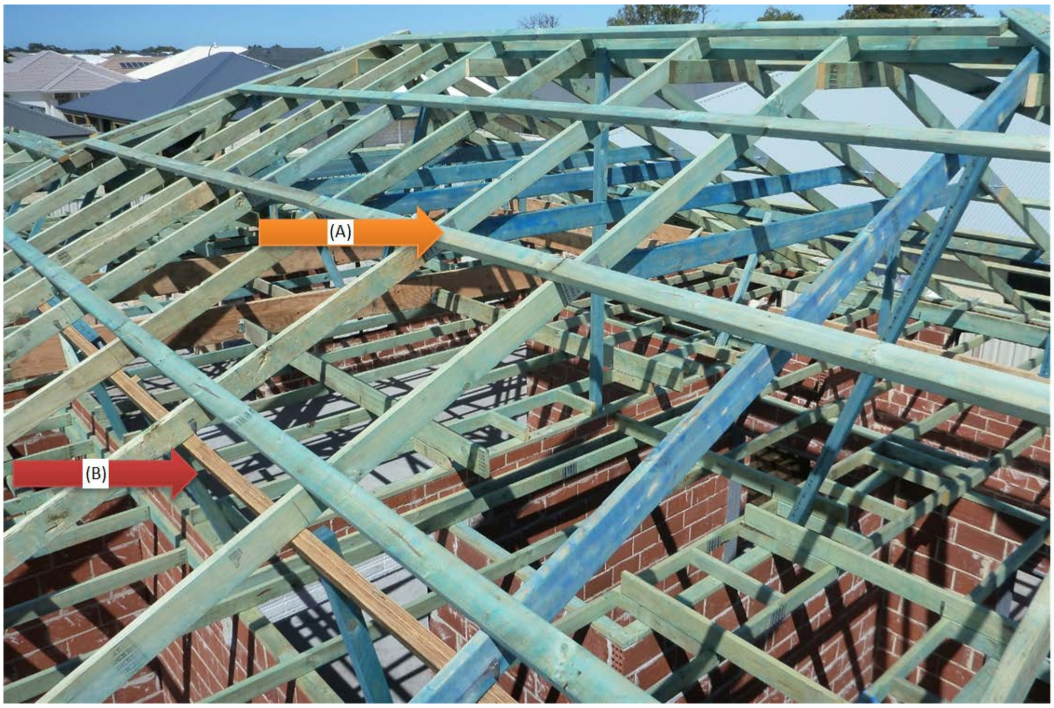
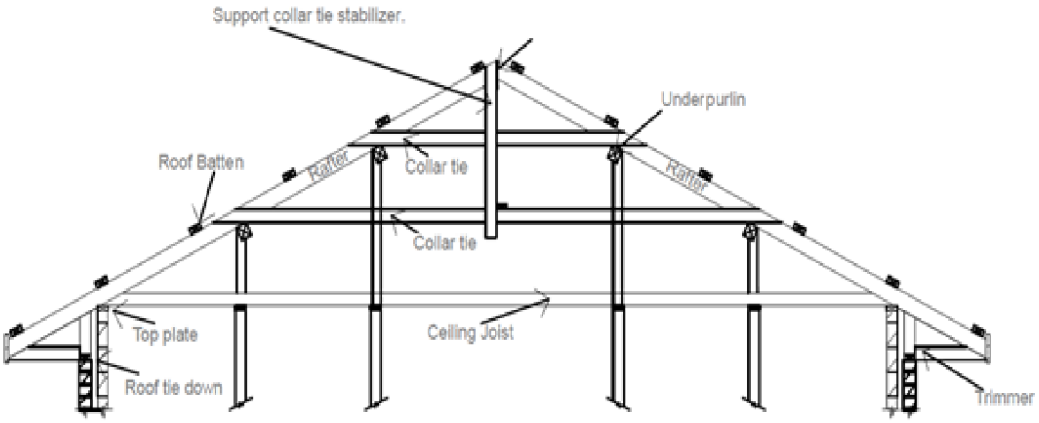
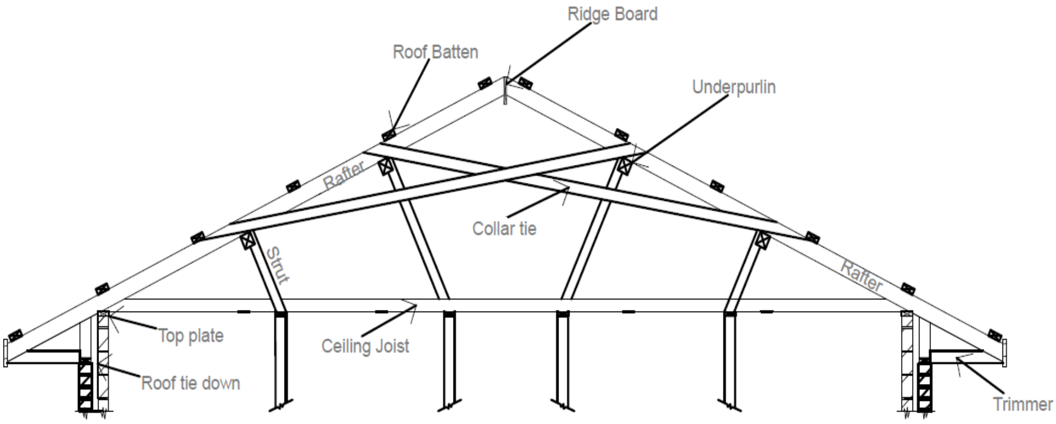


Figure 23. Photograph showing non-compliant collar tie installation



(A)



(B)

Figure 24. Requirements for collar ties as per AS 1684.2-2010

Conclusions

- The reasons for non-satisfactory compliance relating to collar tie size, spans, centres — and the requirements for a set of collar ties above each set of underpurlins; appear to relate to a lack of understanding of the requirements of the standards. This lack of understanding was identified in both the carpenters constructing the roof and also the schedulers who do the take-offs and supply the roofing materials for each construction site.
- WA timber framed stick built roofs can be complex which may make the installation of additional collar ties difficult in some situations. An amendment to the Australian Standard may help clarify this issue.

The following assessment is made on the approximate apportionment of responsibility for where the problems (and therefore solutions) lay in respect to this general inspection point.

Responsibility impact assessment scores for collar ties:

Standards / Codes	Legislation / Regulation	Workmanship	Management / Supervision	Other	Total
0	20	35	45		100

9. Timber trusses

Background

Timber trusses are:

- Designed utilising a computer program, manufactured in a factory and delivered to site. They are supported at the perimeter walls and generally span above the internal walls – thereby requiring all their resistance to uplift from the perimeter connections which should be installed in accordance with the manufacturers' recommendations.
- Able to achieve the same roof structure as a timber framed stick built roof with smaller cross-section timber.
- Supplied with manufacturers' installation instructions /fixing manual which specifies the types of fixings required for each truss top plate connection, roof layout, bracing requirements and connectors and fixings.
- Normally required to have a connection to the top plate via nominal fixings and a metal connector with a minimum 10 nails per connector – ie four per face plus two down into the top plate.

Timber (gang nail) trusses are designed on engineering principles to resist calculated gravity and wind loads. They usually require less volume and weight of timber than conventional roof framing. Normally trusses are designed to span completely across the building and the loads at each end support are considerable. This makes truss roofs particularly vulnerable to poor end connections under wind uplift.

Trusses can be adversely affected when supports are provided on site in inappropriate places, such as mid-way between nodes. This imposes bending forces that the members may not be designed to resist. It is critically important that trusses are installed in accordance with manufacturers' or engineers' details.

Referenced standards for deemed-to-satisfy solutions

- Australian Standard AS 4440: 2004- Installation of nailplated timber roof trusses (Standards Australia, 2004) provides details on the installation of trusses. Some of the information from AS 4440 is also reproduced in the relevant manufacturers' installation guidelines.
- AS 1684.2; Table 9.13 provides values on the wind uplift forces that are also applicable to truss top plate connections.
- AS 1684.2; Table 9.21 provides a variety of connection methods with their capacities, the value of the connection must be greater than the value calculated in Table 9.13.

Inspection approach

- Nine houses with timber trusses were inspected on Perth building sites between February and June 2014 – ie four in Group A and five in Group B.
- No timber trussed roofs were inspected in WA's South West (Group C).
- Inspection sites were predominantly located in high activity areas in the Perth outer metropolitan areas as these sites provided the best opportunity to locate a number of dwellings with roofs at a stage suitable for inspection.
- The majority of the inspected trusses were installed on rectangular (simple design) upper floors constructed from timber wall framing.
- Typically the timber trusses were fixed to the top plates using 2-gun driven 75 mm x 3.06 mm nails with additional metal connectors at the rafter to top plate connection.
- In some cases the metal connector had not been installed where required.
- Satisfactory compliance of roof truss installation was assessed against AS 4440, or AS 1684.2 or the manufacturers' installation recommendations and guidelines.
- Any identified non-satisfactory compliance was conveyed to the builders via a general inspection follow-up letter and further truss roof inspections were normally undertaken three to four months later.

Inspection findings

- The first group of five timber truss roofs inspected for the interim BC roof report (May 2014) were assessed as having 100% non-satisfactory compliance – thus prompting immediate feedback response by the inspector.
- The last four roofs inspected were assessed to have 75% non-satisfactory compliance.

The main areas of non-satisfactory compliance were:

- Insufficient nails per metal connector. In some cases only 25% of the nails required by the standards were present (see Figure 25 as an example of one nail used where four nails per tab are normally required).
- Incorrect installation of metal connectors – ie installed horizontally instead of vertically.
- Incorrect support of the truss over the internal framework – ie blocking between the bottom chord of the truss and the internal top plate at places where the truss is not designed to be blocked.

Figure 25. Rafter top plate connection with only one horizontal nail into the top plate tab (Manufacturer recommends 4 nails)

Inspection comments

- Truss manufacturers usually supply an installation manual with their trusses detailing installation standards and procedures including information on how to install the metal connectors.

- Generally connectors require four nails per face and two nails driven down into the bottom tab. In addition the hip trusses generally require a higher level of hold down compared to the general area trusses.

- AS 1684.2; Table 9.21 “Uplift capacity of rafter and truss tie-down connections”; Diagram (b) clearly shows four nails to each end of a metal connector.

- One metal connector supplier provides guidelines showing four nails per face and advises (where machine driven nails are used instead of the supplier’s nails) that either additional nails may be required or, alternately, the connections capacity should be downgraded (see Pryda 2014, p.3).

- Another supplier of metal connectors advises the level of accuracy required during installation makes the use of pneumatically driven nails in their products impractical to meet certified capacities.

- In the majority of the sites inspected, there appeared to be low recognition of the importance of the truss tie-down in the integrity of the tie-down system – eg it was common to find two nails per face in the triple-grip type connector (and some cases only one nail per face was observed).

- The change improvement from no satisfactory compliance in the first half of the roof truss inspections (n=5) to 75% non-satisfactory compliance in the second half of inspections (n=4) may be attributed to some changes in building practice after notification and feedback by the inspector.

- Although this improvement may imply industry response due to inspection, the small sample size makes it difficult to draw solid conclusions in this general inspection.

Conclusions

- The onsite installation of roof trusses in WA were assessed as largely having non-satisfactory compliance with the truss manufacturers' installation instructions, the fixing details provided by AS 1684.2 -2010, and/or AS 4440: 2004

- This situation potentially reduces the truss's resistance to wind uplift and appears to be due to truss manufacturer supplied installation information and fixings details not being followed.

- .

The following assessment is made on the approximate apportionment of responsibility for where the problems (and therefore solutions) lay in respect to this general inspection point.

Responsibility impact assessment scores for timber trusses:

Standards / Codes	Legislation / Regulation	Workmanship	Management / Supervision	Other	Total
0	20	35	45		100

10. Timber roof beams

Background

- Timber beams at the roof perimeter are used to form alfresco/veranda areas where the beam may be supported by isolated brickwork piers, steel/timber posts or brickwork of the dwelling.

- Timber beams under the main roof space often span between internal walls or an internal wall and the external wall – eg strutting beams can also be used to create raised areas to the ceiling.

- Timber beams when tied down, are normally tied down with round steel rods.

- Adequate tying down of beams is important to prevent wind uplift – especially for the perimeter beams.

- Failure to connect an isolated pier to a beam contributed to the pier collapse at Rottnest Island (see Mulligan 2013) which resulted in a fatality investigated by the state coroner who made recommendations relating to tying piers to the roof structure.

- A complaint considered by the Building Commissioner regarding the failure of a roof was found to result from failing to install tie-downs to the veranda beams.

- Beams can also be tied down using stainless steel wire which is more commonly seen on sites with an N2 wind rating.

- The use of steel cable looped through brickwork to tie down beams is not included in any of the building details in the relevant standards.

Like other structural members and trusses, beams must be correctly connected. Perimeter beams in areas such as verandas can be subject to very high wind uplift forces and must be held down effectively.

Referenced standards for deemed-to-satisfy solutions

Internal timber beams:

- Tie-down to internal timber beams (eg strutting beams) is not specifically detailed in AS 1684.2-2010, however, Section 9.6- Specific tie-down fixings; Clause 9.6.1- General, states: “Continuity of tie-down shall be provided from the roof sheeting to the foundations”.

- The BCA Volume 2 (2014); Part 3.4.4- Structural steel members, requires a steel strutting beam to be tied down at each end when supporting a sheet metal roof. It does not, however, mention requirements for timber beams.

- Some reviewed engineering plans provided no detail of the tie-down requirements of the beams while others required all beams to be tied down at each end.

Perimeter beams:

- The BCA Volume Two (up to and including the 2011 version) included a detail on how an isolated pier should be attached to the roof structure using a strap or a 10 mm rod connected from the concrete footing to the roof structure.

- The 2014 BCA; Part 3.3- Masonry, refers to the AS 4773 series or AS 3700, which do not contain a deemed-to-satisfy solution for attaching an isolated pier to a roof.

- AS 1684.2; Table 9.20 includes details on tie-down of beam/lintels. These details show the beam being supported by timber framework which is non-typical of WA construction.

Inspection approach

- Inspection sites were predominantly located in high activity areas in the Perth outer metropolitan areas as these sites provided the best opportunity to locate a number of dwellings with roofs at a stage suitable for inspection.

- The primary area of inspection was focused on the perimeter beams, especially those beams located on isolated piers or where a beam, including internal beams, intersected an exterior wall.

- Interior beams that were not supported by a perimeter wall were assessed on a case-by-case basis; taking into consideration the wind rating; where the beam was installed; the roof area supported; whether the beam was connected to other parts of the roof structure in such a manner as to resist uplift; and how the tie-down was installed.

- Beams that only supported the ceiling structure such as hanging beams were not expected to be tied down and therefore did not form part of this general inspection assessment.

Inspection findings

- Group A – 20% of the timber beam installations were assessed as satisfactorily compliant.

- Group B – 43% of inspected roofs were found to be adequately tied down and assessed as satisfactorily compliant.

The main areas of non-satisfactory compliance included:

- Either no tie-down at all, or no connection between the tie-down and beam.
- Tie-downs were installed but with a poor connection to the roof beam.
- Although not directly related to the ability of the beam to resist uplift force, in a number of inspections, beams were cut down excessively at their point of support.

Inspector comments

- While the BCA and standards no longer provide a detail on how to connect isolated piers to the roof structure, this connection is usually specified in engineering details.
- There appears to be a range of engineering details for timber beam tie-downs specified – for example:
    - for N1 sheet roof “Veranda or carport beams fix beams to walls with full height 10 mm diameter rods (or three 30 mm x 0.8 mm PGI straps) built into the pier or wall. Maximum beam span to be 6.0 meters” (sic).
    - Another engineering detail specified a single 30 mm x 0.8 mm strap as a tie down.
- A beam is usually only fixed at its ends. To hold down this beam the methods/materials used must match the tie-down forces. This may require the tie down to be of a higher specification than for the remainder of the dwelling.
- Some site inspections found no tie-down installed on beams located on isolated piers.
- In other cases, correctly installed tie-down rods were compromised by not being correctly positioned resulting in not being successfully attached to the beam (eg see Figure 26).
- In some cases the tie down was a suitable size but the plate and fixing connections to the beam were light duty and appeared to be a weak connection.
- In all the above three examples the tie-down will not be adequate to resist the wind uplift forces when the roof experiences wind uplift load near the ultimate design speeds.
- Figure 26 shows a tie down rod bent to make the connection the beam which is unlikely to provide an acceptable tie-down at high design wind speeds.

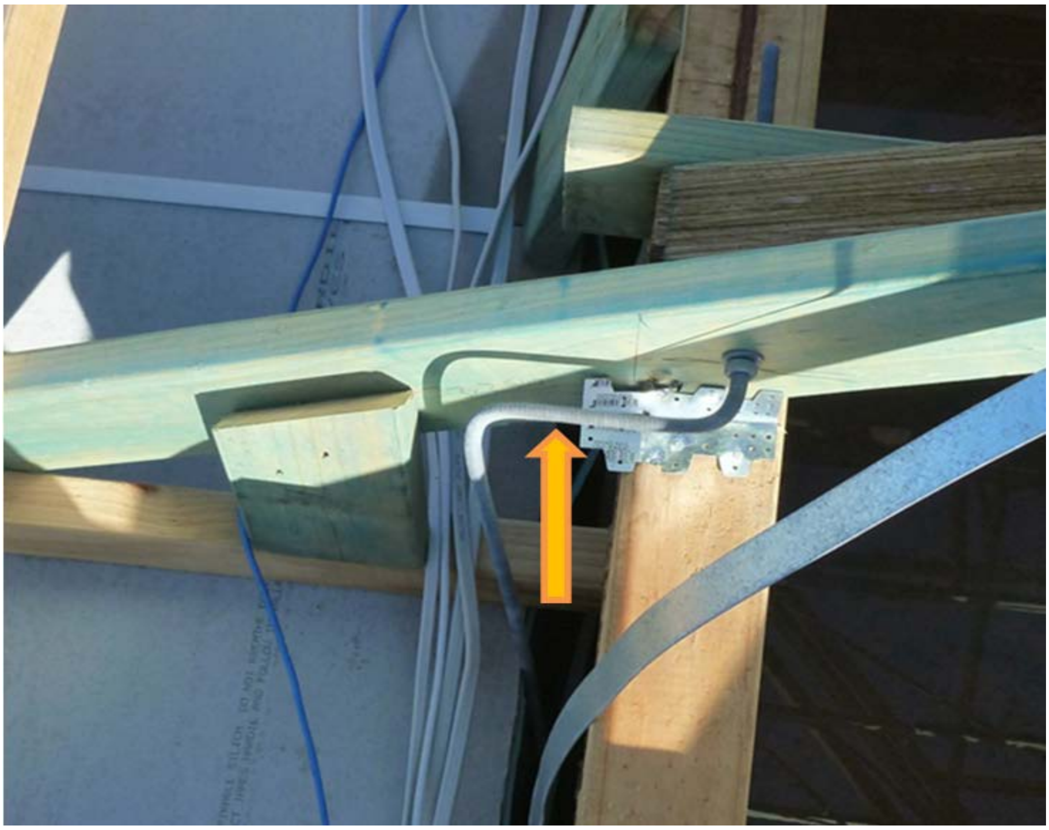


Figure 26. Photograph showing a tie down rod bent to make the connection to the beam

Conclusions

- Industry generally appears to understand the requirement to tie down the timber beams but often the installation and connections between the tie-down and beams have been poorly constructed.
- Hold down requirements may need to be assessed and detailed on a case-by-case basis by a qualified person as the wind force uplift on a beam is dependent on variables such as its span and the area of roof that it is supporting.

The following assessment is made on the approximate apportionment of responsibility for where the problems (and therefore solutions) lay in respect to this general inspection point.

Responsibility impact assessment scores for timber roof beams:

Standards / Codes	Legislation / Regulation	Workmanship	Management / Supervision	Total
20	20	25	35	100

11. Steel roof beams

Background

- The most common use for steel beams is for internal support of the roof structure such as strutting beams. They are also commonly used for spanning garage openings where they provide support for the rafters and or struts.
- Steel beams are typically tied down by the installation of a 10 mm diameter steel rod in the masonry that is usually welded to the steel beam.
- The bricklayer is responsible for correctly installing the steel rods.
- Steel beams are often smaller sections than timber beams that support similar loads.
- Installation of connections between steel beams and timber can be more time consuming compared to installing timber-to-timber connections.

Referenced standards

- The BCA Volume Two; Part 3.4.4- Structural steel members, states that strutting beams "must be tied down at the support points, in the case of sheet steel roofs".

Inspection approach

- Inspection sites were predominantly located in high activity areas in the Perth outer metropolitan areas as these sites provided the best opportunity to locate a number of dwellings with roofs at a stage suitable for inspection.
- The aim of the general inspection for this point was to visit the roofs once the carpentry work had been completed but prior to the roof being sheeted. This inspection window provided the best opportunity to view the critical aspects of roof construction.
- As the connection between the steel beams and tie-down rods is often a welded connection it is possible that in some cases the welding work had been planned but was not carried out at the time of the inspection.

  For this reason, the level of final satisfactory compliance in this section may be slightly higher than the general inspection assessment figures indicate.

Inspection findings

- Group A – 18% of steel beams inspected were assessed as satisfactorily tied down.
- Group B – 33% of steel beams inspected were assessed as satisfactorily tied down.
- Group C – 18% of steel beams in the South West were assessed as satisfactorily tied down.

The reasons for the 15% difference between Group A and Group B results were difficult to determine from builder feedback. Suggested improvements for tying-down steel beams are not as obvious as other aspects of the roof inspection program. Higher Group B rating could be due to improvement via feedback to the industry (following earlier Group A assessments) or other factors such as differences between the suburbs north and south of the Swan River raised in previous sections – ie generally less complex housing inspected in the southern Perth suburbs.

The main areas of non-satisfactory compliance were:

- No tie-down installed or no connection between the tie-down rod and the beam.
- Connections between the beam and the tie-down rod were unlikely to resist peak design wind loads.

Although not formally inspected as part of the steel beam assessment, the timber top plate to steel beam connection was often made by nailing with an explosive power tool or fixing through the steel beam from the underside with either hex-head screws or bolting. In several cases the number of connectors used and method of connection did not appear adequate to connect the timber frame to the beam.

Inspection comments

- A number of inspected roofs did have provision for the steel beams to be tied down, however, there were some very poor techniques used to attach the beam to the tie-down.
- Often the tie-down rod was located in a position in the masonry that required it to be bent at excessive angles in order to connect with the beam – eg see Figure 27 where a tie-down rod is bent and pulled across the roof horizontally to be fixed to the steel beam some distance from the location of the rod in the masonry.

Figure 27. Photograph shows poor installation of a bent tie down rod

- In some instances, where the rods were missing or poorly placed, a review of the plans indicated the poor installation resulted from failure of a bricklayer to install the rods in accordance with the plans.
- The BCA acceptable construction practise and deemed-to-satisfy provisions does not provide complete information regarding the tie-down requirements of steel beams in roofs.

Conclusions

- Industry generally understands the requirement to tie down the steel beams but more attention to the detailing of the connection is required to ensure a compliant tie-down connection has been made.
- As the tie-down requirements for all steel beams are not provided in the deemed-to-satisfy sections in the BCA, the hold down requirements may need to be assessed and detailed on a case-by-case basis.

This detailed information needs to be provided to all persons responsible for installing the tie down and connection to the beam – ie especially the bricklayers.

The following assessment is made on the approximate apportionment of responsibility for where the problems (and therefore solutions) lay in respect to this general inspection point.

Responsibility impact assessment scores for steel roof beams:

Standards / Codes	Legislation / Regulation	Workmanship	Management / Supervision	Total
0	20	35	45	100

12. Other related inspection issues

Background

This category covers other related aspects of roof construction which may affect the roof's capacity to resist wind uplift loads but are not included in the previous sections (1 – 11). This detailed report section is not designed to detail all other aspects of sheet metal clad timber framed roof construction in WA.

Inspection approach

Inspection sites were located in high residential building activity areas in the Perth outer metropolitan areas as these sites provided the best opportunity to locate a number of dwellings with roofs at a stage suitable for inspection.

Inspection findings

- Group A – approximately 42% of roofs inspected were assessed as satisfactorily compliant.
- Group B – approximately 32% of roofs inspected were assessed as satisfactorily compliant.
- Group C – approximately 46% of roofs inspected were assessed as satisfactorily compliant.

Inspection comments

The following lists the most common areas of other non-satisfactory compliance:

- Ridge propping at centres exceeding that limited by the standard.
- Rafters at the ridge misaligning by a distance greater than allowed.
- Rafter overhang in excess of the length allowed.
- Birdsmouthing of rafters to a depth greater than one-third the rafter depth.
- Connection of laminated beams to form raised ceiling sections not in accordance with the respective manufacturer's recommendations.
- Missing chocks at the base of struts.
- Insufficient depth of the hanging beam at the wall plate.
- No underpurlin connection to hip or valley rafter where required.
- Poor placement of underpurlins.
- Struts installed at angles in excess of those specified in AS 1684.
- Inadequate blocking or bracing of beams.

Conclusions

- The areas of non-satisfactory building work are either detailed in the AS 1684.2 or in various manufacturers' recommendations.
- Non-satisfactory building work appears related to lack of awareness of the Standard's requirements.

The following assessment is made on the approximate apportionment of responsibility for where the problems (and therefore solutions) lay in respect to this general inspection point.

Responsibility impact assessment scores for other related inspection issues:

Standards / Codes	Legislation / Regulation	Workmanship	Management / Supervision	Total
0	20	35	45	100

References

Australian Bureau of Statistics (ABS 2014). *3218.0 – Regional Population Growth, Australia, 2012-13: Feature Article: Capital Cities: Past, present and future*. See www.abs.gov.au

Australian Bureau of Statistics (ABS 2016). *8731.0 – Building Approvals, Australia, Nov 2015.* Table 08. Number of Private Sector Houses Approved - States and Territories. See www.abs.gov.au

Boughton, G. N. and Falck, D. J., (2008). *Shoalwater and Roleystone WA tornadoes, Wind damage to buildings, Report: TR54 August, 2008.* Cyclone Testing Station, James Cook University, Queensland.

Boughton, G. N., Falck, D. J., Duong, A. V. N., A., Pham, S., and Nguyen, A. (2015). *Static Testing of Batten Connections at University of Western Australia*, *CTS Technical Report No 62 December ,2015.* Cyclone Testing Station, James Cook University, Queensland.

Data Analysis Australia (2015). *BCWA/1 – Inspection Point Compliance Rates Summary*, 12th October 2015. Nedlands, Western Australia.

Department of Commerce (2012). *Building Act 2011 Overview*.
See www.commerce.wa.gov.au/publications/building-act-2011-overview

Department of Commerce (2015). *Compliance and enforcement policy*, June 2015, Building Commission, Perth, Western Australia.
See www.commerce.wa.gov.au/sites/default/files/atoms/files/compliance_and_enforcement_policy_2015.pdf

Engineers Australia (2015). 'Weak links let down strong buildings', *Engineers Australia (Civil Edition)*, Vol. 87 No. 3: April, pp.12-15.
See https://cyclonetestingstation.com.au/publications/content/cyclone-marcia-article-in-engineers-australia

Fogliani, R. V. C. (2015). *Inquest into the deaths of Debora Till (1103/07) and Craig Allan Raabe (211/07) – Ref No. 45/14*, 18 August 2015, Coroner, Western Australian Government.
See www.coronerscourt.wa.gov.au/_files/Raabe_Till_finding_2015.pdf

HIA (2015). *HIA Housing Forecasts - October 2015, Dwelling Starts: by state and territory,* HIA Economics. See https://hia.com.au/en/BusinessInfo/economicInfo/housingForecasts.aspx

Hunn, D., Bond, I. and Kernohan, D. (2002). *Report of the Overview Group on the Weathertightness of Buildings. Building Industry Authority*. New Zealand Government, Wellington.

MiTek (2010). *MiTek Guide to Connectors for AS 1684.2 and AS 4440 Compliance – Edition 2.* MiTek Australia Ltd. See www.mitek.com.au

Mulligan, D. H. (2013). *Inquest into the death of Thomas Michael Brasier – Ref No. 19/13*, Coroner, Western Australian Government.
See http://www.coronerscourt.wa.gov.au/_files/Brasier%20finding.pdf

National Archives of Australia (no date). *Cyclone Tracy, Darwin – Fact Sheet 176*.
See www.naa.gov.au/collection/fact-sheets/fs176.aspx

PricesaterhouseCoopers (2009). *Department of Building and Housing, Weathertightness- Estimating the Cost, 29 July 2009*. PwC *obo* Department of Building and Housing, Wellington, New Zealand.

Pryda (2010). *Pryda's Guide for WA Builders on Prefabricated Timber Truss & Frame – November 2010*. Pryda Australia. See www.pryda.com.au/builders-guides

Pryda (2014). *Pryda Timber Connectors – Connectors & Tie downs Guide – March 2014*. Pryda Australia.

Queensland Building and Construction Commission (2014). *Review of the Building Act 1975 and building certification in Queensland – Discussion paper*. A. Wallace, Barrister-at-Law, June 2014. Brisbane.
See http://www.hpw.qld.gov.au/SiteCollectionDocuments/ReviewOfTheBuildingAct1975AndBuildingCertificationInQueenslandDiscussionPaper.pdf

Queensland Building and Construction Commission (2015). "[V1.0] 44 fact Sheet - Supervising building work". See www.qbcc.qld.gov.au/sites/default/files/Supervision%20of%20Building%20Work.pdf

Tasmanian Department of Justice (2014). *Review of the Tasmanian Building Regulatory Framework: Issues Paper 1.0 July 2014*, Hobart, Australia.
See www.justice.tas.gov.au/building/regulation/building_regulatory_framework_review

Yates, D. (2003). *Weathertightness of Buildings in New Zealand: Report of the Government Administration Committee's inquiry into the weathertightness of buildings in New Zealand: Forty-seventh Parliament (Dianne Yates, Chairperson) March 2003, Presented to the House of Representatives*. New Zealand.
See http://www.parliament.nz/resource/mi-nz/47DBSCH_SCR2389_1/f93fe1a93056986fb2dbca1480cd219cfcac0505

Notes: All online reference links above were sighted in October, 2015

Design Codes and Standards:

Australian Building Code of Australia (BCA 2014/ NCC Vol 1). *National Construction Code Series 2014 Volume One: Building Code of Australia Class 2 to Class 9 Buildings*.

Australian Building Code of Australia (BCA 2014/ NCC Vol 2). *National Construction Code Series 2014 Volume Two: Building Code of Australia Class 1 and Class 10 Buildings*.

National Association of Steel-Framed Housing Inc., *NASH Standard; Residential and Low-rise Steel Framing, Part 1: Design Criteria, 2005*, Victoria, Australia.

Standards Australia Limited/ Standards New Zealand (2011). *AS/NZS 1170.2: 2011- Structural design actions, Part 2- Wind actions,* Standards Australia Limited/ Standards New Zealand, Sydney, Australia/ Wellington, New Zealand.

Standards Australia Limited (2010). *AS 1684.2-2010: Residential timber framed construction, Part 2- Non-cyclonic areas,* Standards Australia Limited, Sydney, Australia.

Standards Australia Limited (2010). *AS 1720.1: 2010- Timber Structures, Part- Design methods,* Standards Australia Limited, Sydney, Australia.

Standards Australia Limited/ Standards New Zealand (2000). *AS/NZS 2699.2: 2000- Built-in components for masonry construction, Part 2: Connectors and accessories,* Standards Australia Limited/ Standards New Zealand, Sydney, Australia/ Wellington, New Zealand.

Standards Australia Limited (2011). *AS 3700: 2011- Masonry structures,* Standards Australia Limited, Sydney, Australia.

Standards Australia Limited (2012). *AS 4055: 2012- Wind loads for housing,* Standards Australia Limited, Sydney, Australia.

Standards Australia (2004). *AS 4440–2004 Installation of nail plated timber roof trusses*. Standards Australia Limited, Sydney, Australia.

Standards Australia Limited (2010). *AS 4773.1: 2010- Masonry in small buildings; Part 1- Design,* Standards Australia Limited, Sydney, Australia.

Standards Australia Limited (2010). *AS 4773.2: 2010- Masonry in small buildings; Part 2- Construction,* Standards Australia Limited, Sydney, Australia.

Notes: All quotes from Australian Standards are reproduced with permission from SAI Global Ltd under Licence 1602-c026

Referenced Acts and Regulations:

Government of Western Australia, *Building Act 2011*. See www.slp.wa.gov.au

Government of Western Australia, *Building Act 2011- Building Regulations 2012*.
See www.slp.wa.gov.au

Government of Western Australia, *Builders' Registration Act 1939*. See www.slp.wa.gov.au

Government of Western Australia, *Building Services (Complaint Resolution and Administration) Act 2011* (CRA). See www.slp.wa.gov.au

Government of Western Australia, *Building Services (Registration) Act 2011*. See www.slp.wa.gov.au

Appendices

Appendix A: General inspection environment

A total of 123 general inspections were conducted from January to October 2014 covering 26 Perth suburbs and the WA's South West costal region (see Table A1).

Suburb	General Inspections	Suburb	General Inspections
Perth region			
Alkimos	15	Lakelands	4
Aubin Grove	3	Madora Bay	1
Baldivis	9	Mindarie Keys	1
Burns Beach	16	North Coogee	7
Churchlands	1	Perry Lakes	2
Doubleview	2	Piara Waters	4
Eglinton	4	Scarborough	1
Forrestdale	1	Secret Harbour	4
Golden Bay	7	South Yunderup	1
Harrisdale	3	Swanbourne	1
Iluka	2	Wandi	5
Innaloo	6	Wellard	2
Karrinyup	1	Yanchep	5
		Total:	108
South West region:			
Australind	3	Treendale	4
Busselton	1	Vasse	1
Dalyellup	3	Yalyalup	1
Eaton	2	Total:	15
Total WA building construction sites inspected and assessed:			123

Table A1. Number of general inspection sites per Perth suburb and South West costal region during 2014

Table A2 indicates the compliance scores per approximate BC inspection zone code.

Inspection area	Building Commission Zone Code	Inspection Points	Satisfactory compliance	Non-satisfactory compliance
North coastal	A	265	32%	68%
South coastal	B	330	35%	65%
City	C	87	41%	59%
South inland (east)	F	121	27%	73%
South West Region	S	133	31%	69%
Total:		936	33%	67%

Table A2. Satisfactory compliance and non-satisfactory compliance statistics across BC inspection areas

WA BC inspection zone codes are indicated approximately at Figure A1 (below).

Table A3 summarises the compliance and non-compliance statistics across WA Local Government areas.

Local government	Inspection points	Satisfactory compliance	Non-satisfactory compliance
City of Armadale	67	30%	70%
City of Busselton	26	31%	69%
City of Cockburn	85	47%	53%
City of Joondalup	92	34%	66%
City of Kwinana	63	22%	78%
City of Mandurah	46	52%	48%
City of Rockingham	182	26%	74%
City of Stirling	81	40%	60%
City of Wanneroo	173	31%	69%
Shire of Capel	25	44%	56%
Shire of Dardanup	18	39%	61%
Shire of Harvey	64	23%	77%
Shire of Murray	8	25%	75%
Town of Cambridge	6	67%	33%
Total:	936	33%	67%

Table A3. Satisfactory compliance and non-satisfactory compliance across WA local government areas

Figure A1 outlines the approximate map of the Building Commission's WA inspection zones.

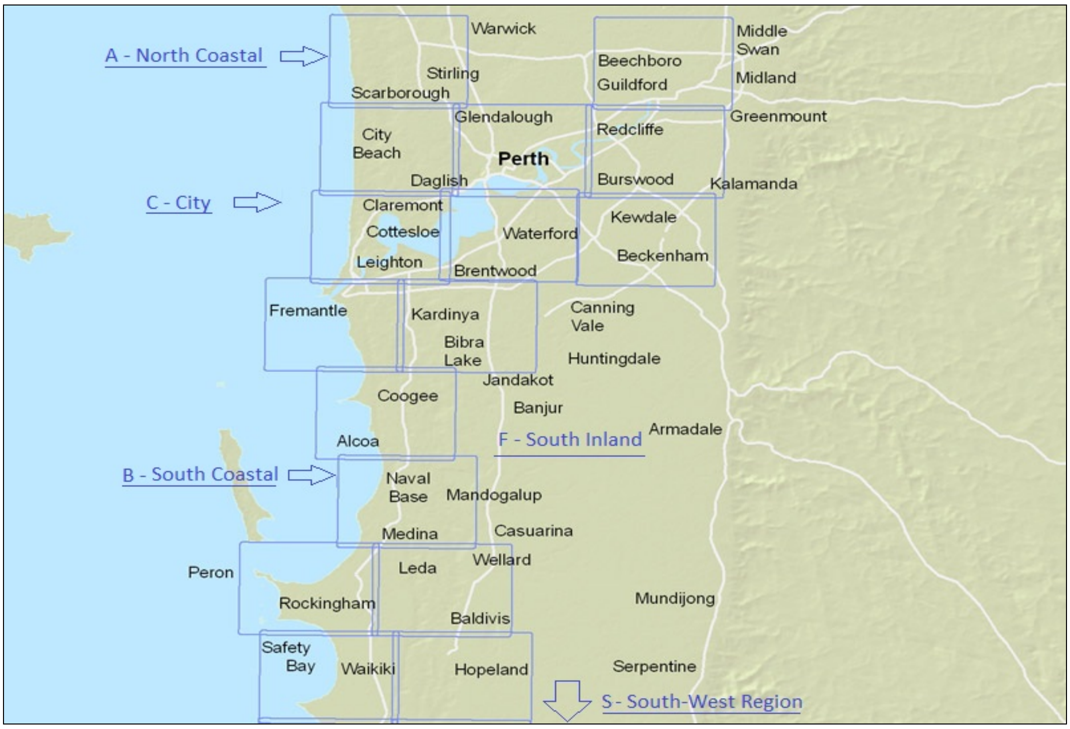


Figure A1. Map of WA BC general inspection zones

Source: www.ozcoasts.gov.au/climate/Map_images/Perth/Perth_North.jpg

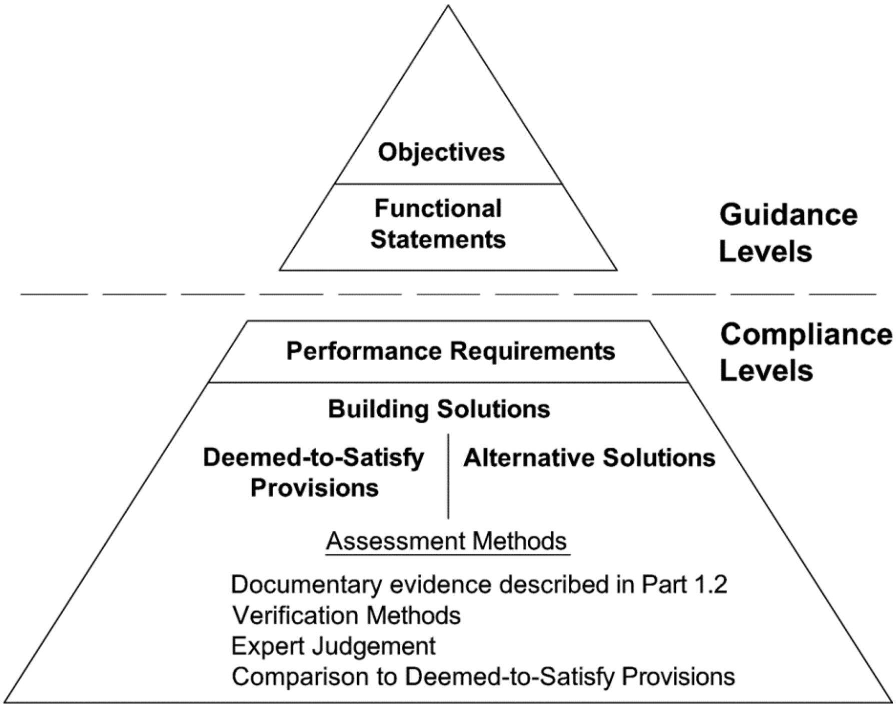


Figure A2. The BCA Hierarchy

Source: "Figure 1.0.3" Building Code of Australia (2014, p. 16)[31]

[31] Information sourced from the Australian Building Codes Board (ABCB) www.abcb.gov.au

Appendix B: Summary of stakeholder feedback, statistical opinion and engineering test results

Stakeholders

The following stakeholders were invited to provide comment and feedback in relation to the preliminary findings of the general inspection into WA roof construction 2014:

- Australian Institute of Architects
- Australian Institute of Building Surveyors (WA)
- Building Services Board
- Consumer Advisory Committee
- Engineers Australia
- Housing Industry Association
- Master Buildings Association
- James Cook University, Cyclone Testing Station
- Royal Institute of Chartered Surveyors
- WA Local Government Association

Outline of key criticisms and concerns

While supporting the general inspection in principle two stakeholders were critical of the report's tone, style. One stakeholder was also critical of a number of recommendations which may add "counter-productive red tape". This stakeholder requested further revision of the draft report to "better reflect the findings of the audits and should not be used as a basis of wider reforms until more consultation is undertaken".

The points raised by this stakeholder to support this critical view were based primarily on:

- the limited number of dwellings investigated (n=123) as a valid representative sample;
- the industry being in transition with respect to consumer preferences, building supplies and corrosion protection requirements;
- the review only considering deemed-to-satisfy provisions; and
- the review not providing a complete picture of roofing systems compliance.

Analysis of critical stakeholder responses

The Building Commission considers all detailed stakeholder concerns should be addressed in the next IRG phase – ie the GIR1's findings and recommendations being the basis for discussion and implementation where accepted by that group.

Apart from a number of critical comments about the draft report's general tone and style by two stakeholder groups, the only outstanding issue raised related to the suggestion by one stakeholder that the report not be published at this time and in its current format.

Building Commission’s response to stakeholder concerns

The Building Commission notes these specific stakeholder concerns and has incorporated suggested changes where appropriate in the final report – specifically:

1. Given the report has undergone extensive review, and no other stakeholder group expressed similar suggestions about its publication, it is considered in the public interest to release of the final report via the Building Commission’s web site.

2. The general inspection and final report conformed with the Building Commission’s compliance and enforcement policy “Objectives & Guiding principles” (Department of Commerce 2015).

3. The general inspection’s references to two WA Coroners’ reports into deaths resulting from tie down related work and the original draft front cover photograph (see Figure 7) indicate the results and worst-case outcomes on the wider WA community of roofing system failure – whether the determined causes of failure relate to poor supervision, materials or high wind events.

4. Including reference to two recent Coroners’ reports (Mulligan 2013; Fogliani 2015) indicate public risk outcomes resulting from poor supervision and oversight systems which are covered in the recommendations of this report.

5. The photograph of a skillion roof failure on a neighbour’s house (Figure 7) on the original draft front cover has been replaced with a more general view of the home construction working environment covered by this report.

Table B1 summarises the key stakeholder issues raised and the Building Commission’s response.

Table B2 summarises stakeholder comments by general inspection recommendation.

Box B1 provides a commissioned independent expert option on the statistical interpretations that can be reasonably derived from the general inspection and its field data.

Issues raised	Stakeholder comments	Building Commission response
1. **Points of editorial accuracy and need for clarification.**	A number of comments were received pointing to possible need for correction of fact, reference or improved accuracy.	All comments on the draft report were reviewed and amendments made where appropriate in this final report publication.
2. **Comments relating to writing style and front cover picture (a copy of Figure 7).**	Two stakeholder responses were critical of the draft's written style and presentation – one stakeholder response suggesting that it not be published in its current form and that any such release of information be under the responsibility of a future phase of the project – eg the proposed IRG. Specifically, two stakeholder responses suggested not using the draft's front cover photograph (see Figure 7) and one of these respondents suggested a large number of changes to approach and therefore not proceeding with publication at this time. All other responses were either positive or silent on these various issues.	The Building Commission considered the criticisms and reviewed any matters specifically referenced in these stakeholder responses. Changes have been incorporated into the final report where it was possible to accommodate views without undermining the primary integrity of the detailed report which is based on factual evidence of 123 site and files inspections. Sections of the report which analyse and evaluate the data have been improved to address any specific issue raised and provide better clarity and balance in the final report. In response to the two core criticisms the Building Commission has: (a) selected a new neutral front cover; and after final Ministerial endorsement (b) included a summary of relevant issues raised by stakeholders for later IRG review and action where appropriate. Fundamentally, the general inspection conformed to Building Commission policy and therefore was conducted in the public interest to facilitate industry improvement and guide future general inspections.
3. Mandatory inspections	Strong response from two stakeholder groups against any suggestion of introducing mandatory inspections in WA. The issues raised related mainly to additional cost and inefficiencies of additional red-tape. This perspective was countered by most other stakeholders who appeared to support further reviewing this topic area during the subsequent IRG phase.	Any introduction of mandatory inspections appeared in line with trends in other states. After careful consideration and high-level discussion during late 2015 the Building Commissioner has recommended prescribed minimum standards and mandatory inspections (and consistent compliance monitoring and enforcement by permit authorities) of completed roof framing and tie downs in WA.

4. **Introduction of the new legislative framework in 2011**	One stakeholder found the draft report appeared critical of the new 2011 Legislation framework (without providing specific examples) by suggesting poor results stemmed from this change.	It is unclear to the Building Commission where this stakeholder opinion has been generated from within the draft report. Many of the requirements implemented under the 2011 legislation simply carried across the requirements of the previous legislation. <u>Action</u>: Ensure the final report is clear in this regard the next IRG phase clarifies any outstanding stakeholder concerns in this regard. .
5. **The general inspection report does not provide a complete picture of roofing compliance**	The general inspection takes a small sample size (n=123) of a narrow building area (metal roofs) and this should not form the basis of a broader industry reform agenda.	The general inspection takes a highly quantitative focus on a specific area of roofing system and generally finds low satisfactory compliance scores. Analysis of specific issues and broader building context indicate these findings point (in part) to a number of industry related factors which need to be improved. To extend the general inspection's scope would require greater time and resources and not necessarily provide any additional useful information in respect to materials and workmanship and supervision. There is scope for future general inspections to cover broader topics. In response to concerns regarding how 123 building sites can be seen to fairly represent the whole WA sheet metal clad timber framed roofing population the Building Commission engaged expert statistical opinion to verify the methodology and findings and advise on the statistical confidence interval. See Box B1 below.
6. **WA home building industry is in transition**	Standards may be out of date and lagging WA consumer preferences, new products and supplier options.	The changing home construction environment is acknowledged (see Table 3) and the economic surge underway in 2014 and work with industry to deliver buildings which comply with Australian Standards.
7. **New compliant products**	As a result of the 2015 Building Minister's forum a Senior Officer group (SSG) has been established and therefore reference products with inadequate corrosion protection should be removed from the final report.	The use of compliant tie down strapping material improved throughout the general inspection and certain suppliers report increased demand for a compliant product. The SSG will provide advice and recommendations to Building Ministers on non-conforming building products. The Building Commission has been working with industry and universities on static testing of batten connections. See additional notes in detailed report (#5).

Table B1. Stakeholder issues raised and Building Commission response

Box B1: Expert statistical opinion

DATA STATISTICS ANALYSIS MATHEMATICS AUSTRALIA INFORMATION

97 Broadway NEDLANDS 6009
Western Australia
PO Box 3258
Broadway Nedlands WA 6009
Phone: (08) 9468 2533 or (08) 9386 3304
Facsimile: (08) 9386 3202
Internet: http://www.daa.com.au
ABN 68 009 304 956

12th October 2015

To Building Commissioner,

BCWA/1 – Inspection Point Compliance Rates Summary

The Building Commission has utilised a sampling approach to compare inspection points of metal-clad timer-framed roofs against the applicable building standards referenced by the BCA. The sample can be described as a cluster sample, whereby a number of cluster units (i.e. roofs) are first sampled and then all sampling units (i.e. inspection points) at the clusters are sampled.

In total 123 roofs were sampled in several tranches between January and October 2014. As the sampling was undertaken without a sampling protocol, some caution must be applied when interpreting the results. 1,079 inspection points were sampled, of which compliance could not be identified for 143 (13.3%). Of the 936 assessable inspection points, 308 were found to be compliant (or 32.9%).

The following assumptions have been made in order to calculate estimates for the broader population:

- The sampled roofs were selected using simple random sampling;
- The sampled roofs are representative of the population (i.e. metal-clad timber-framed roofs constructed in Western Australia during 2014);
- Inspection points for which compliance could not be identified are not more or less likely to comply (i.e. are not biased);
- There is no significant temporal trend in compliance rates (within 2014);
- 14,161 metal-clad timber-framed roofs were constructed in Western Australia in 2014 (the population provided by the Building Commission); and
- The population was comprised of 124,192 inspection points – assuming the average number of 8.77 inspection points per roof (as observed in the sample);

The overall compliance rate $\hat{p}$ for a cluster sample can be estimated as:

$$\hat{p} = \frac{N}{nM}\sum M_i p_i$$

Where N is the number of metal-clad timber-framed roofs in the population, n is the number of roofs in the sample and M is the number of inspection points in the population. For sampled roof i, M_i and p_i are the total number of applicable inspection points and the observed compliance rate respectively. This leads to an estimated overall compliance rate of **32.8%**.

Due to the clustered nature of the sample, the preferred method of understanding the uncertainty associated with the estimate is the bootstrap. The distribution of the bootstrap estimates has a standard deviation of 2.0 and this leads to a **95% confidence interval of 32.8% ± 3.9%** (Lower Confidence Limit = 28.9%, Upper Confidence Limit = 36.7%). This indicates that if the sampling activity were repeated many times (with the same population), the subsequent overall compliance rate estimates would fall between 28.9% and 36.7% for 95 out of 100 samples.

Yours sincerely

John Dickson, **Senior Consultant Statistician**

STRATEGIC INFORMATION CONSULTANTS

Summary overview of stakeholder comments by original draft recommendation

The final general inspection report reframes the original nine discussion draft recommendations (May 2015) under five strategic recommendations. The following table reflects stakeholders' comments about the draft recommendations which listed various actions to improve the contribution of various industry sectors (listed below) as well as the establishment of an Industry Response Group (IRG). The stakeholders' feedback is presented to reflect whether they provided general comments or whether the comments were directly linked to a recommendation.

The key difference between the final five recommendations and the original nine draft recommendations reflects work completed by the Building Commissioner during the final three months of 2015 in strategic discussions with industry and government. The draft report largely viewed this work being completed under the next IRG phase. In the final report the IRG phase (the final Recommendation 5) now focuses on the implementation of the general inspection's findings and recommendations.

<table>
<tr><th rowspan="2">Stakeholder</th><th colspan="9">Recommendations 1 – 9 of the Draft General Inspection Report</th></tr>
<tr><th><u>1</u>
IRG</th><th><u>2</u>
Builders</th><th><u>3</u>
Roof carpenters</th><th><u>4</u>
Engineers</th><th><u>5</u>
Building surveyors</th><th><u>6</u>
Suppliers</th><th><u>7</u>
Training providers</th><th><u>8</u>
Permit authorities</th><th><u>9</u>
Building Commission</th></tr>
<tr><td>1</td><td colspan="9">• Supported the general inspection initiative but not all recommendations – especially any suggesting mandatory inspections.
• Considered draft recommendations related to permit authorities were too vague and appear to overlook their key role in issues related to building permits and occupying permits.
• Contended the same legal requirements exist for design, construction and inspection prior to, and following, legislative changes in 2011.
• Queried the front cover (skillion roof) but appeared to have misread the meaning of including the photograph was intended to draw attention to the impacts of metal roof failure in high wind conditions (ie in a neighbour's house not shown) on the broader environment and community.</td></tr>
<tr><td>2</td><td colspan="9">• Supported the general inspection initiative but lists a number of objections to its publication before further review by the IRG (ie next phase).
• Tone of feedback appeared somewhat defensive (for suppliers) and somewhat focused on questioning the report's tone, approach and the small sample size (n=123) having any significant relevance to supporting any broad industry reviews.
• Believed key findings are "controversial and prompted a lot of discussion" and a "lot more work is required to address the report" – it is assumed this reference to "work" is required by industry to address the defects rather than the draft report itself.
• Recommended a rewrite to "better reflect the findings of the audits…" and noted it should not form the basis of wider reforms without further consultation.
• In respect to corrosion, the findings reflect an industry in transition adopting new practices and changing consumer preferences.
• Noted that any measuring against the DTS does not necessarily imply non-satisfactory compliance with performance standards.
• Noted the draft report does not provide a complete picture of roofing systems' compliance and does not provide evidence of roofing failure so, therefore, it should not be the "vehicle for any major changes to building approval processes until more work is done".
• <u>Bottom line</u>:
(a) Requested the draft report not be released in its current form and would benefit from more industry "input" before public release.
(b) Suggested a number of possible proactive industry initiates related to improved education and training; reducing possible "red-tape"; dealing with non-compliant products separately outside the general inspection; and looking at other states for "voluntary" checklist approaches (eg South Australia).

Note: this is the only stakeholder response which directly suggests the final report should not be published at this time (and in this format).</td></tr>
</table>

	Believed the evidence presented (n=123) does not justify implementing mandatory critical-stage inspections. Contended inspections are being done and a counter view by the report is not supported by the evidence. Contended no evidence is provided "… of the capacity of our roofs to withstand extreme wind events" – poorly worded statement which actually (if read carefully) is one of the key issues of the draft report – ie evidence could not be found in the sample for 70%! Believed the report's "language and tenor needs to be amended" to better reflect the need for further investigations.	Supported the introduction of voluntary checklists to assist etc. Stakeholder is "happy" to work with the BC to promote information and education programmes. Considered the recommendation related to suppliers and materials is not clear and "most quality providers" indeed do provide specifications. Supported the promotion of professional development training for supervisors and trades involved. Appears to flag the possible need for registration or licencing of roofing contractors in WA.	Noted the need for – but raises the issues of "time cost" of training is "a major deterrent for many industry participants". Feedback focused on the need for education/training and possible "overall trade licencing" in WA. Also noted the possible benefits of "voluntary checklists" in WA.	Believed the language for this recommendation was loaded and appears to assume they are not being done (ie without providing evidence).	Believed the rationale for ensuring all high-risk areas are clearly detailed is not clear and needs further definition. Noted in respect to the detailed recommendations related to ensuring alternative solutions were consistent with the BCA and evidence being available during inspections that – "this is a current requirement under the Building Codes" without further comment.	Believed any general inspection recommendations related to suppliers should be "excised and dealt with separately as there are currently national consultations and a federal parliamentary enquiry underway".	Noted the issue is a national concern currently being addressed by state and federal regulators. Also noted that "extensive audits" are undertaken of RTO's. Considered this topic is "beyond the scope of the report to address these issues". Noted the industry has the capacity to deliver relevant quality training courses but the challenge is to "get industry workers to participate".	Agreed with the recommendation without further comment.	Agreed in principle but "only after report is revised to ensure findings are based upon suitable evidence". Supported in principle developing electronic systems to increase BC capacity but is uncertain how this will assist monitoring. Believed working with ABCB and Standards Australia is important. Considered recommendation to ensure experience, qualifications, and monitoring of registered building service providers meet consumer expectations regarding confidence in the quality of construction to be ambiguous and needing better clarity (language is "loaded with presumptions" and should be revised). Figure 7 is not representative & should be removed.
3	• Supported the general inspection initiative. • Noted market forces and cost pressures as a key factor leading to reduced involvement by professional services within the WA residential housing industry. • Considered improvement in education and training (eg of bricklayers) related to better appreciation of ramifications of variations of details is needed. • Believed costs (eg of inspections) and risks (of future roofing system failure) need to carefully balanced.								

	• Supported recommendations updating Australian Standards to better reflect WA construction conditions and noted more focus is needed on apparent disconnects between designers and the trades. • Included additional supportive feedback from the national Structural College Board – specifically in relation to AS 1684.								
4	• Supported the general inspection initiative. • Believed the general inspection supports numerous past requests to 'roll out the entire Building Act'' in respect to regulating, mandatory inspections, and enforcement & compliance guidance. • Considered to evidence supports a clear message to industry regarding is "severely lacking" in quality assurance. • Noted poor compliance in one area covered by the general inspection reduces confidence in satisfactory compliance in other areas.								
	Supported detailed recommendations as long as there is a clear scope of work involved. Very supportive of mandatory inspections. Supported WA Coroners' recommendations on tie downs but noted it may require fee structure changes.	Generally supported but questioned why there is no detailed recommendation on sub-contractor & trades. Noted possible positive effect if approved plans contained accurate and complete details of critical aspects and "acceptable documentation" was regulated. Questioned knowledge & training of suppliers' staff to give advice. Professional development training should evolve into CPD linked registration.	Generally support & sees other additional links reinforcing draft recommendations in respect to Builders. Included a list of additional detailed questions better raised in IRG phase. Made a comment (also noted by stakeholder #3) related to whether plan details are adequate etc.	Generally supported the recommendation but raised questions related to whether: (a) engineers undertake site visits (ie generally considered not the case – also see stakeholder #3); and (b) information actually gets to the trades people on site.	Supported but considered a need to clarify what "high risk" means in context. Noted that documentation certification is normally poor. Recommended that mandatory CPD training be provided.	Supported all detailed recommendations.	Supported recommendation and noted that training is key to this issue. Considered the BCITF/BCTF should be involved (noting $funds are provided by the Board).	Supported the recommendation but noted possible impacts on fees and charges need to be reviewed within this context. Recommended the IRG consider the issue.	Supported the recommendation and all sub-recommendations. Noted that ensuring qualifications, experience and monitoring of registered building service providers meet WA's consumer expectations regarding confidence in the quality of construction may require registration of all trades related to building etc.
5	Supported Coroners on providing an independent compliance regime and option	Agreed with all aspects of the recommendation.	Agreed in principle although the stakeholder also noted the reading difficulty	Agreed fully with recommendation. Recommended that registration of a range of professional	Agreed and noted more training is required in many areas.	Agreed and suggested the country of origin for supplies be looked at.	Agreed.	Agreed (& as per comments on 1). Suggested a review of fee structures to	Agreed and noted the BCA may benefit from a stronger focus on the need for local WA variations etc. Several additional

<table>
<tr><td></td><td>should be pursued albeit with some cost concerns.

Agreed but added with “severe reservations” regarding any industry self-certification.</td><td></td><td>levels with various Standards and a possible need for inclusion of manufactures’ ‘standards’ within in manuals etc.</td><td>bodies be considered.</td><td></td><td></td><td></td><td>ensure “equity”.</td><td>detailed recommendations were also provided to improve the system. These will be provided to the IRG.</td></tr>
<tr><td>6</td><td colspan="9">Supported the general inspection initiative and all recommendations.
Noted the cost to the consumer of the issues raised.
Agreed more focus on need for WA variations in Australian Standards and building codes.
Agreed with all general inspection recommendations and contents the insurance industry/companies needs to be involved.
Appeared to appreciate the reports statistical analysis sections and implications etc.
Noted the general inspection focuses on systemic issues related to market pressures and lack of awareness of and attention to performance requirements.
Strong support for mandatory inspections of “critical stage” elements – similar to other Australian jurisdictions.
Recommended more quantitative analysis is required to support informed discussion on cost/benefit implications of system change.
Contends consumers need better access to relevant information on supplies (eg manufacturers, suppliers and importers) – especially with increasing trends towards using new lightweight materials etc.
Submitted several additional research orientated questions about what the data and analysis implies which could justify further research projects orientated towards local councils etc (ie permit authorities).
Supported a stronger focus on training and development etc.</td></tr>
<tr><td>7</td><td colspan="9">Strong support for the general inspection initiative and endorsed all recommendations.
Agreed the correct construction of roofs in the residential building sector is a very important component of a residential building project.
Submitted a strong understanding of the relevant Australian Standards, along with competent trade skills to construct a roof, is critical to provide consumer confidence in the building industry.
Considered there is a need for the roof structure to be inspected and signed off for compliance by a suitably qualified and experienced building professional.
Advocated further research into this issue and product conformity of the building process and a “thorough and cost-effective inspection and education regime”.
Provided a detailed list of particular concerns with non-conforming building structures related to consumer satisfaction, increased costs, overall poor quality, supervisor workload and the need for improved training and education of “suitably qualified and experienced trades and building professionals”.
Suggested Australia needs a national building compliance office.</td></tr>
<tr><td>8</td><td colspan="9">Supports GIR1 initiative and all recommendations – feedback mainly provided technical advice on corrections and accuracy etc.</td></tr>
<tr><td>9</td><td colspan="9">Stakeholder appreciated inclusion but declined to comment in this instance.</td></tr>
<tr><td>10</td><td colspan="9">Stakeholder declined to comment in this instance.</td></tr>
</table>

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List of abbreviations

ABCB	Australian Building Control Board
ABS	Australian Bureau of Statistics
AS	Australian Standards
AS/NZS	Australian Standards / New Zealand Standards
AZ	Aluminium Zinc
BC	Building Commission
BCA	Building Code Australia
BCIFT	Building Construction Industry Training Fund or Building Construction Training Fund (BCTF)

BMT	Base Metal Thickness
CDC	Certificate of Design Compliance
CPD	Continual Professional Development
CRA (Act)	Complaint Resolution and Administration (Act)
GIR1	General Inspection Report N^{o} 1
gm	gram
HIA	Housing Industry Australia
IB	Industry Bulletin
IRG	Industry Response Group
ISO	International Organization for Standardization
IT (Apps)	Information Technology (Applications)
JD5	Classification assigned to a timber species or species group for the purpose of calculating joint capacity. Stress grade MGP 10 joint group is designated as JD5
kg	kilogram
kN	Kilonewton – International System of Units derived unit of force (1.0 kN = 1020 kg)
MBA	Master Builders Association
MGP	Machine grade Pine
mm	Millimetre
N1	Wind class with design gust wind speed of 34m/s
N2	Wind class with design gust wind speed of 40m/s
NASH	National Association of Steel Framed Housing
NOC	Notice of Completion
NSW	New South Wales
NZ	New Zealand
PGI	Pressed Galvanised Iron, Common term used for galvanised tie-down strap.
QA	Quality Assurance
RTO	Registered Training Organisation
SAT	State Administrative Tribunal
SSG	Senior Officers Group
WA	Western Australia
WALGA	Western Australian Local Government Association

List of definitions

Accreditation	*Accreditation* is the procedure by which an authorised independent body gives formal recognition that a conformity assessment entity is competent and proficient to carry out calibrations, tests, inspections and/or certifications.
Alternative solution	A *Building Solution* which complies with the *Performance Requirements* other than by reason of complying with the *Deemed-to-Satisfy Provisions*
Building Code Australia	The BCA is published in two volumes: *Volume One: pertains primarily to Class 2 to 9 buildings* and *Volume Two: pertains primarily to Class 1 and 10 buildings (houses, sheds, carports etc).*
Building solution	A solution which complies with the performance requirements and is: (a) An alternative solution; (b) A solution which complies with the Deemed-to-Satisfy provisions; or (c) A combination of (a) and (b).
Compliance	*Compliance* relates to the extent to which products are applied or installed by the building practitioner to fit the purpose as intended by the manufacturer. A non-compliant product is one that is misapplied or installed in a manner that is not fit for the purpose intended by the manufacturer.
Conformity/Conformance	*Conformance,* or conformity, focuses on the extent to which products meet or comply with applicable law, regulation and/or specified industry codes, national or international standards. A non-conforming product does not meet the minimum technical requirements or performance as specified by the relevant standard, regulation or law.
Conformity Assessment	*Conformity assessment* is a systematic examination to determine the extent to which a product, process or service fulfils specified requirements.
Consumer groups	Consumer representative bodies for the WA housing sector.
Deemed-to-Satisfy provisions	A provision contained in Section 3 (of the BCA) for alternative design solutions which are deemed to comply with the *Performance Requirements*.
Fixings	Component stocks used to fasten items including screws, nuts, nails, washers and bolts.
Industry associations	Representative bodies for the WA housing sector – eg Housing Industry Association (see www.hia.com.au).
Insurance industry	Representative bodies for the WA housing sector – eg Insurance Council of Australia (see www.insurancecouncil.com.au).
ISO 9000	A family of quality management systems standards designed to help organisations ensure they meet the needs of customers and other stakeholders while meeting statutory and regulatory product related requirements.
Local government	One of Australia's three spheres of government – ie Federal, State, and Local. Local Government most closely affects the daily lives of citizens and may also be referred to as elected Councils, Shires or Local Councils. The WA Local Government Association (WALGA) represents Local government in Western Australia (see www.walga.asn.au).
Owner builders	Anyone who wishes to carry out builder work for which a building permit is required, where the value of those works is over $20,000 and they own the land where the building work is to be carried out.
Performance requirements	A requirement which states the level of performance which a building solution must meet.

Permit authority	The permit authority for the building or incidental structures as defined in section 6 of the *Building Act 2011* – unless otherwise prescribed normally the local government in whose district the building or incidental structure is, or is proposed to be, located.
Registered builders	Includes, individual, partnership and company. Entitled to carry out builder work for another person for which a building permit is required and where the value of work is over $20,000.
Registered building service providers	Means either a building practitioner or a building contractor.
Standards associations	Representative bodies covering standards in the WA housing sector – eg Standards Australia (see www.standards.org.au).
Stick roofing	Constructed on site as distinct from using standard pre-assembled trusses.
Suppliers	Commercial suppliers of products, tools and services to the WA construction sector.

Acknowledgements

The general inspection report design was broadly modelled on the Western Australian Auditor General's Report *Our Heritage and Our Future: Health of the Swan Canning River System* (Report 16: August 2014).

Assoc. Prof. G. Boughton and Ms D. Falck provided technical advice to the Building Commission on structural issues relating to WA's roofing systems following the high-wind events in 2008.

Data Analysis Australia Pty Ltd (Nedlands, Western Australia) assisted with reviewing the construction site field data and providing expert statistical opinion on confidence intervals.

Mr G. Flowers (Building Inspector) conducted the construction site inspections, follow up investigations and detailed analysis findings for this inaugural general inspection report.

Other members of the Building Commission general inspection report team who contributed to the report's production include: Ms S Randall, Mr A Shiell and Mr R Clemens.