



# **Resilient buildings: Informing maintenance for long-term sustainability**

## ***Project 1.53***

***Presenter: Prof. Rodney Stewart  
Griffith University***

***Maintenance prevention strategies at the design, construction and asset  
handover stage is the missing link to improving building resilience***



# 1.53 Project chair

Graeme Newton, CEO, Cross River Rail

# 1.53 Project team



- Maintenance for **flash floods**
- Maintenance for **bush fire**



- Maintenance for **high winds**



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# Industry partners

- Queensland Dept. of Housing and Public Works
  - Dean Luton, Rosemary Axon, Amanda Alan, Stacey McInnes
- Western Australia Government (Departments of Communities and Finance)
  - Sarah Mewett, Veronica Pannell, Dean Wood, Samantha Johnston
- BGC Residential
  - Carl Barrett and Dan Gardiner
- NSW Land and Housing Corporation
  - Jessica Dominguez

# Project summary

- **Aim:** maintenance prevention and preventative maintenance strategies for making buildings more resilient to extreme weather events.
- **Weather events:** cyclone/storm (GU), bushfire and flood (SUT)
- **Buildings:** public state assets particularly of QLD, WA & NSW
- **Project 1.53 has three sub-projects:**
  - **Griffith University** to look at **storm/cyclone events**
  - Swinburne University to look at bushfire and flood events
- **Approach:** looking for gaps in current policy and practice and strategies to improve them

# Extreme event costs

- As percentage of total national reported losses (yearly average - \$3.7B).
- From Handmer, Ladds and Magee 'UPDATING ON DISASTER LOSSES FROM NATURAL HAZARDS IN AUSTRALIA, 1967-2013' (46 years)
- Figures in ( ) are from BTE 1967- 1999 (32 years)

State	Bushfire	Flood	Cyclone	Storm	Total
VIC	8.9 (3.0)	3.6 (3.5)	0	9.0 (2.1)	21.5 (8.6)
NSW	1.8 (1.8)	7.2 (12.9)	0	16.8 (18.2)	25.8 (32.9)
SA	1.2 (1.1)	1.6 (1.6)	0	0.4 (1.47)	3.2 (4.2)
WA	0.4 (0.4)	0.1 (0.2)	2.7 (3.8)	1.2 (1.0)	4.5 (5.5)
<b>QLD</b>	<b>0.6 (8.4)</b>	<b>14.4 (10.3)</b>	<b>13.1 (0.04)</b>	<b>3.8 (3.5)</b>	<b>31.9 (22.3)</b>
TAS	1.9 (1.0)	0.4 (0.6)	0	0	2.3 (1.6)
NT	0	0.8 (0.8)	3.2 (12.3)	0	4.0 (13.1)
ACT	2.2 (0.03)	0.2 (0)	0	0.5 (0.07)	2.9 (0.1)
Total	17 (16)	28 (30)	19 (16)	32 (26)	96 (88)

# Drivers for project 1.53

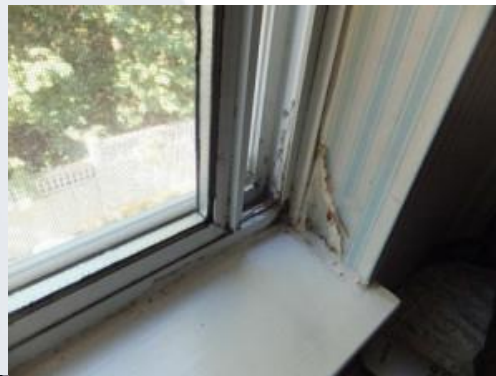
- Extreme events (e.g. cyclones, bushfire, flash floods) cause considerable damage to buildings and **incur repair costs**
- **Non-structural failure** of certain weak building elements (e.g. roof sheeting) leads to costly damage (e.g. water ingress)
- Building inspection & **maintenance largely unregulated**, and where undertaken has limited focus on resilience
- Poor record of getting **'as-built' info** for maintenance purpose
- Maintenance should be better considered in the **design process**
- There is generally **no handover maintenance manual**
- **Inadequate inspection of non-structural** elements of buildings
- Opportunity to **improve current regulatory and non-regulatory** regime for building maintenance prevention



# Gap identified by partners (1.53 Sub-project)

*Development of a maintenance prevention strategy to mitigate wind-driven rainwater ingress through windows and external glazed doors in social housing*

**New social housing in wind Regions C and D now resilient to structural failure during storms and cyclones. However, there are still some life cycle maintenance issues related to water ingress through windows and glazed door openings during storms and cyclones.**



**1.53 Sub-project  
Maintenance for  
high winds**



Repeated minor to moderate maintenance ordered



# Digging deeper to unpack the issues

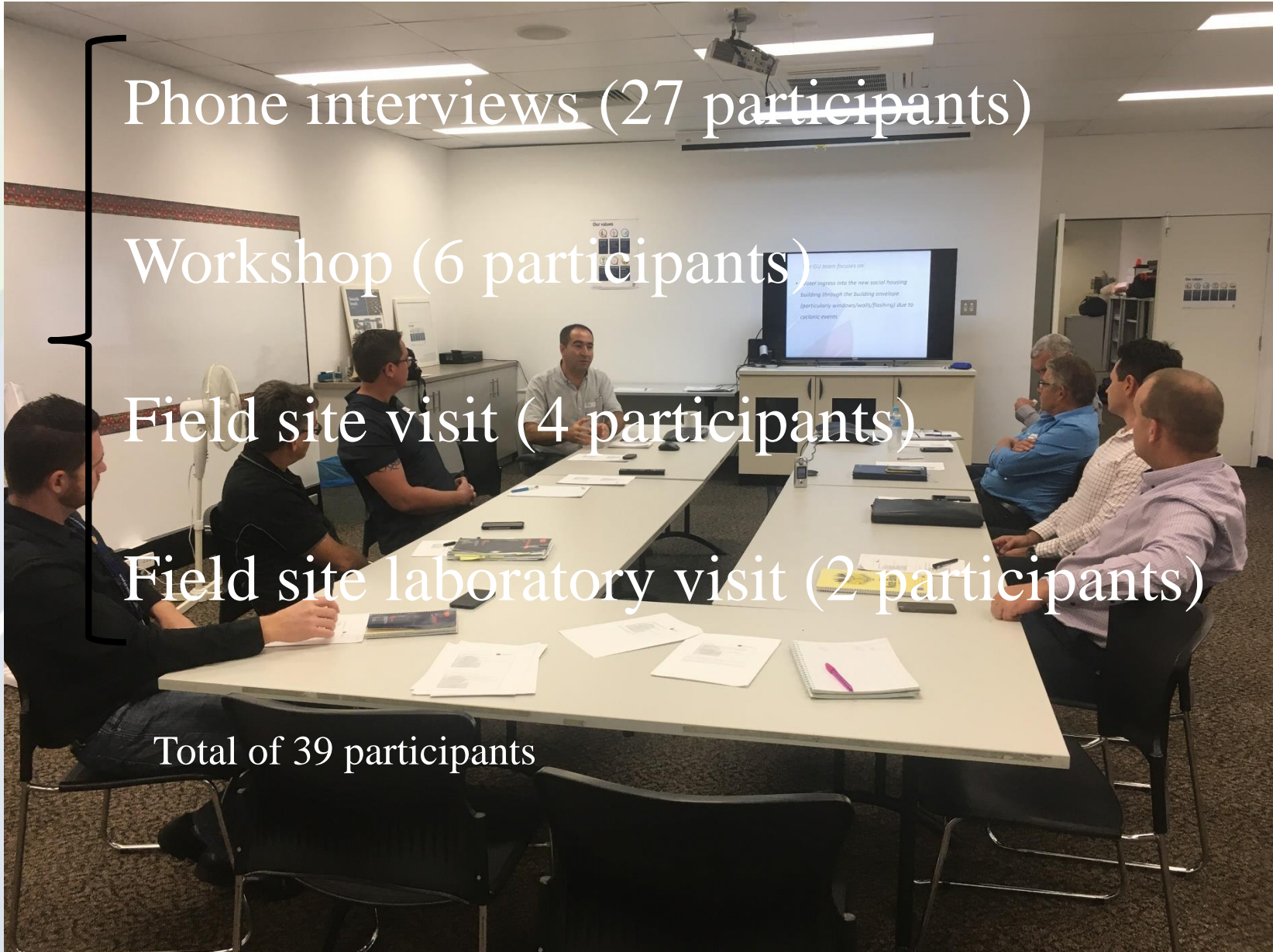
Phone interviews (27 participants)

Workshop (6 participants)

Field site visit (4 participants)

Field site laboratory visit (2 participants)

Total of 39 participants





# Thematic analysis - Transcripts

Questions	Inspector/Certifier Details:
Inspector/Certifier Details:	
Question	Answer
1 <i>Is the level of specification provided by builders sufficient for HPW inspectors to inspect works? We have been told that builders are only required to provide light specs for HPW projects. Is it contractually difficult for HPW inspectors to state that builders have not confirmed to requirements for windows/doors/building envelope waterproofing? What level of documentation would they like to have?</i>	<i>Has done work for HPW before. HPW don't require form 15/16. Windows and doors comply to NCC &amp; Aus Standards. Additional required specifications should be provided to the builder throughout the tendering process.</i>
2 <i>Do construction maintenance coordinators notice a spike in water ingress related minor/moderate maintenance orders in the weeks (i.e. carpet) and months (mold, termite) after severe storm events? We are not referring to the non-preventable damage related to projectiles, etc. but more the preventable related to water ingress.</i>	<i>After a extreme weather event there is a spike in water ingress related maintenance. Usually minor repairs (carpet, gyprock).</i>
3 <i>Perceptions of installer labour and skills in region? Do installers of windows and waterproofing of building envelope receive sufficient training on recommended practices (e.g. AWA and manufacturer guidelines)? Do the inspectors believe they follow practices or cut corners when it comes to these details?</i>	<i>Skills are satisfactory. AWA provide installation information online. Doors must have 50mm step down to prevent wind blown water. Windows typically rebated in block work.</i>
4 <i>Do the inspectors notice whether builders of public/domestic housing are using lower quality windows (i.e. potentially inferior windows)? Probably not the case but maybe.</i>	<i>Have seen incorrect windows (glass thickness ect) installed in C1 cyclonic region. Manufacture rectifies issues.</i>
5 <i>What are the most critical causes of water ingress in windows/doors/building envelope? How can they be mitigated? (Asking for their thoughts on strategies - especially ones for HPW)</i>	<i>Incorrect windows and doors being used in tropical region.</i>
6 <i>For Building Certifiers, how do they conduct the windows inspection. What stage and how they see they could improve? Form 15/16 enough responsibility?</i>	<i>Inspection checklist: Anchoring @ 300mm centres, Sealing (mastic), Glass specification, Form 15/16.</i>
7 <i>Documentation related to the waterproofing of the building envelope/windows/doors/flashing/etc. Apart from builders providing certificates on window quality, is there any quality documentation provided about window installs and building envelope waterproofing such as flashing, etc. ? Would inspectors like builders to provide them with some sort of quality documentation about the window/door/building envelope installation process in addition to the product quality information?</i>	<i>Flashings cannot be inspected after install, Typical install follows NCC (National Construction Code) and Australian Standards (2188 Glazing). Form 15 from manufacture (glass thickness) derived from glazing standards, where windows are designed for wind driven water. Timber frame construction must have top metal flashing 150mm out.</i>

# Thematic analysis - Clustering

<b>Category</b>	<b><i>I. Inspection</i></b>
<b>Suc-categories</b>	<i>I1. Trade skills</i>
	<i>I2. Form 16</i>
	<i>I3. Limited liability resource</i>
<b>Category</b>	<b><i>D: Documentation</i></b>
<b>Suc-categories</b>	<i>D1. Form 16</i>
	<i>D2. Poor specification of designing/tendering</i>
	<i>D3. Limited liability resource</i>
<b>Category</b>	<b><i>S: Standards</i></b>
<b>Suc-categories</b>	<i>S1. Testing - Static wind load</i>
	<i>S2. Requirements/</i>
	<i>S3. Frequency of water ingress through openings</i>

## ***Barriers***

### ***CATEGORY D: Documentation***

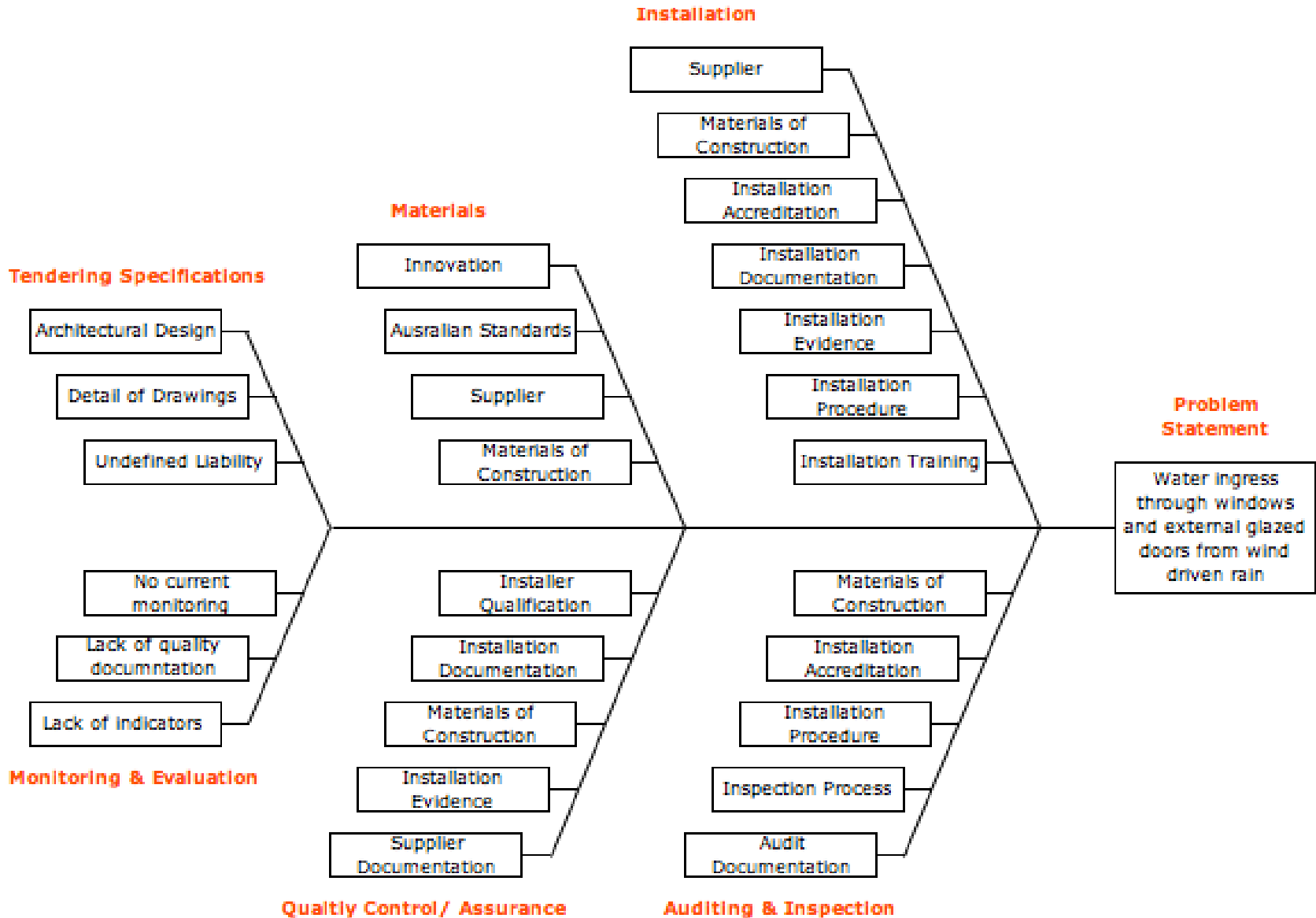
#### **Sub-category D1. Form 16**

BC1	Form 15/16 is only documentation. Information can be found on the glazing manufactures website
BC2	Buildings certifier only check structural elements, not windows. For windows, the form 15 must be filled for the engineer/designer for the window specification and the manufacturer for the installation. The form 16 must filled by the engineer inspector or building inspector for the foundation and footing slabs
BC3	Inspection checklist: Anchoring @ 300mm centres, Sealing (mastic), Glass specification, Form 15/16
	Flashings cannot be inspected after install, Typical install follows NCC (National Construction Code) and Australian Standards (2188 Glazing). Form 15 from manufacture (glass thickness) derived from glazing standards, where windows are designed for wind driven water.
BC4	Final inspection (only check glass classification and form 15/16) No improvement required

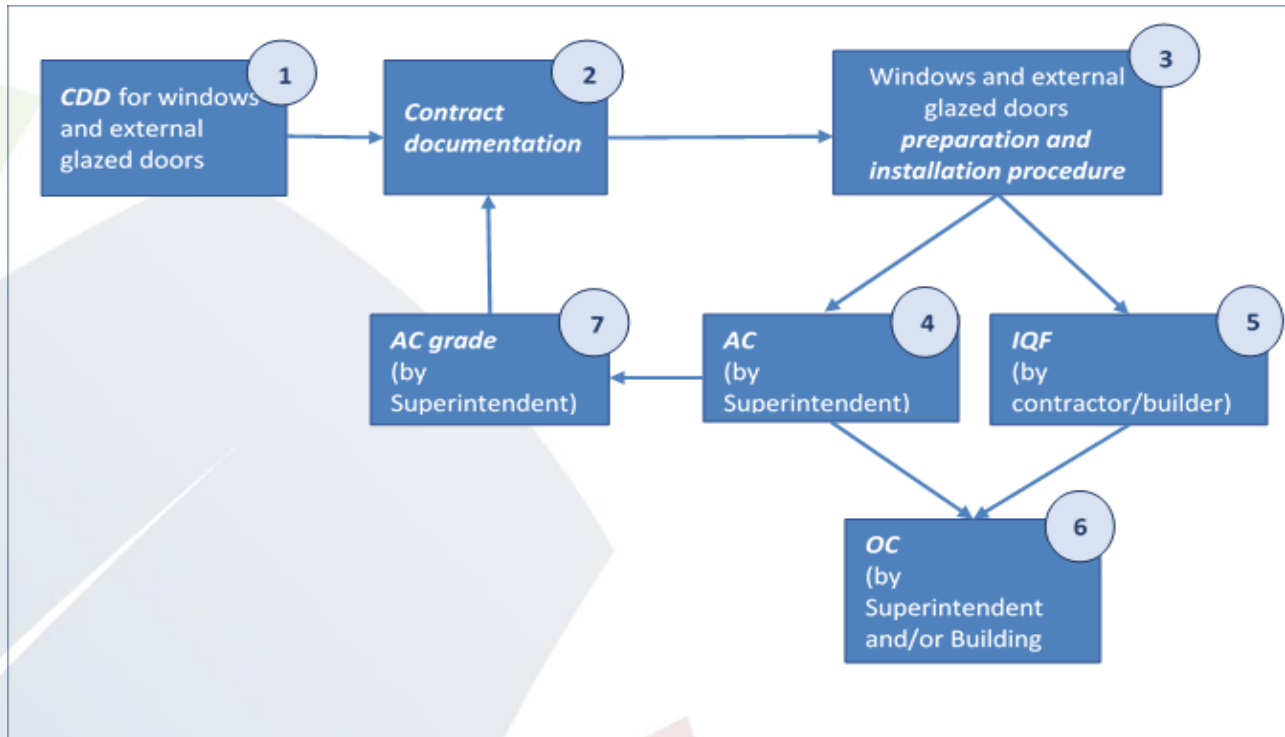
# Thematic analysis - Classification

Barriers		Evidences
1	Limited inspection	M1;BC2;BC8;M1;BC3;BC4;BC6;BC1;BC2;I/B/1;I/B3;I/B7;G
2	Form 16 (Qld form number) provides limited information of work completed	BC1;BC2;BC6;BC11;BC12;I/B1;I/B12;M1;G;M1
3	AS for water penetration resistance “They are currently not sufficient”. "In fact, this test does not reflect a cyclonic pressure "	BC11;BC12;BC3;BC4;BC6;BC8;BC9;BC10;M1;A1;A2;I/B1;I/B3;I/B10;BC10;BC11;M1;M2;G
4	Lack of knowledge with Australian Standards for specification, installation and waterproofing of windows and external glazed doors	G;M1;M2;BC1;BC3;BC4;BC6;BC7;I/B1;I/B2;I/B3;I/B4;I/B5;I/B7;I/B8;I/B9;I/B10
5	Culture whereby installers and builders with lower concern for this building elements	BC1;BC2;BC4;BC6;BC8
6	DHPW have less work oversight than previously when traditional Construction Documentation used to be very detailed.	G;I/B4;CC1;BC3

# Findings - Root cause analysis



# Recommendations



QA

- **Recommendation 1:** Construction Design Documentation (**CDD**)
- **Recommendation 2:** Contract documentation
- **Recommendation 3:** Preparation and installation procedure
- **Recommendation 4:** Auditing check list (**AC**)
- **Recommendation 5:** Installation quality form (**IQF**)
- **Recommendation 6:** Openings certificate (**OC**)
- **Recommendation 7:** Auditing check grade (**AC grade**)



# Recommendation 1

## Recommendation 1: Construction Design Documentation (CDD)

Require greater emphasis on CDD document at the design and 'as built' stage (even for design & construct constructs)

### Aspects to specify for windows and glazed door openings:

1. *Durability and compatible sealants;*
2. *Preparing the substrate;*
3. *Preparing the opening with appropriate membrane system;*
4. *Curing;*
5. *Head, side angle flashing, sub sill & dam ends;*
6. *Flashings, drip moulds, storm moulds and trims;*
7. *Fasteners; and*
8. *Consideration for storm shutters.*

# Recommendation 2

## Recommendation 2: Contract documentation

- ❖ Tendering process should specify the addition of the recommended quality assurance process that will be included in the contract documentation.
- ❖ Contract documentation should outline the quality assurance process for the preparation and installation of windows and external glazed doors in an effort to increase quality and direct liability in the construction phase.
- ❖ Contract documentation to cover the remaining recommendations:
  - **Recommendation 3:** Preparation and installation procedure
  - **Recommendation 4:** Windows and external glazed doors installation quality form (IQF)
  - **Recommendation 5:** Auditing check list (RAC)
  - **Recommendation 6:** Openings certificate (OC)
  - **Recommendation 7:** Auditing check grade (AC grade)

# Recommendation 3

## Recommendation 3: Preparation and installation procedure

- ❖ **Stage 1** – Describes the opening preparation.
- ❖ **Stage 2** – Describes the opening installation.
- ❖ On completion of stage 1 an inspection is required by the both the contractor and superintendent.
- ❖ It is recommended that these procedures are included in the contract documentation to ensure they are followed.

# Recommendation 4

## Recommendation 4: Auditing check list (AC)

### AC - Auditing Checklist

Use this checklist to help identify potential water Ingress risks that may be caused by an insufficient waterproofing membrane and flashing system. This inspection is to be carried out after the opening has been prepared for the installation of the window or door.

**To:** ..... **Attn:** ..... **Date:** .....

**Project:** ..... **Project No.:** ..... **Time:** .....

**Issued By:** ..... **Received By:** ..... **Comments:** .....

#### Superintendent

MEMBRANE & FLASHING SYSTEM		YES	NO
1.	Adhesion of waterproofing membrane	<input type="checkbox"/>	<input type="checkbox"/>
2.	Waterproofing membrane termination	<input type="checkbox"/>	<input type="checkbox"/>
3.	Sealants, over sealing & adhesion	<input type="checkbox"/>	<input type="checkbox"/>
4.	Minimum falls in substrate	<input type="checkbox"/>	<input type="checkbox"/>
5.	Continuous water stop	<input type="checkbox"/>	<input type="checkbox"/>
6.	Sub head & sub sill	<input type="checkbox"/>	<input type="checkbox"/>
7.	Dam ends	<input type="checkbox"/>	<input type="checkbox"/>
8.	Appropriate drip moulds & flashing	<input type="checkbox"/>	<input type="checkbox"/>
9.	Fasteners	<input type="checkbox"/>	<input type="checkbox"/>

#### Further information provided below:

1. Check waterproofing is free from protrusions & voids. Check adhesion with sealants & substrate.
2. Check waterproofing membrane cover (minimum 180mm).
3. Check adhesion with waterproofing membrane and substrate. Ensure the over sealing of fasteners.
4. Check fall are In accordance with AS 4654.2.2012 (minimum 1:100).
5. Check water stop provided (Rebated and/or fixed metal angle).
6. Check sub sill up & down turn flashing heights and sealant are sufficient.
7. Ensure dam ends have sufficient sealing and allow for drainage.
8. Ensure the flow of water down he building is directed away from openings below.
9. Check the amount & fasteners used are appropriate for the region.

**Further Comments:**

# Recommendation 5

## Recommendation 5: Installation quality form (IQF)

### **IQF – Installation quality form**

Use this checklist to help identify potential water Ingress risks that may be caused by an insufficient waterproofing system. This inspection is to be carried out after the opening has been prepared for the installation of the window or door.

**To:** ..... **Attn:** ..... **Date:** .....

**Project:** ..... **Project No.:** ..... **Time:** .....

**Issued By:** ..... **Received By:** ..... **Comments:** .....

#### **Building Contractor**

<b>MEMBRANE &amp; FLASHING SYSTEM</b>		<b>YES</b>	<b>NO</b>
1.	Compatible primer, membrane & sealants	<input type="checkbox"/>	<input type="checkbox"/>
2.	Minimum falls in substrate	<input type="checkbox"/>	<input type="checkbox"/>
3.	Continuous water stop	<input type="checkbox"/>	<input type="checkbox"/>
4.	Application of membrane system as per AS 4654.2	<input type="checkbox"/>	<input type="checkbox"/>
5.	Curing of primer, membrane & sealants	<input type="checkbox"/>	<input type="checkbox"/>
6.	Sub head, side/jamb flashing & sub sill	<input type="checkbox"/>	<input type="checkbox"/>
7.	Primed & sealed fasteners & dam ends	<input type="checkbox"/>	<input type="checkbox"/>
8.	Appropriate drip moulds	<input type="checkbox"/>	<input type="checkbox"/>
9.	Photo documentation of the membrane & flashing system. Inspection and acceptance testing as per AS 4654.2	<input type="checkbox"/>	<input type="checkbox"/>

#### **Further information provided below:**

1. Ensure the compatibility of all products used on the substrate (Consult the material technical data sheet).
2. Ensure falls are in accordance with AS 4654.2:2012 (minimum 1:100).
3. Ensure a continuous water stop around all sides of the opening.
4. Ensure appropriate primer and membrane system installed on a clean surface. Multiple layers of membrane being without protrusions or voids. Membrane minimum cover 180mm.
5. Ensure curing of membrane and sealants as per manufactures specifications.
6. Ensure sub sill flashing heights and sealant are sufficient. Ensure an unobstructed flow of water from head to sill.
7. Ensure dam ends are incorporated with head and side flashings to ensure the unobstructed flow of water. Ensure sufficient priming & sealing and allow for drainage.
8. Ensure drip moulds are installed to direct the flow of water away from openings.
9. Provide photo documentation of the membrane & flashing system

**Comments:**

# Recommendation 6

## Recommendation 6: Openings certificate (OC)



# Recommendation 7

## Recommendation 7: Auditing check grade (AC grade)

Building Certifier Companies logo	PROJECT:	AUDITING CHECK LIST (RAC)	Date:
	BUILDER:	ACTIVITY: Installation of windows and external glazed doors	Level:

Check list items	Window Unit												External glazed door Unit												Comments
	1		2		3		4		5		6		1		2		3		4		5		6		
	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	
1																									
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Sum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

*Closing the loop and keeping contractors on their toes*

Satisfactory
  Unsatisfactory

Initials and Signed as completed by:

# Other recommendations

## ➤ Australian standards

- Even certified and adequately installed windows experience water ingress in Regions C and D
- Water penetration resistance test follows the AS/NZS 4420.1:2016 and occurs under static wind pressures which does not reflect dynamic pressure conditions occurring during cyclones
- JCU may propose new requirements for AS 2047-2014 and AS/NZS 4420.1:2016

## ➤ Better knowledge transfer and education

- Better dissemination of best-practice
- Workers in regional areas have less access to installation and waterproofing training

# Acknowledgements

- We would like to acknowledge the **Sustainable Built Environment National Research Centre (SBEnc)** and its partners for funding Projects 1.53.
- We also acknowledge the valuable support provided by members of the project steering group.
- We acknowledge the support of industry partner personnel that aided certain stages of the project (e.g. workshop participants).

Thank you!

Any questions?