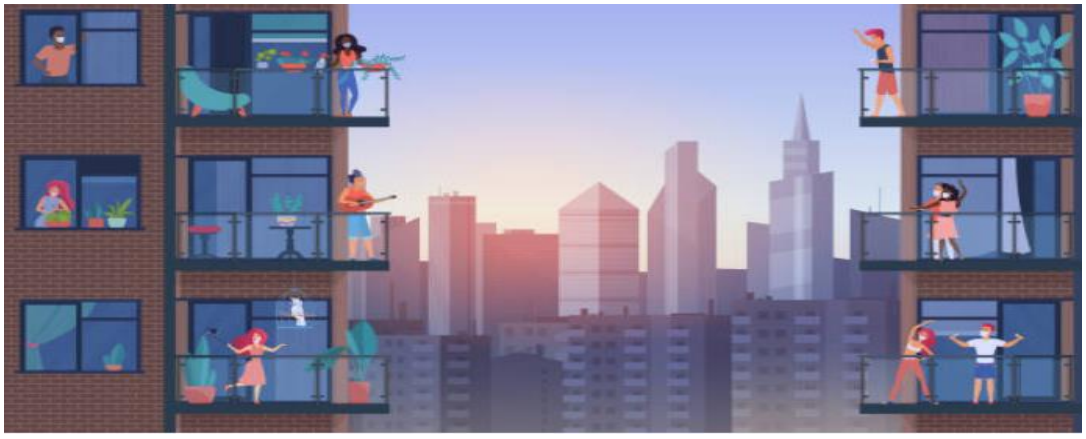
Investigation of Water Leakage in Apartment Building Concrete Balconies

Briefing Paper



July 2023 -Final- Issue 2 -10-07-23

Executive Summary

Swinburne University of Technology (SUT) is undertaking research (Chapter 1) to identify the causes of water leakage in concrete balconies in Class 2 buildings[1].

This project aims (Chapter 2) to reduce the frequency of water-related defects encountered in concrete balconies in apartment buildings by identifying opportunities for improvement in concrete balcony design and construction practices (Chapter 3), as well as regulatory standards.

The project will interrogate the identified issues (Chapter 5) and seek to identify recommendations and/or proposals to overcome the current issues. Recommendations may include changes to the National Construction Code (NCC)[2] and/or Australian Standards[3] (Chapter 4) and potential solutions that will find, or contribute to, new and innovative solutions that minimise water leakages and water damage for apartment buildings.

In this Briefing Paper at the end of each chapter, a series of questions have been posted for further discussion with stakeholders and other interested parties.

The second phase of this research will be an online survey, stakeholder interviews followed with workshops.

The third phase is scrutinising the data collected in phase 2 with selected case studies and arriving at solutions and recommendations to minimise water leakage in concrete balconies.

The project team comprises:
Simon Croft (HIA)
Prof. Emad Gad (SUT)
Prof. Shan Kumar (SUT)
Prof. Jay Sanjayan (SUT)
Dr Scott Menegon (SUT)
Prof. Lam Pham (Peer Review)

Funding
This research is supported by the Victorian Building Authority (VBA) through a research grant.

[1] A Class 2 building is a building containing two or more sole-occupancy units where people live above, beside or below each other. This class may also include single storey attached dwellings with a common space below such as a carpark.
[2] National Construction Code, (2022). National Construction Code. Accessible from [https://ncc.abcb.gov.au/]
[3] Australian Standards Waterproofing membranes for external above ground use-AS4654.1 -Materials and AS4654.2-Design and Installation

Table of Contents

Acronyms

- **ABCB** - Australian Building Code Board
- **AIW** - Australian Institute of Water Proofing
- **BMF** - Building Minister's Forum
- **BCA** - Building Code of Australia
- **CSV** - Cladding Safety Victoria
- **CRP** - Cladding Rectification Program
- **Jas-Anz** - Joint Acreditation system of Australia Newzelad
- **NCC** - National Construction Code
- **NATA** - National Association of testing Authority
- **HIA** - Housing Industry Association
- **SUT** - Swinburne University of Technology
- **VBA** - Victorian Building Authority
- **VCAT** - Victorian Civil and Administrative Tribunal
- **VMIA** - Victorian Managed Insurance Agency

Definitions[9]

- **Defects**: lack of something necessary for completeness; shortcoming.
- **Building Defect**: any problem that reduces the value of a home, apartment, or building
- **Defective Building**: a building that is not fit for purpose due to a failing or shortcoming in the function, performance, satutory or user requirements of the building, where the failing or shortcoming has exsited since construction or been triggered later on by faulty original construction or design.
- **Failure**: a lack of success in doing or achieving something, especially in relation to a particular activity.
- **Building Failure**: the condition or fact of not achieving the desired end or ends.
- **Catastrophic failure**: sudden and complete failure which cannot be put right
- **Leak**: a crack, hole, or other gap that a substance such as a liquid or gas can pass through.
- **Membrane**: an impervious barrier moisture, which can be sheet or liquid applied.
- **Waterproof**: property of a material that does not allow moisture to penetrate through when tested accordance with AS4564.1

1 Purpose of this Briefing Paper

This project aims to identify and analyse causes of water leakage in residential apartment concrete balconies, and identify opportunities to improve current regulations, standards, and work practices to reduce or eliminate water leakage[4]/ingress in concrete balconies for Class 2 buildings.

The findings from this research have the potential to inform future regulatory decisions and effect change in the regulatory system and to support an informed and thriving industry, with good practice and competent and skilled practitioners[5].

The research will seek to identify opportunities to improve structural systems, methods of build, and the properties and performance of materials to limit balcony water ingress.

This briefing paper is part of the first phase of the research project. It offers background information and identifying key issues that have been identified by the project team in the preliminary stages of the research project.

It is shared with the stakeholders to assist with the consultation phase of the project which involves interviewing/conducting workshops and/or surveying the interested parties to further identify and examine current regulations and work practices for waterproofing of concrete balconies.

The second phase of the project will include preparation of a report which will incorporate the findings from the consultation and recommendations for further work and/or proposals addressing the identified issues with regulations and work practices.

Responding to this Briefing Paper

Interested parties are encouraged to review and respond to this briefing paper.

There are number of questions and discussion points posed throughout this paper to assist in highlighting areas that respondents may wish to provide feedback on.

However, if you would like to provide feedback on other water leakage issues in residential apartment concrete balconies not discussed in this paper or would like to provide your own specific feedback on items relevant to this project, this feedback would be welcomed.

There are two options for responding to this Briefing Paper:

1. Provide written response to tshanmugananthakumar@swin.edu.au
2. Respond to the survey on the SUT website/HIA website.
   Responses are requested to be provided by close of business on **Friday 4 August 2023**.

[4] Leakage - Accidently losing or admitting contents, especially liquid or gas, through a hole or crack:
[5] Building confidence: Building Ministers' Forum expert assessment (2018)

For further information on this project please contact Prof Shan Kumar by email at shanmugananthakumar@swin.edu.au

Item1-Discussion items and questions for stakeholder engagement:

1. There is not enough research on concrete balcony failures due to water leakage. Do you agree with this statement?
2. Other than interview and survey, what are the other methods of securing quality data on water leakage in concrete balconies? Will a statewide seminar engaging stakeholders and other interested parties be helpful?
3. Are relevant building practitioners competent in the regulatory provisions with respect to concrete balcony design and construction and certification?
4. Is current training and education in concrete balcony waterproofing design sufficient for building practitioners to practice confidently?

Note: **"relevant building practitioners":** only those who are dealing with certain areas of work that is related to concrete balcony design and construction.

2 Introduction

2.1 Background

Water leakage due to inadequate water shedding and waterproofing/weathertightness, particularly of external balconies of mid to high rise apartments, is often cited as one of most common defects in Class 2 buildings, both nationally and in Victoria.

Through its work on the Victorian Government's Cladding Rectification Program, Cladding Safety Victoria has identified defective building work associated with balconies on Class 2 buildings[6]:

> Of the 270 buildings that have received rectification funding in the program (as at October 2022), nearly one-third of them have been identified as having balcony defects.
>
> - *84 buildings (25% of the total funded buildings to date) have been identified with* ***leaking balconies, balustrades and terraces causing structural damage.***
> - *In total, more than* ***550 defective balconies*** *have been identified with these problems that have been left unaddressed by the owners.*
>   - ***52% have defective balconies caused by water ingress issues.***
>   - *19% have waterproofing issues due to lack or insufficient waterproofing.*
>   - *64% of impacted buildings were constructed more than 10 years ago.*
>
> ***The costs of defective balconies over total construction contracts (initiated for cladding works) comprises approximately 38%.***

Further to this, an Australian Institute of Waterproofing (AIW) article on this issue highlighted[7]:

> *Insurance statistics have shown the highest number of waterproofing failures are balconies, terraces, rooftops in high rise dwellings and commercial buildings.*

These points were further emphasised in a recent statement from the Victorian State Building Surveyor, Andrew Cialini[8]:

> *Water damage routinely tops the list of defects encountered in buildings and in complaints to the VBA.*

Recent research from NSW on apartment buildings found[9]:

> *Around 39% of buildings had experienced serious defects in the common property, with the* ***majority related to waterproofing (63%)*** *followed by fire safety systems*

---

[6] Vic,gov,au, (2023, April 28). Research analysis on issues and risks associated with balcony defects | Victorian Government (www.vic.gov.au)

[7] AIW, (2018, September 12). A Few Common Reasons Why Balconies Leak - Australian Institute of Waterproofing

[8] VBA, (2023, March 1). Research into building design to combat water damage | Victorian Building Authority (vba.vic.gov.au).

[9] NSW Government, (2021, September). Serious defects in residential apartments research report (nsw.gov.au)

(38%), structure (27%), enclosure (26%), key services (17%) and non-compliant cladding (16%).

Furthermore, the cost of rework to address these defects has been found to be substantial, ranging from 2% to 4% of the initial contract value, with direct and indirect expenses reaching up to 6.4% and 5.9% of the contract value, respectively[10,11]

These reports reinforce the need to improve building practices, which would in turn reduce associated health, amenity, and structural integrity impacts from water leakage and water damage in apartment buildings. However, whilst the potential impacts of water leakage and water damage in apartment buildings are well understood, the reasons for why and how this is occurs in buildings, and solutions to help minimise this from occurring, are more complex to establish.

Hence, this project is seeking to investigate the causes, examine case studies of projects where the design may have subsequently failed, and identify what the issues were in those cases.

The project will also consider the fitness for purpose of current building codes and standards and where there may be areas for reform drawing from industry and building regulators' feedback and on international comparisons.

2.2 Objective and Scope

2.2.1 Objectives

The key objectives of this project are to:

- identify the causes and prevalence of water ingress/leakage in concrete balconies in Class 2 buildings
- identify opportunities for improvement to current regulations, standards, and work practice (in concrete balcony design and construction) to reduce or eliminate water ingress/leakage in concrete balconies in Class 2 buildings through:
    - identifying improvements to properties and performance of build materials and methods, such as concrete mix design, falls and drains
    - identifying different structural systems to limit balcony water ingress, and
    - studying waterproofing methods to quantify their efficacies that are to be informed by a whole-of-life (WOL) investigation framework, which includes repair and replacement costs.
- make evidence-based recommendations for improvements to current regulations, standards and work practice, and areas of focus for practitioner education and training.

2.2.2 Scope

The scope of this research is limited to concrete balconies on Class 2 buildings.

[10] Love E.D.P. and Edwards J.D., (2007). Calculating total rework costs in Australian construction projects. Civil Engineering and Environmental Systems, 22:11-27.
[11] Sandanayake, M., Yang, W., Chhibba, N., & Vrcelj, Z. (2022). Residential building defects investigation and mitigation–a comparative review in Victoria, Australia, for understanding the way forward. Engineering, Construction and Architectural Management, 29(9), 3689-3711.

Issues associated with balconies on Class 2 buildings of other forms of construction (such as timber and lightweight balconies) are not within the scope of this work.

Balconies for single, standalone houses and horizontally attached houses (Class 1 buildings) or large podiums or roof top spaces/occupiable roof tops for commercial buildings are not within the scope of this work.

Notwithstanding some of the items expected to be identified through the research may have benefits or provide learnings to inform the design and construction for other types of balcony construction systems and/or other occupiable outdoor areas that are constructed in a similar manner.

Item2-Discussion items and questions for stakeholder engagement:

1. Is the current scope adequate for collection of quality data? Is there anything missing from this scope?

3 Balcony Construction

A balcony is defined as a platform enclosed by a wall or balustrade on the outside of a building, with access from an upper-floor window or door. This definition is applicable to Class 2 apartment building balconies (refer fig 1-Extract from design guide BS 8579:2020).

Balconies can be used for enjoying the view, growing plants, relaxing or entertaining guest and Australians love their balconies for these reasons.

Some common types of balcony designs incorporated into modern buildings in Australia include:

- Cantilevered and or supported by load bearing elements such as walls and columns.
    - Projecting open balcony
    - Projecting enclosed balcony
    - Recessed open balcony
    - Recessed enclosed balcony
- stacked
- hung
- false.

The most common materials used for structural framing of a balconies are timber, steel, and concrete and the overlay flooring is generally pavers, tiles, decking or similar.

The scope of this research will include the following cantilevered and or supported by load bearing elements such as walls and column concrete balconies:

- Projecting open balcony
- Projecting enclosed balcony
- Recessed open balcony
- Recessed enclosed balcony

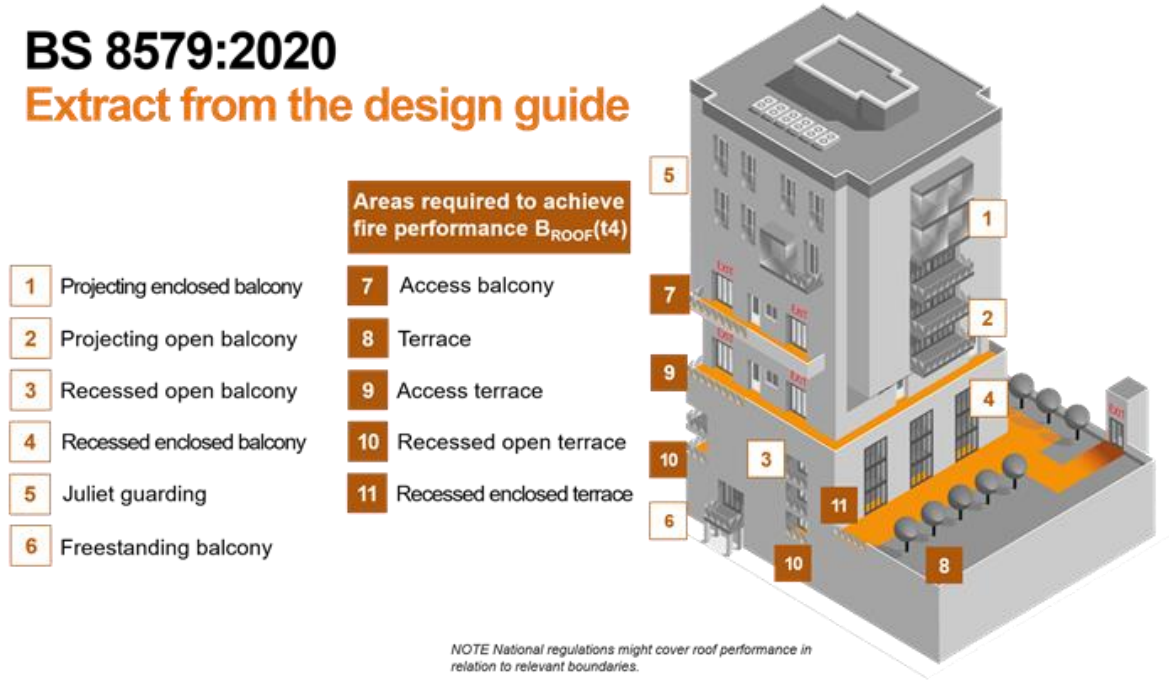


Fig 1 Balcony Types. Source Bauder.co.uk

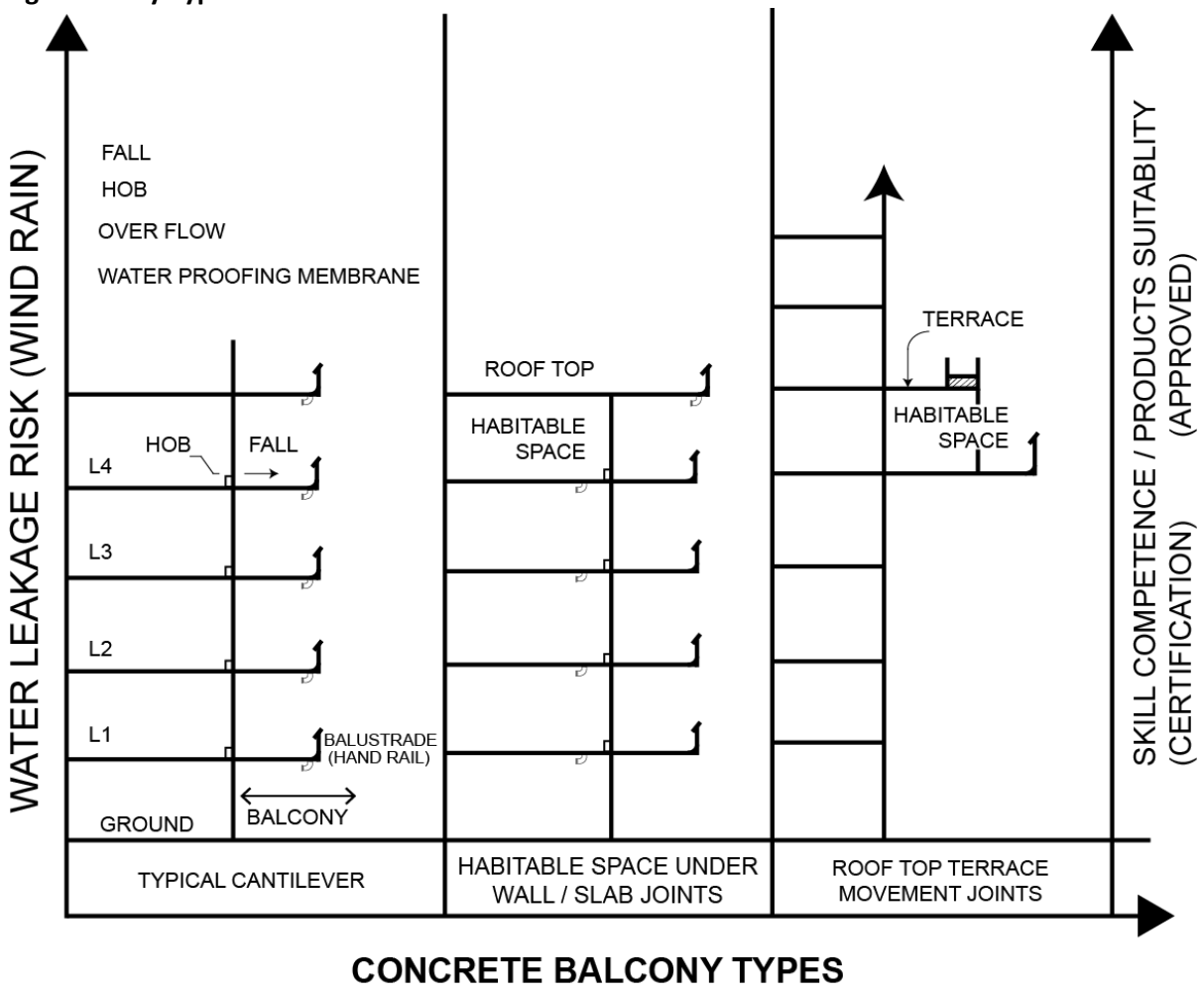


Fig 2 Balcony Types and Details and the associated Risks (Class 2 Apartment Buildings) Source: SUT team interpretation

The research team has analysed different types of concrete balconies and plotted on a chart as shown above (fig 2). This will be a useful for our stakeholder interview and discussions along with the construction detail on fig 3.

The main components of the balconies within the scope of this investigation include: (refer Fig 3)

- cantilevered concrete slab (or supported on walls/columns)-structural concrete.
- balustrades/Handrails
- waterproofing membrane
- protective screeding and/or pavers
- floor drainage and associated components.

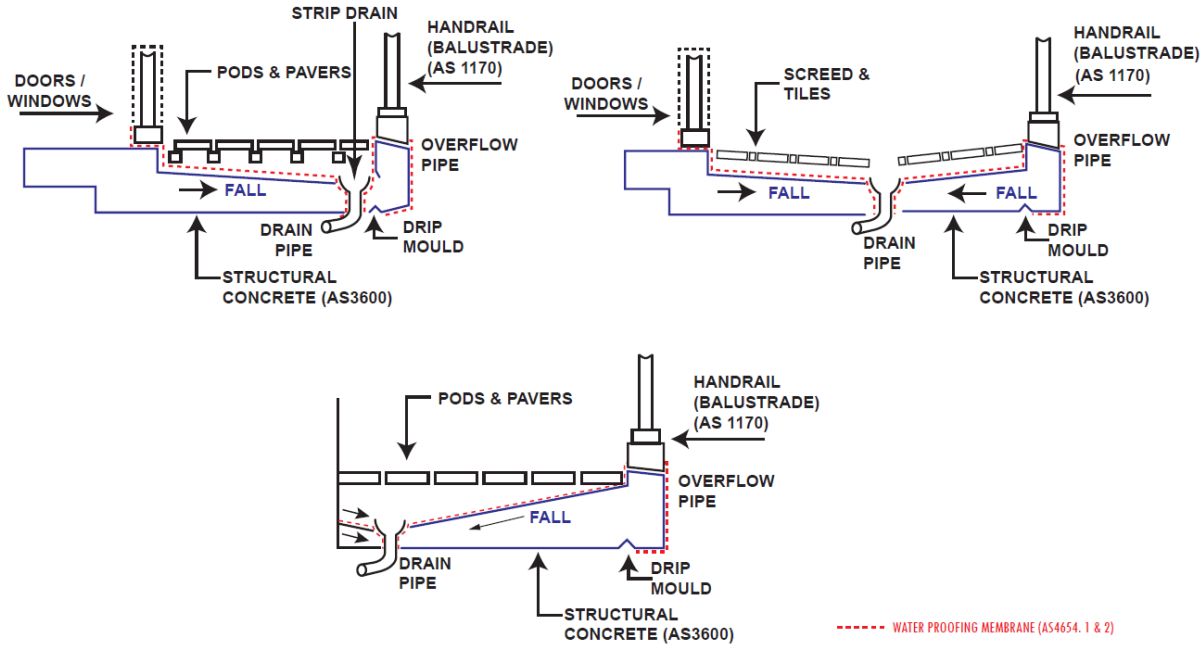


Fig 3 Typical Concrete Balcony Construction Details (Source: SUT team interpretation)

The research team, with their combined knowledge and the experience, completed an initial review of literature and defect reports.

From the initial research and analysis, the key types of balcony designs that are most susceptible to water leakage issues and potential failure of expected performance levels[12] are:

- cantilevered balconies due to shear failure and flexural cracking.
- designs of balconies immediately over habitable and other internal areas of buildings.

[12] Refer to Victoria Guide to Standards and Tolerances for expected performance level. A defect is defined as "Fault or deviation from intended condition of a material, assembly, or component. A major defect is defined as a defect of sufficient magnitude where rectification is to be carried out in order to avoid unsafe condition, loss of utility or further deterioration of the property.
Expected performance level to be free from major defect. Performance requirement to be as per NCC 2022 Vol 1.

Further to this, initial analysis appears to indicate that many current balcony designs place a heavy reliance on the waterproofing membrane itself being the primary protection measure. This is as opposed to a more holistic design that considers issues such as:

- the placement of the balcony for the building and the individual apartments in Class 2 buildings, i.e., designs where the balcony is directly above a habitable and other internal areas of buildings results in a higher risk application if a failure does occur as opposed to one where it may be over another balcony below.
- the design of the balcony and any doors or windows opening on to the balcony and appropriate step downs and threshold designs and taking into account potential wind driven rain
- a move away from the inclusion of freeboards into balconies in higher rainfall areas
- how more complex features such as balcony hobs, fixed balustrades, and shielding impact design
- fixing of balcony balustrades to a supporting structure
- treatment of joints in balconies and planter boxers
- construction materials used in both the structural substrate and finishing/topping
- how falls/grades are designed into the structure
- how the provision of drainage and drainage termination
- overflows and penetrations
- compatibility of the waterproofing membrane to the topping/finishing, and
- the roof or cover or overhead protection of the concrete balcony and overflow provisions.

Item 3-Discussion items and questions for stakeholder engagement:

1. Are there particular types of concrete balcony designs (refer fig 1) that may be more susceptible to water ingress than others in Class 2 buildings?
2. Should some concrete balcony designs be limited to certain building types? Should there be a classification/risk rating system (i.e., low, medium, high risk) for grouping certain concrete balcony designs, which in turn has greater design requirements imposed for higher risk categories? (Refer fig 1)
3. Should there be different design requirements of balconies that are located above habitable space?
4. Should there be a greater focus on providing a holistic approach to the design of concrete balconies in Class 2 buildings for water tightness?
5. Are there other components of concrete balconies in Class 2 buildings that should be a key consideration in their design and construction?

4 Building Codes and Standards

Residential construction, and all other forms of building construction, is subject to a raft of regulations and controls based on the planning and building administrative frameworks in place in each state and territory.

The National Construction Code (NCC)[13] is Australia's primary set of technical design and construction provisions for buildings. As a performance-based code, it sets the minimum required level for the safety, health, amenity, accessibility, and sustainability of certain buildings.

The NCC primarily applies to the design and construction of new buildings and plumbing and drainage systems in new and upgrade and renovations of existing buildings. In some cases, it may also apply to structures associated with buildings and new building work or new plumbing and drainage work in existing buildings.

The Australian Building Codes Board (ABCB), on behalf of the Australian Government and each State and Territory government, produces and maintains the NCC. The NCC is called up by the Victorian *Building Act 1993* as technical regulatory document that practitioners need to follow for the design and construction of buildings.

In Victoria, the Victorian Building Authority (VBA) is established under the *Building Act 1993* and regulates Victoria's building and plumbing industries.

Building regulatory authorities and Government bodies in the other states are:

- NSW office of Fair Trading
- Queensland Building and Construction Commission (QBCC)
- South Australian Building Commission
- Western Australian Building Commission
- Tasmanian Consumer, Building & Occupational Services (CBOS)

The primary users of the NCC include architects, builders, plumbers, building surveyors, hydraulic consultants, engineers, and other building and plumbing related professions and trades.

The NCC calls up relevant standards (Australian Standards and others) which set benchmarks for the material, design, and construction requirements.

4.1 National Construction Code (NCC)

The NCC 2022 Vol.1 is applicable to Class 2 buildings, and in general, balcony waterproofing is covered under Section F1 Surface water management, rising damp, and external waterproofing. The most applicable section for balcony waterproofing is F1D5 "external waterproofing membranes".

[13] National Construction Code, (2022). National Construction Code. Accessible from [https://ncc.abcb.gov.au/]

Verification methods for F3P1 weatherproofing are detailed under F3V1, with a risk severity of "high" and a score of 4 for a cantilevered balcony for first floor level, and for Level 2 and above a risk severity of "very high" coupled with a score of 6 is documented in table F3V1a (refer Fig1 also).

With any key component of construction, the better the design is documented in the plans and specifications, and the better and competencies of all parties involved in the design and construction, will provide the best chance of a successful compliant outcome. How this is currently applied for balcony design is presently identified as inconsistent and one of the key issues require further discussion.

NCC 2019 has been superseded by NCC Vol. 1 2022[14], and the damp and weatherproofing requirements and external waterproofing and weatherproofing provisions went through a review by the ABCB and enhanced provisions, with a subsequent more substantial review identified for NCC 2025 that is currently in progress by the ABCB with an expert working group.

NCC 2022 included a new provision that specifically deals with waterproofing of exposed joints in the drainage surface (F1D4).

F1D4 Exposed joints (NCC Vol. 1 2022)

Exposed joints in the drainage surface on a roof, balcony, podium, or similar horizontal surface part of a building must:

- be protected in accordance with Section 2.9 of AS 4654.2; and not be located beneath or run through a planter box, water feature or similar part of the building.

NCC 2022 also included revised provisions at F1D5 covering the scope of application of the external waterproofing provisions and a more explicit clause to which parts of the buildings the provisions and in turn the external waterproofing Australian Standards apply to:

F1D5 External waterproofing membranes (NCC Vol. 1 2022)

A roof, balcony, podium, or similar horizontal surface part of a building must be provided with a waterproofing membrane.

- consisting of materials complying with AS 4654.1; and
- designed and installed in accordance with AS 4654.2.

4.2 Australian Standards

The main Australian Standards that cover residential balcony waterproofing are:

AS 4654.1 2012-Waterproofing for external above-ground use, Part1: Materials

This Australian Standard was first produced in 2009.

Section 2 provides the testing requirements for a membrane. For a concrete balcony, the movement, bonding characteristics of concrete, slip resistance (AS 4586)[15] and heat ageing

[14] National Construction Code, (2022). Table of BCA 2022 references by BCA 2019 reference. Retrieved from [Table of BCA 2022 references by BCA 2019 reference (abcb.gov.au)]

[15] Australian Standards. AS4586:2013 – Slip resistance

requirements (AS/NZS 4858)[16] required to be considered when selecting the appropriate membrane.

The concrete slab designed according to AS 3600[17] will have a design life of 50 years, though how this is incorporated into current designs and assessed in the building approval process is identified as being somewhat inconsistent, which also extends to how this is maintained through the life cycle of the building post-occupancy through regular home owners' maintenance and if the need for replacement of the membrane or protective coating over the building's occupancy.

AS 4654.2 2012 Waterproofing for external above-ground use, Part 2: Design and Installation

This Australian Standard was first produced in 2009. It provides the design requirements and installation requirements for the installation of above-ground waterproofing systems. For concrete balconies, the substrates and preparation for the membrane can be very demanding:

- falls requirements minimum 1:00 (e.g., 10mm per 1m)
- laying of the membrane including laps and curing, moisture content of concrete at the time of laying
- termination of the membrane including vertical upturn heights
- installation details around doors and windows
- membrane to drainage systems
- movement and control joints
- overflows and penetrations.

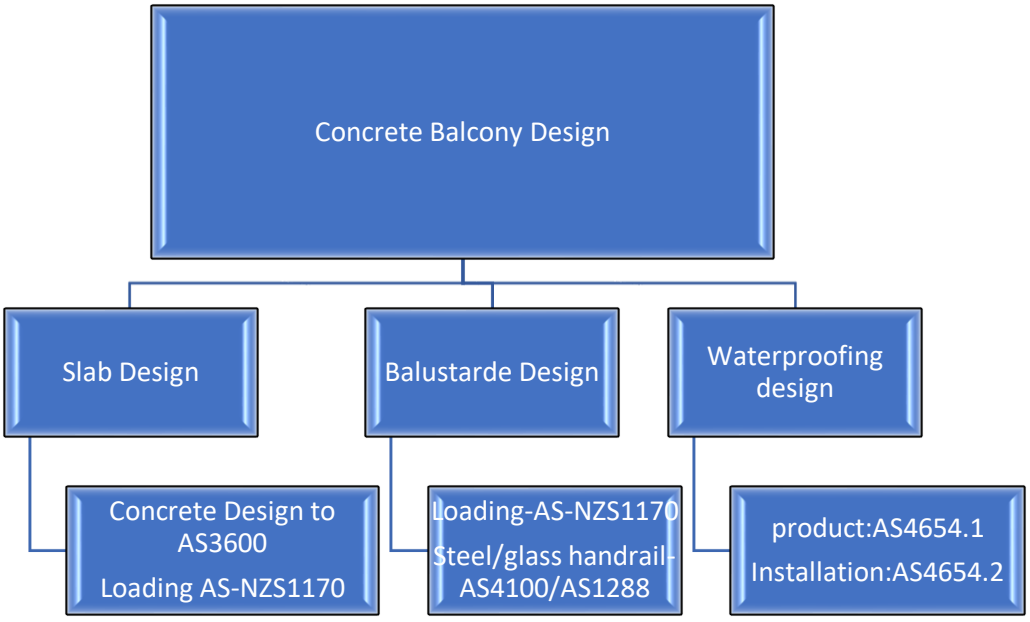


Fig 4 Concrete Balcony Design Process (Source SUT Team Interpretation)

[16] Australian- New Zealand Standard. AS/NZS 4858:2004 - Wet area membranes (reconfirmed 2020)
[17] Australian Standard. AS3600:2018-Concrete structures referenced by NCC 2022 for balcony substrate design.

Item 4-Discussion items and questions for stakeholder engagement:

1. Is the NCC clear in prescribing current concrete balcony design, waterproofing and construction requirements? Do we need a watertight concrete slab? Is AS 3735 [18]more appropriate than AS 3600 for a balcony concrete slab to ensure water tightness?
2. Should there be a dedicated standard or section of the NCC added for Concrete balcony construction rather than having general first principal design standards that cover structures broadly?
3. Should concrete balconies, and timber, steel, etc. balconies be treated differently?
4. Is insufficient regulation the issue? Or are better and clearer guidance documents on the application of current requirements needed?
5. Are there any overseas codes and standards that have better regulatory provisions with respect to concrete balcony design and construction (including waterproofing)?
6. Do we need to consider additional measures specifically for waterproofing of concrete balconies? Are more stringent requirements with prescriptive structural design and material specifications required?

[18] Australian Standard. AS 3735:2001-Concrete Structures for retaining Liquids.

5 Identifying the Issues

5.1 Analysis of currently available research and defects reports

Research, specifically on concrete balcony water leakage found to be very limited.

A range of organisations have undertaken research or reported on water leakage and water damage in residential buildings:

- Australian Industry and Skills Committee: Construction, Waterproofing Design & Survey, Case for Change; Construction, Plumbing and Services Industry Reference Committee, Artibus Innovation [1].

  Key findings: Many buildings today are multi-unit, multi-storey with features such as basements deep underground, swimming pools, roof top gardens, planter boxes and balconies. There is a lack of training to design, inspect and test the waterproofing systems required for more complex situations. Inadequate training in the designing of the waterproofing, and the selection of the waterproofing methods and materials best for the job, in addition to lack of training in inspection and test plans, has contributed to widespread failures in waterproofing.

- Victorian Building Authority (VBA): Examining Indoor Mould and Moisture Damage in Victorian Residential Buildings [20].

  Key findings: Poor or incomplete design documentation, non-compliant design in construction of balconies and internal wet areas.

- NSW Fair Trading: Serious Defects in Residential Apartments research report [10]

  Key findings: Around 39% of buildings had experienced serious defects in the common property, with the majority related to waterproofing (63%).

- An Examination of Building Defects in Residential Multi-owned Properties (Deakin University and Griffith University). [7]

  Key findings: Defects in waterproofing were highly correlated to structural defects and defects in building fabric and cladding, and roof and rainwater disposal.

- Cracks in the compact city: Tackling defects in multi-unit strata housing-UNSW -Built Environment- City Future Research Centre[19]

  Key findings: Out of the 635 buildings waterproofing/weatherproofing/water leakage tops the list with 42%. (Compare to data from NSW office of the Building Commissioner analysis showed issues with water proofing is 53%)

[19] Cracks in the Compact City: Tackling defects in multi-unit strata housing Final Project Report Dr Laura Crommelin, Dr Sian Thompson, A/Prof Hazel Easthope, Prof Martin Loosemore, Hyungmo Yang, Dr Caitlin Buckle and Prof Bill Randolph October 2021 (pages 4,47)

- Leaking Balconies: The New High-Rise Paradigm (Lovegrove & Cotton Construction and Planning Lawyers. [11]

  Key findings: Typically, balconies are constructed such that the floor slopes gently towards a stormwater outlet/drain and the balcony has a water barrier or membrane mechanism to prevent the ingress of water and dampness into internal living areas. The failure of a waterproofing membrane or device can occur at any stage of the life of a building, it may fail straight away or after 1, 5, 12 or 20 years. The failure of a waterproof membrane may in some cases constitute a building defect and in others it may be a maintenance issue. The failure of a waterproof membrane where it is a defect may be actioned against the relevant builder for up to 10 years, and/or where the waterproof membrane is a proprietary product that carries a guarantee to the life of the warranty. Insurance will not typically cover balcony water leaks in high rise developments, but the circumstances and extent of cover depends on the relevant insurance scheme and the terms of the applicable policy.

- Australasian Concrete Repair and Remedial Building Association (ACRA)[20].

  Key findings: A typical cantilever balcony has its main reinforcement at the top. Further, with normal deflection of the balcony concrete, it is not unusual for a crack to develop in the concrete at a point just outside the wall of the building. This crack allows salt from sea air to penetrate to the main top steel. The resulting corrosion reduces the steel cross-section over time, thereby eroding the capacity of the balcony to carry its design load.

- Why buildings leak part one. Built Environment Economist: Australia and New Zealand, 61-64. Ross Taylor.[22]

  Key findings: Unclear and wrong inputs between different professionals, such as between Project manager and Engineer; Engineer and Architect; Architect and Builder, Engineer and Builder – can create opportunities for flaws to emerge.

- Residential building defects investigation and mitigation–a comparative review in Victoria, Australia, for understanding the way forward. Engineering, Construction and Architectural Management: Victorian University Sandanayake, M., Yang, W., Chhibba, N., & Vrcelj, Z. (2022)[21].

  Key findings: The observations and findings reveal that new single and multi-dwellings are the major source of residential defects, amounting to 92% of the total claims from 2010 to 2018. More than 85% of the total defects are caused by poor workmanship and 42% of these claims are attributed to structural defects. Further observations indicated that waterproofing related defects have the highest defect costs while plumbing, frame and cladding related defects have a major share in the total defect costs.

[20] Dr. David Mahaffey. (2000, December). Australian Concrete Construction. ACRA.
[21] Sandanayake, M., Yang, W., Chhibba, N., & Vrcelj, Z. (2022). Residential building defects investigation and mitigation–a comparative review in Victoria, Australia, for understanding the way forward. Engineering, Construction and Architectural Management, 29(9), 3689-3711.

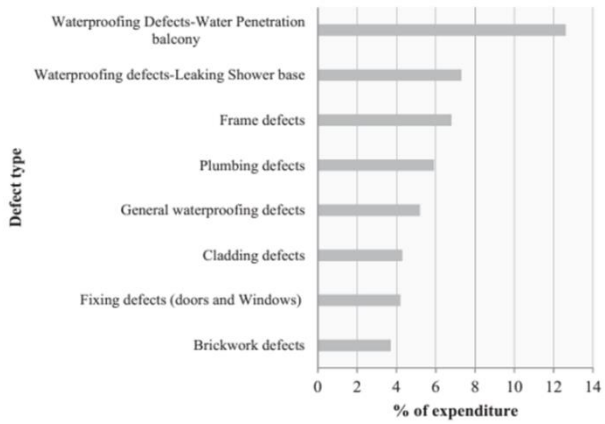


Fig 6. An analysis was conducted on a data set from VMIA between 2011 and 2018, the largest expenditure related to waterproofing defects – water penetration (Sandanayake et al, 2022).

Some international reports have summarised the main issues present in defects reports (8) (conducted in wet areas of 1500 high-rise residential buildings between 0-35 years of age are) are:"

- 36% of building defects are related to water leakage in wet areas.
- More than 50% of the buildings suffered from internal water leakage problem within a year after occupation and this has accounted for the high life-cycle cost with high requirements for maintenance, repair and replacement throughout the service life.
- The survey has identified four major locations of water leakage:
    - pipe penetrations/floor traps
    - construction joints
    - cracks
    - porous internal walls and slabs.

A vast number of the defect reports [6, 7, 8, 12, 14, 16, 17, 22, 23,24] (refer to Table 1), with respect to concrete balconies, identified that the failure of waterproofing membranes and little or no maintenance contributed towards the water leakage through concrete cracks/joints/slab wall junctions and resulted in not only making the habitable space under unusable, but also corroding the reinforcement in the slab and slab/wall junction.

Some reports highlighted the overloading of the structures with heavy equipment and pot plants full of soil. Another notable fatal defect was the balustrade failure at the base connection due to corrosion[22].

Table 1 Causes for water leakage identified by various defects reports.

Issue 1: Waterproofing membrane failure
Issue 2: Little or no maintenance
Issue 3: Insufficient or no slope, no hob, no overflow pipe
Issue 4: Cracked tiles, cracked concrete/mould formation/corrosion.
Issue 5: Pipe penetration & floor trap
Issue 6: Inadequate movement joints (MJ)/poorly designed detailed MJ

[22] Wittocx, L., Buyle, M., Audenaert, A., Seuntjens, O., Renne, N., & Craeye, B. (2022). Revamping corrosion damaged reinforced concrete balconies: Life cycle assessment and life cycle cost of life-extending repair methods. Journal of Building Engineering, 52, 104436.

Issue 7: Poorly treated construction joints
Issue 8: Porous internal walls and slabs
Issue 9: Lack of planning and design coordination
Issue 10: Lack of supervision, inspection and certification

References	Issue 1	Issue 2	Issue 3	Issue 4	Issue 5	Issue 6	Issue 7	Issue 8	Issue 9	Issue 10
6	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
7	✓	✓	✓		✓	✓		✓	✓	✓
8	✓	✓	✓						✓	✓
12	✓	✓	✓						✓	✓
14	✓	✓	✓	✓					✓	✓
16	✓	✓	✓	✓	✓	✓			✓	✓
17	✓	✓	✓		✓			✓	✓	✓
22	✓	✓	✓						✓	✓
23	✓	✓	✓		✓	✓		✓	✓	✓
24	✓	✓		✓					✓	✓

Opportunities to avoid/minimise balcony defects identified in these reports are summarised below:

- Initial Design coordination: Structural engineer, hydraulics engineer, civil engineer, architect, and the builder - If possible, a consultation with certified waterproofing contractor would be ideal. Submission of approved waterproofing details must be made mandatory[23].
- Assessing the regulatory environment: Stages of design and construction require review and responsible party must be identified for each stage. (Refer Table 1)
- Private certification Policing & Auditing: Current inspection and approval processes as they relate to balconies would benefit from development of a detailed checklist of key items to check off in the design and construction of balconies.
- Licensing (Quality Control): Various parties involved in design and construction of Class 2 buildings are already required to be licensed/registered, but this could be approved with regular auditing and oversight.
- Insurance: Revisit and ensure what is covered and what is not.
- End-user consultation: Warranty and associated maintenance with respect to waterproofing membrane and water tightness of the concrete slab.

[23] 90% of leaks and cracks are due to design and design coordination issues [24]. Taylor R., (2020). Why buildings leak part one. Built Environment Economist: Australia and New Zealand, 61-64.

Item 5-Discussion items and questions for stakeholder engagement:

1. Do you consider that the issues identified through the previous Australian research on causes of balcony failures are representative of common issues encountered that are leading to higher rates of water leakage? Are there any missing from the list? (Table 1)
2. Are you aware of other countries' regulatory settings for balcony design and construction that have resulted in fewer defects and issues being encountered with water ingress?
3. Do you think more concrete balcony inspection should be required during construction, with structural engineers' input?
4. Is BS 8579:2020[24] a good starting point for a similar adoption of an approved guidelines for concrete balconies?

5.2 Analysis of current regulations

In this section a broad discussion on the implementation of the regulations is discussed to find out whether any gaps and/or omissions in the regulations lead to the identified key issues for the concrete balcony water leakage.

Conformance to NCC

In conjunction with the detailed design and construction requirements of the NCC and Australian Standards, the core components are requirements for building product testing, certification, and approval (building product conformity).

The NCC contains building product conformity requirements under the 'evidence of suitability provisions' which lists product evidentiary requirements and ways for which a material, product, design or form a construction to demonstrate compliance with the NCC.

Many of the Australian standards referenced in the NCC contain testing requirements for products to show compliance with that standard. Under these provisions the NCC provides a number of ways to demonstrate compliance, these are:

- A CodeMark[25] Certificate of conformity.
- A WaterMark[26] Certificate of conformity.
- A certificate of accreditation under a state government certification scheme (where one exists).
- A test report by a National Association of Testing Authorities (NATA) lab.
- A certificate issued by a certification body accredited by the Joint Accreditation System of Australia and New Zealand (JASANZ)[27] – this includes industry schemes such as ACRS and EWPAA.
- A certificate or report by a professional engineer or other appropriately qualified body.
- Another form of documentary evidence such as a Product Technical Statement or Technical Appraisal.

[24] British Standards Institution/BS 8579:2020. Guide to the design of balconies and terraces.
[25] CodeMark Certification Scheme. Accessible from CodeMark Certification Scheme | CodeMark (abcb.gov.au)
[26] WaterMark Certification Scheme. Accessible from WaterMark Home | WaterMark (abcb.gov.au)
[27] Joint Accreditation System of Australia and New Zealand (JASANZ). [https://www.jasanz.org/about-us]

With concrete balcony waterproofing design and construction, there are various stages of construction (Refer to suggested table 2), and the responsibility is:

- Overall, the builder, building designer, and architect are equally responsible for the final product.
- Construction of the concrete balcony slab in accordance with NCC requirements. Design engineers, concrete supplier, concrete subcontractor, membrane supplier and waterproofing contractor are responsible for their role they carryout according to NCC.
- Selection of appropriate approved waterproofing membrane is unclear, but generally should be specified by the building designer/architect and the waterproofing contractor in undertaking the work.
- The waterproofing subcontractor, and in turn the builder, are responsible for on-site installation.

Stages that require regulatory acceptance

The research team has identified stages for the planning, design and construction of a residential building concrete balcony that require regulatory acceptance, and the responsible party as shown in Table 2.

This table highlights the associated issues which are responsible for water leakage in residential apartment concrete balcony.

Table 2: Suggested stages of design and construction that require regulatory acceptance.

Stage	Regulatory requirements	Responsible party/ Approval Authority[22,23]
Concept Design	Customer Acceptance	Architects/Engineers
Develop suitable specification	No regulatory requirements. Do we need a coordinated concept design at the beginning with warranty confirmation at the beginning?	Competent/Registered practitioners signoff on coordinated design details and specification. Appropriate guidelines and approved sample details must be made available
Detailed design	NCC 2022 Vol 1 -F1D5 Demonstration of compliance with NCC performance requirements, including deemed-to-satisfy solutions and approval for performance-based solutions. AS 4654.2-approved registered practitioner	Structural Engineer to provide building movement report. Completed by architect/engineer and approved by building surveyor. Seek ABCB approved detail. Competent registered practitioner approved by regulators.
Building work Concrete Slab Design Specific requirements of waterproofing and associated plumbing and drainage work	Building approval. Design to AS 3600 (normal concrete). Loading AS-NZS 1170. Do we need a watertight concrete and less reliance on waterproofing membrane? Do we need a stringent structural design requirement with different types of concrete balconies and associated loads and support systems? (Fig 1)	Submitted by builder/designer and typically granted by local council.

Stage	Regulatory requirements	Responsible party/ Approval Authority[22,23]
Waterproofing Membrane	NCC 2022 Vol 1- F1.D5 Manufacturer quality assurance procedures- AS4654.1	Supplier/manufacturer-certified product
	Inspection of components once completed and assembled- AS 4654.2	Engineer/surveyor
	Approval for waterproofing membrane?	
	Approval for construction of waterproofed slab. Do we need a separate design detailing section for cantilevered concrete balconies?	Approved building inspector
Installation of Waterproofing Membrane	Inspection of concrete slab. Appropriate moisture content/grade/fall/drain/Loadings	Competent engineer & architect along with certified waterproofing contractor.
	Special requirements around plumbing works. Junction between walls & slabs	Builder/engineer/architect/waterproofing contractor.
	Inspection of water proofing during installation.	Registered waterproofing practitioner[23]
Site inspection	NCC-AS 4654.2	Registered waterproofing practitioner[23]
On-site testing	NCC- AS 4654.1	Approved testing authority/Labs
Final approval	NCC-AS 4654.1 & 2	Building surveyor[28] [29]
Maintenance	Manual/Guidance-Prepared by the design and construction team.	Construction team brief the Owner. Owner must promptly follow the maintenance manual

Item 6-Discussion items and questions for stakeholder engagement:

1. Are the above identified stages appropriate for concrete balcony waterproofing design?
2. Are there any approved design/construction guidelines available for cantilevered concrete balconies[30]?
3. Who signs off on set down hop, fall and drainage requirements?
4. Who checks and signs off on approved membrane products?
5. Who checks and signs off on membrane installation and associated testing?
6. Is there any approved design checklist available for concrete balconies?
7. Is there any approved inspection checklist available for concrete balconies?
8. Will BMF's 24 recommendation[31] solve some of the issues with certification & inspections?

[28] Department of Industry, science and Resources. (2019, December). Building Confidence report Jurisdictional Update. Retrieved from [(2019)

[29] ABCB, (2021). Evidence of experience for building surveyor registration – Model guidance on BCR recommendation 4. Retrieved from [Evidence of experience for building surveyor registration (2021)]

[30] VBA, (2019, September). Designing and building waterproofed balconies. Retrieved from [https://www.conpro.com.au/wp-content/uploads/2021/01/VBA-Waterproofing-Balconies-Guide.pdf]

[31] Department of Industry, Science and Resources, (2018, April 1). Building confidence: Building Ministers' Forum expert assessment. Retrieved from [Building confidence: Building Ministers' Forum expert assessment | Department of Industry, Science and Resources]

6 Summary of key issues for further discussion

Cantilevered concrete balconies are very common in residential apartment buildings throughout Australia.

Through its preliminary analysis, the research team has identified that insufficient water shedding design (fall, hob, overflow, drainage), the failure of the waterproofing membrane and little or no maintenance post-occupancy contributed to water leakage through concrete cracks/joints/slab wall junctions. This resulted in not only making the habitable space under the balcony unusable with associated health risks and corroding the reinforcement in the slab and slab/wall junction, but they also made the balcony structure fails with no warning.

Throughout this briefing paper, background information and identified key issues have been presented and each section includes a questions/issues section for further identification and examination of current regulations and work practices for waterproofing of concrete balconies.

A summary of the main key issues identified through the preliminary analysis are presented in Fig 7 and Fig 8 for phase 2 stakeholder discussions.

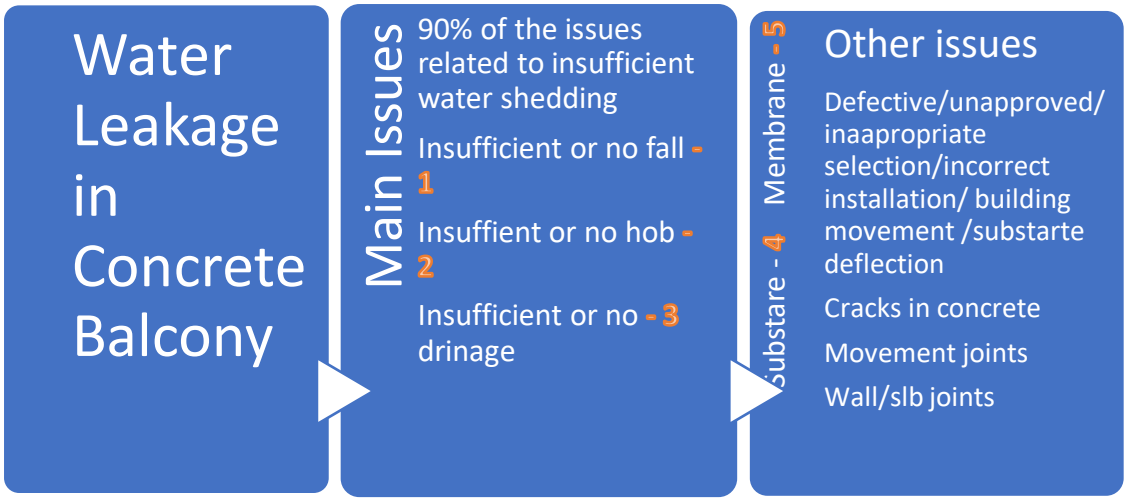


Fig 7: Key Issues Summarised for Phase 2 discussion.

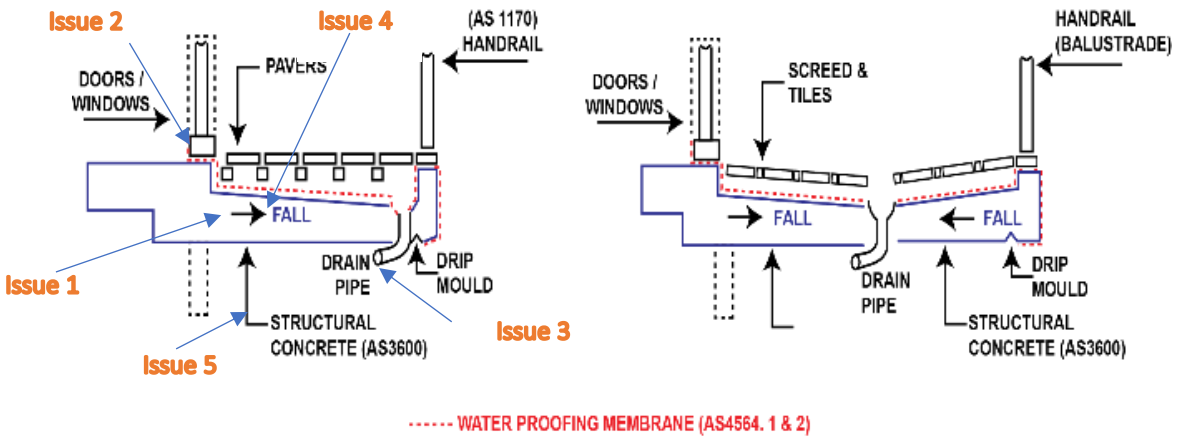


Fig 8 Key issues contributing to concrete balcony water leakages (Source: Identified by SUT team)

The key contributors for key issues (refer to Fig 7 and 8) contributing to water leakage in concrete balconies were identified to be:

Design Coordination[32]: Failure to capture the overall structural requirements to construct set down, hob, fall and watertight concrete and failure to provide adequate regulatory compliant waterproofing details of a cantilevered concrete balcony.

Compliance: Lack of mandatory provisions/lack of enforcement of mandatory provisions.

Construction: Incompetent builders/waterproofing subcontractors, lack of supervision and lack of certification. Inconsistent understanding and knowledge in regulatory provisions that are complex and conflicting and lack of clarity.

Maintenance: Owner/customer/user are not provided with the load restriction on the cantilevered balcony and the importance of regular maintenance.

Responsibility: Lack of clarity on supply chain responsibility between key parties i.e., builder, subcontractors and specialist contractors, architect/building designer, design engineer, building surveyor, regulator, and owner.

Item 7-Discussion items and questions for stakeholder engagement:

1. Design coordination, compliance, construction, maintenance, education and training - which is the most important with respect to minimising water leakage in concrete balconies?
2. Are you aware of structural engineers provide the critical expected deflection for concrete balcony slabs?
3. Is the current regulatory framework adequate for ensuring water tightness of concrete balconies? Or is greater on-site oversight and QA systems required?
4. Is it good to have more inspections on cantilevered concrete balconies?
5. Is it good to have higher risk rating on cantilevered concrete balconies?

[32]Taylor, R., (2018, July 11). Waterproofing…the bottom of the compliance iceberg. Retrieved from https://www.youtube.com/watch?v=i4_fXseDt8s

7 References

1. Construction, Plumbing and Services Industry Reference Committee, Artibus Innovation. (2021, October). Construction Waterproofing Design & Survey - Case for Change. Australian Industry and Skills Committee. Retrieved from [Case-for-Change-Construction-Waterproofing-Design-and-Survey-1.pdf (artibus.com.au)
2. Board, A. B. C., Dewsbury, M., Law, T., Potgieter, J., Fitz-Gerald, D., McComish, B., Chandler, T & Soudan, A. (2016). Scoping Study of Condensation in Residential Buildings.
3. Australian Institute of Waterproofing (AIW). (2018, September 12). A Few Common Reasons Why Balconies Leak. Retrieved from [A Few Common Reasons Why Balconies Leak - Australian Institute of Waterproofing]
4. Khan, H., (2016, November). Concrete Problems Today are Multifactorial – Root Cause. Retrieved from [CM-Nov-2016-Concrete-Problems-today-are-Multifactorial-Tech-Note.pdf (corrosion.com.au)]
5. Code of Practice for Reinforced Modified Bitumen Membrane (RMBM) Systems for roofs and Decks:4th Edition: Consultation document, Published March. (2021).
6. PICA, (2021, February 26). The most common issues with decks and balconies in strata. Retrieved from [Common Issues with Decks & Balconies in Strata | PICA Group]
7. Johnston, N., Reid, S. (2019, June). An Examination of Building Defects in Residential Multi-owned Properties. Deakin University; Griffith University.
8. Chew, M. Y. L., & De Silva, N. (2002). Factors affecting watertightness in wet areas of high-rise residential buildings. *Architectural Science Review*, *45*(4), 375-383.
9. Housing Industry Association. (2022, October 17). External waterproofing requirements explained. Retrieved from [External waterproofing requirements explained (hia.com.au)]External waterproofing requirements explained (hia.com.au).
10. NSW Fair Trading: Serious Defects in Residential Apartments research report
11. Smith, S. (c. 2017). Leaking Balconies: The New High-rise Paradigm. LC Lawyers. Retrieved from [Leaking Balconies - LC Lawyers]
12. Waterproofing FEW. (2018, June 7). How to Fix Leaking Balconies. Retrieved from [Melbourne Waterproofing Company –Fix Leaking Balconies - Balcony Repairs & Waterproofing - Specialist Builder (waterproofingfew.com.au)]
13. Dow, A. (2016, September 25). Melbourne's high-rise nightmares taking a tall toll on residents and investors. The Age. Retrieved from [Melbourne's high-rise nightmares taking a tall toll on residents and investors (theage.com.au)]
14. MyBodyCorpReport.com.au. (2017, May 2). Balconies: Common Property or Part of the Lot. Retrieved from [Body Corporate Balconies: Common Property or Part of the Lot - MyBodyCorpReport.com.au]
15. Queensland building and Construction commission waterproofing regulations. [Waterproofing | Queensland Building and Construction Commission (qbcc.qld.gov.au)]
16. Ross, T. (2018, July 11). Waterproofing ...the bottom of the compliance iceberg. Retrieved from [https://www.youtube.com/watch?v=i4_fXseDt8s]
17. de Souza, R. A., & de Souza Araújo, M. J. (2011). The progressive failure of 15 balconies and the engineering techniques for their reconstruction. Engineering Failure Analysis, 18(3), 895-906.
18. Victorian Building Authority. (2022, December 23). Keep balcony maintained and your guests safe. Retrieved from [Keep balcony maintained and your guests safe | Victorian Building Authority (vba.vic.gov.au)]

19. Law, T., Sorrentino, G., Barry, R., Ronngard, P. (2021, December 2). Scoping study on the nature and extent of moisture damage in houses & apartments in Victoria. Retrieved from [Examining indoor mould and moisture damage in Victorian residential buildings | Victorian Building Authority (vba.vic.gov.au)]
20. Victorian Building Authority. (2023, March 1). Research into building design to combat water damage. Retrieved from [Research into building design to combat water damage | Victorian Building Authority (vba.vic.gov.au)] Research into building design to combat water damage | Victorian Building Authority (vba.vic.gov.au).
21. CROSSAUS. (2021, November 25). Waterproofing exposed concrete slabs (Report No. 959). Retrieved from [Waterproofing exposed concrete slabs | CROSS (cross-safety.org)]
22. Taylor, R. (2020). Why buildings leak part one. Built Environment Economist: Australia and New Zealand, 61-64.
23. Sriravindrarajah, R., & Tran, E. (2018, August). Waterproofing practices in Australia for building construction. In *4th International Conference on Rehabilitation and Maintenance in Civil Engineering*. EDP Sciences.AIW Committee. (2022, October 14).
24. Waterproofing in 2022 and Beyond. Retrieved from [Waterproofing in 2022 and Beyond - Australian Institute of Waterproofing]